



The

**MODERN
GUNSMITH**

HOWE

THE MODERN GUNSMITH

A Guide for the Amateur and Professional Gunsmith in the
Design and Construction of Firearms, with Practical
Suggestions for All Who Like Guns

By
JAMES VIRGIL HOWE

Formerly in Charge of the Small-Arms Experimental Division at
the United States Frankford Arsenal; also Formerly of
Griffin & Howe, Inc., of New York City

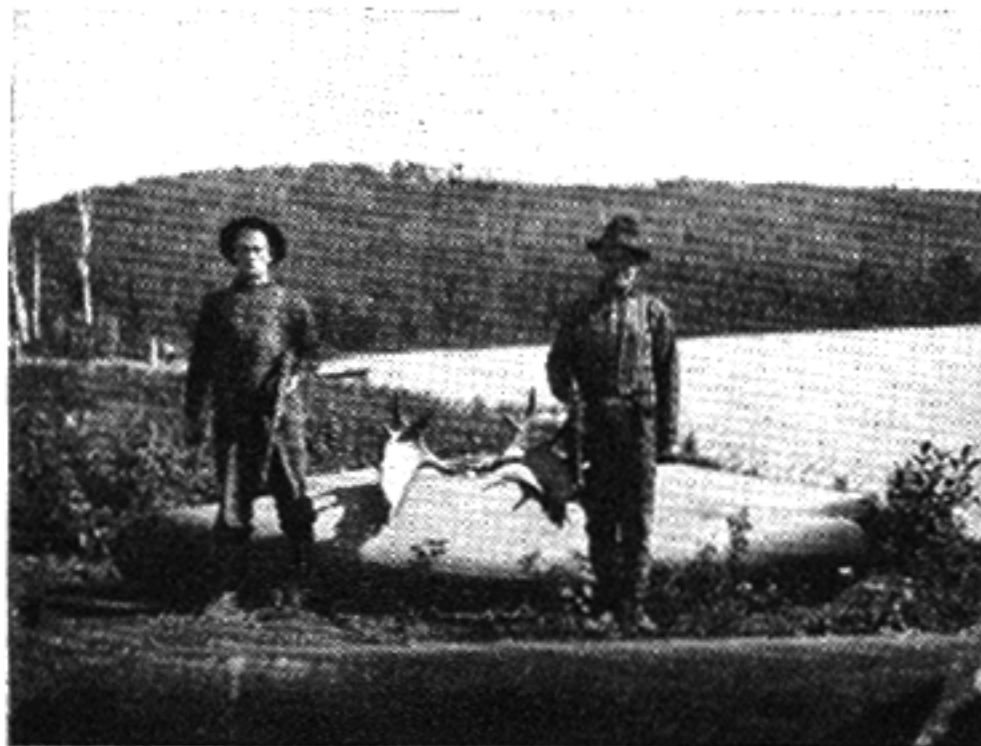
IN TWO VOLUMES

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Volume II



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The only choice: the great outdoors, when you own a gun

Upper center: Dr. Richard L. Sutton, his son on the left, taken on their Arctic expedition. Upper right: Mrs. Elmer Keith with trophy and rifle. Lower left: Guides employed on a hunting trip in northern Quebec. Lower center: Mr. E. Keith with large bull elk secured in Idaho. Lower right: Our camp in northern Quebec.

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VOLUME II

Supplement

THE MODERN GUNSMITH

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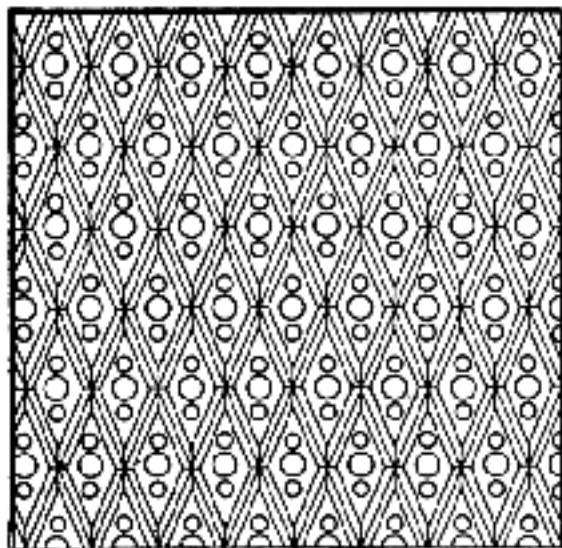
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INTRODUCTION

**Mainly for the
Advanced Student**



The Modern Gunsmith

INTRODUCTION

Mainly for the Advanced Student

MOST men, I think, build air-castles to which they can retire in moments when the monotony of life becomes oppressive. Most, also, are just a little diffident in acknowledging these excursions into the realms of fancy, not realizing perhaps that here there is born the best that comes to a man's life. The desire to be and to do takes form, which eventually, in most instances, will lead to substance.

To be able to follow one into this magic realm and unostentatiously become a companion in the dream takes a sympathetic nature and a love of one's fellow men; but think of the life-long friendship it has made and how the little help and encouragement given has led to results never dreamed of or anticipated. Here is where "can't" is abolished and laughed at, and "I can and will" are born.

So, in writing the second volume of this work on gunsmithing, my mind goes forth into the ethereal and I see many aspiring, still in secret, to achieve the things that hitherto have seemed impossible in this science; it is to them that I address myself. In all seriousness, I say to them that what I preach they can practise; that what I teach they can learn; that what has been done they can do.

The fact that Harry Pope was able to produce his matchless barrels with no other machine than an old lathe, that he could fashion makeshift barrels with a makeshift contrivance would excite no wonder, but that he could and did make barrels superior to those produced by machines designed and built for this particular purpose is a tribute to his patience and ingenuity, and should dispose of the word "can't" forever.

Following the lead of the great mechanic, I have outlined a better set-up, using a milling machine instead of a lathe. Many will doubt the possibility of such a feat, but I assure them it can be done and the work so produced will be equal in quality to that produced on a standard rifling machine—a machine quite out of the question in the ordinary gunsmith's equipment.

The general use of machines in our age has made us mechanical-minded. We do not think any more of getting results from things beyond us. We are not only willing but eager to be shown our capabilities. This is where the word "can't" comes in again. Let us in this book put brains above every other consideration and make ingenuity and stick-to-it-iveness the great aiders and abettors. Let us show the world that our forefathers who did wonderful things with their fingers and the tools at their command still have in us their worthy successors.

Those of my readers who live in the larger towns and cities have opportunities never available in the world before. High schools are often equipped with standard machine tools, and instruction in their use is made a part of the curriculum. Even those beyond high-school age have a place in the night sessions which every winter brings. This is a great advantage, but it must not be thought an exclusive one. A canvass of the greatest inventions reveals that the attic was ever the rival of the laboratory and the wood-shed the rival of the machine shop.

I do not say, attempt the impossible. It would be folly to make, at a tremendous expense of labor, a part that a machine makes better and at trifling cost; but I do want to retain for the student the joy of creating—the satisfaction of having "done it himself."

How many air-castles have had little machine shops tucked away among their turrets? I venture to say that they are innumerable. And how much easier they are to obtain in the workaday world since power can be brought in on a wire! Such a shop is the dream of the experimenter, the technician, lawyer, doctor, padre, banker, or tired business man. Here is a little realm where he is the god, where he can create, express himself, and do as he pleases. Such a place of retirement is the most wholesome, sanitary, and restful place discoverable. Too long have we sought inertly to

be amused. Let us try amusing ourselves for a change. Let *us* be the actors in our little life's drama. It doesn't make any difference what we do. Tinkering, just tinkering, is one of the most desirable ways of spending leisure that I know of. And these hobbies—do you ever stop to realize their value in the scheme of things? To have no hobby means that work and care are slowly stealing from you every ounce of unrecoverable energy. Men without hobbies never retire from business—they have no place to retire to.

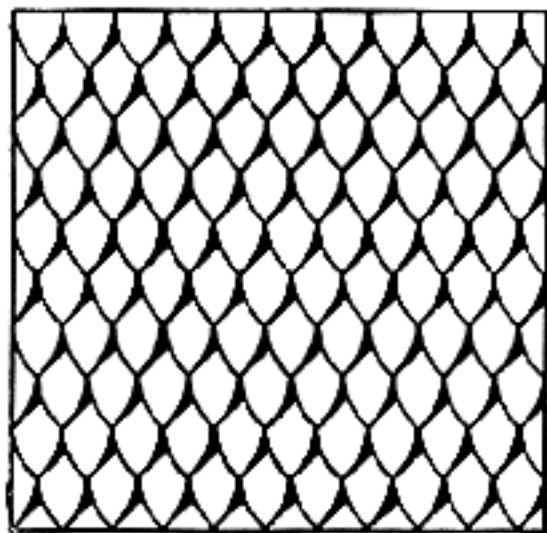
Readers of outdoor magazines are constantly being treated with articles pertaining to firearms. Some of these are of great merit, being contributed by writers of knowledge and experience. Naturally, because of the limitations of such articles, they are fragmentary and incomplete. I have purposely tried, in this book, to augment such instructions, to complete the information. A large demand has forced me to include a chapter on heat-treating. This important subject is still a new thing to most mechanics, amateur or professional. It was not realized until recent years, how

susceptible metal was to structural change through temperature; how lost and destroyed qualities might be restored, fatigue checked, and elasticity preserved; how the stresses lost in manipulation could be released, and varying qualities distributed over a piece of metal. This, I am sure, will be an interesting and informative chapter. There are also two chapters which at first might seem unessential in a book of this nature; but I assure you that chapters on tool making and die making are as important in the production of firearms as any other chapter in the arrangement of information.

You may now turn to the book itself. It has been written in the spare moments of many busy working days. It must not be considered a literary effort. To classify it thus would only add to my discomfiture. It has been a labor of love, accomplished with the fond hope that it may add to the knowledge of the amateur and suggest to the professional other ways of doing things that perchance are improvements on his own. It will also take its place, I trust, as a work of reference—a storehouse to supplement one's memory.

CHAPTER I

Machinery, Power, and General Tool Equipment



Machinery, Power, and General Tool Equipment

THE selection of machine tools for any gun shop depends to a great extent upon the class of work anticipated. If one is dexterous he should only select the machine tools which will profit him in their investment and then add the ones which will make the establishment more complete. A gun shop is a highly specialized tool room or machine shop, and machine shops are to be found in nearly every city, town, village, and hamlet throughout all civilized countries over the globe. There are few products used by humanity which do not depend in some way upon the machinist and the tool room for their production. The shrewd and calculating gunsmith or machinist can always render service in other lines of work during slack times with the equipment at his disposal, and if he has an inventive mind originate some useful article needed by humanity.

Any young man who intends to become a gunsmith, machinist, tool maker, or die maker, should take advantage of every opportunity to become independent of the industrial plants and strive for his own shop. There are really more opportunities for independence here than in a great many other lines of work. In fact a survey of industrial establishments will show that the majority of owners have risen from among those who started at the bottom.

Power for Machine Tools — The motive power required to drive machine tools is either electricity, gas, oil, steam, or gasoline. Because of our rapid advancement, electric power is the universal standard, and very few isolated districts in the world are without electrical power of some description. Gun establishments are usually located in or near cities, so electrical connections are always available; therefore I shall presume that the reader is contemplating using this means of power transmission to drive the various machine tools recommended throughout this chapter.

The individual motor drive with a separate motor attached to each machine makes an installation expensive, and altho this form of drive is the most flexible, it is frequently replaced with the group drive for light gun-shop work. In the group drive the motor drives a short length of line shaft-

ing from which, in turn, the machine tools are driven. The best arrangement for a group drive is to divide the gun shop into small units for wood working, barrel making, the tool room and the machine shop, and have a motor for each unit or department. The line shafting should be as short as possible and the motors placed in accessible position. A small platform makes an excellent mounting for a motor. Motors suspended from the ceiling do not, as a rule, receive the careful attention they need, and it is difficult to replace them when mounted thus.

The horse power of the motor required for group driving in the gun shop is much less than the sum of the horse power required for each individual machine. The reason for this is that some of the machines are idle and others consume only a small amount of power at a time when the remaining machines absorb the maximum amount. Actual experience has shown that for group driving in any ordinary gun shop a motor of between three and five horse power is sufficient.

Lathe — Various ways of driving an engine lathe by motors are in use. Some makers furnish motor-driven lathes as standard equipment; some have a headstock with a limited number of speeds and depend upon a variable-speed motor to fill out the speeds of the lathe. Others apply a constant-speed motor or one with a limited amount of variation to an all-g geared headstock. General practise, the use of which this class of machine is a part in the shop, would naturally lead to a group drive. There is no material advantage, in my opinion, in the individual motor drive if the lathe is just used for the regular run of operations.

Drill Presses — The only reason why the sensitive drill press should have an individual motor drive is that it is used more than any other machine in the shop, not on long and constant application as in a manufacturing plant, but for a variety of special jobs which require only a few minutes of time. Most sensitive drill presses have in themselves all the speeds required for the work intended, so that any type of motor will be adaptable. The motor may either be directly applied to

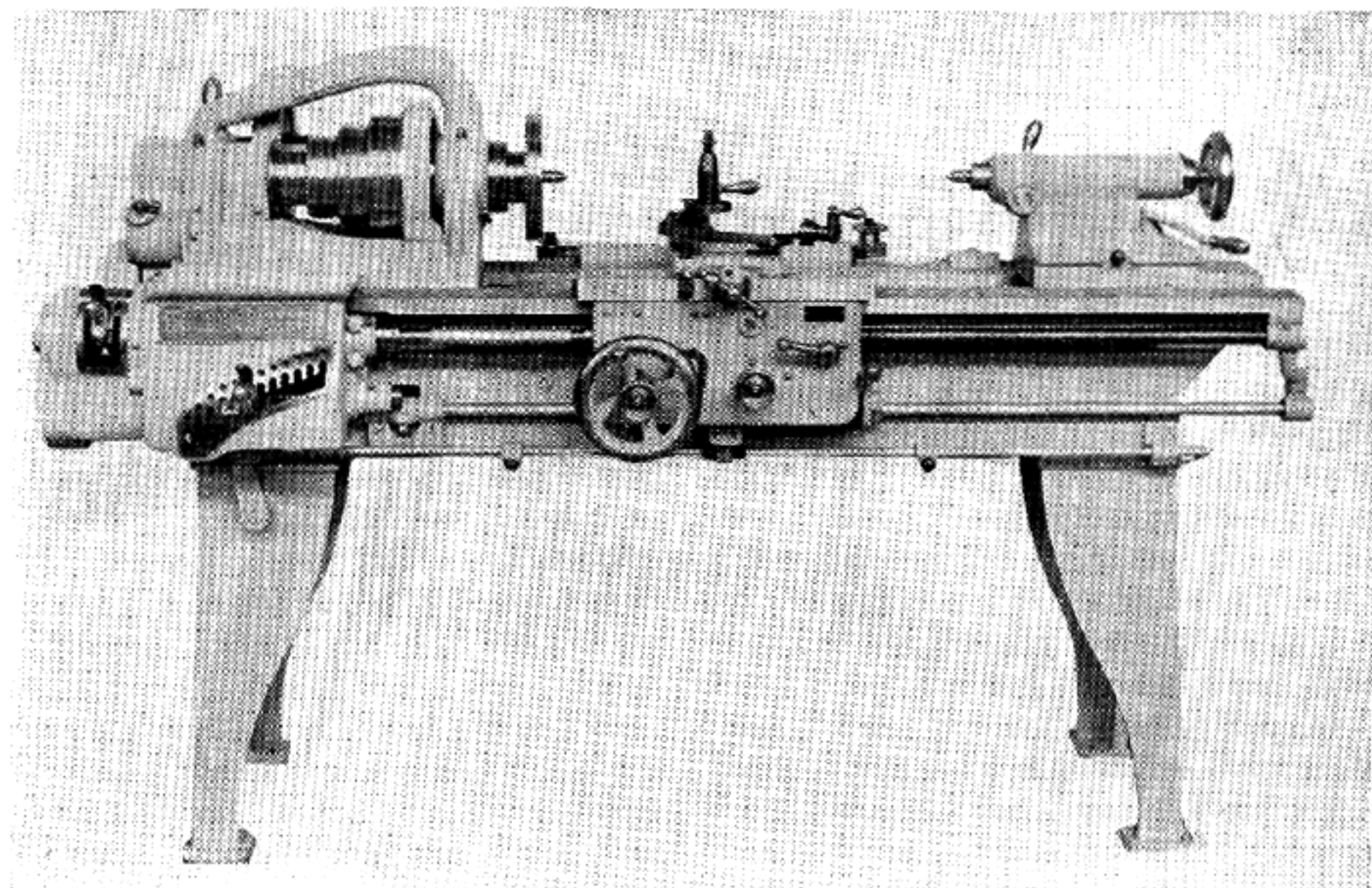


Fig. 1
Hendey screw-cutting engine lathe. Such a machine is essential in the gun shop

the machine or may drive a countershaft on a stand, or it may be placed on the floor by the side of the machine in case the press carries its own set of cones or other variable-speed devices.

Small shop owners often prefer a small upright drill press for work of a manufacturing nature or for drilling and reaming operations on sight ramps, barrel bands, swivel bases, etc. Such machines do not require frequent changes of speed. There are, however, many exceptions; for instance, where an upright drill press is used for all the operations on a piece of work by means of a jig. In this case frequent changes of tools, and therefore of speed, are required, and an individual motor drive, whether directly connected to the machine or operating on a countershaft, is of great value. No special benefit is derived from a constant-speed motor with this type of machine.

Grinders: Cylindrical, Surface, and Internal
—Grinders in general require so many various movements driven from countershafts that it is hardly possible to apply a single motor directly to the machine. The best that can be done is to attach the countershaft to the machine and drive the former from a motor standing on the floor or on a bracket attached to the machine. In isolated cases it would be well to have one or more motors, each controlling a single operation attached to the machine. The average gun shop making all its own tools requires a plain cylindrical grinder for

reamers, counterbores, rifling heads, etc. It is therefore advantageous to select one of the universal type so that all angles can be ground on any reamer. When a great amount of production work is encountered, a tool grinder is an additional advantage and every large shop should be equipped with one for the grinding of milling cutters, special tools, etc., where the average grinder cannot be used. A large cylindrical grinder is often employed to grind plain rifle barrels to reduce the cost of labor in finishing.

Very little use will be found for an internal grinder in gun work except when used in the tool room, and then much of this work can be done on the bench lathe with the internal grinding attachments that are mere accessories for light machines, and used for grinding holes in hardened work. Now there are constructed rigid, massive, compact machines having instantaneous changes of speed and feed, and designed for rapid production of round holes, both straight and tapered. The plain surface grinder offers wonderful possibilities in the gun shop. These machines have been used in the tool room for years and may be used for finishing straight parts on rifle accessories in place of the file, emery cloth, and the buffing wheel. It is better in many instances to utilize the advantages offered by surface grinding. The application of a motor to an older machine does not pay, but in most of the newer types of machines motors are housed in such a manner that they are not seen

and a motor applied is more efficient than an overhead countershaft.

Shapers and Planers — Planers in general do not require the application of a motor, particularly in the gun shop, for these are only used at times for roughing out surplus material from gun barrels, forming oil grooves in oil tubing, and machine-chasing shotgun ribs; also for making various fixtures and for repair work about the shop. In regular production work, however, motor-driven planers give better results because of the facility of handling the work. Another possible advantage when using a variable speed motor and controlling the speed of the motor at the end of the stroke is that much higher return speeds can be obtained with any desired cutting speed. Local conditions may make it advisable to drive individually by motor, but in my opinion this is not advantageous.

Shapers should either have motor connections or friction clutches. The highest type in this class is the all-motor-driven machine with the control handle placed in such a position that it is at the operator's hand, which is also true of the friction-clutch-driven machine. This type is driven directly

from the main-line shaft, which eliminates a countershaft. These machines are of the variable-speed type and are changed by a gear shift. Generally speaking, there is little reason why a shaper should be motor-driven when provided with the friction clutch. A few types handling large work may be motor-driven for convenience, but these are not used for gun-shop work.

Bench and Speed Lathes — Bench lathes should be driven from a countershaft attached to the wall or bench and driven in turn by a motor. Any kind is acceptable; one with a variable speed will be very satisfactory, particularly if it be of the precision type with all attachments for different speeds. The object of the motor drive is to have the lathe in the best possible location without regard to the location of the line-shafting. A bench miller may also be installed on one end of the bench that the lathe is on, and thus the two machines be driven from the same motor.

Speed lathes should be driven from a countershaft located under the lathe, or by a directly-connected motor. In the latter instance, a variable-speed motor is preferable, provided direct cur-

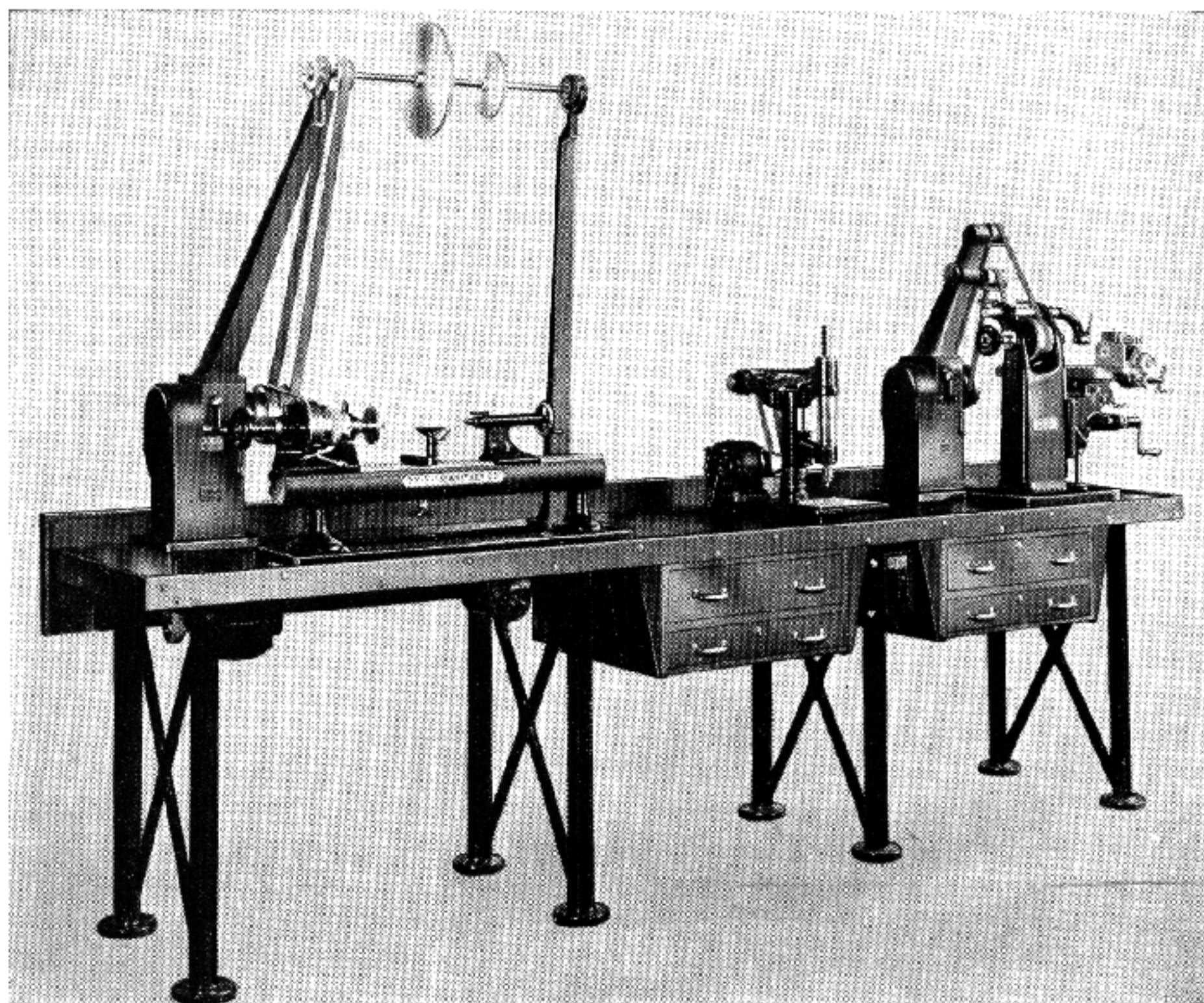


Fig. 2

Pratt & Whitney equipment. Bench lathe, bench miller, and drill press. All electrically driven and made as one unit on a well constructed bench

rent is available. Motor drive is recommended when the machine is used for polishing and filing parts such as screws, pins, etc., as the machine may then be placed where it is most needed, or close to the assembling benches.

Milling Machine — The instructions given for shapers also apply to milling machines, as the arrangement of motor and friction clutch are identical in the two machines. The milling machine is called upon to do such a large variety of work in the gun shop that a study of the different types should be made and the best selected for the work to be done. It is therefore important that the speed should be as close to the permissible limit as possible. When applied to any type of milling machine, the motor should be as low as possible, for vibrations in the machine have a marked effect on the quality of the finish.

Wood-working Tools — Since nearly all wood-working tools are constructed in separate units it pays at times to drive them from a line shaft, provided there is work enough in the shop to keep them continually employed; otherwise, the individual motor drive proves the most economical from the standpoint of efficiency. When most of the stock work is done by hand, only machines of light construction are necessary and these provided with separate motors.

Selection of Machine Tools — Only a brief outline can be given on this subject, for a vast amount of information is required to make a complete treatise, so I must assume that the reader will avail himself of valuable suggestions in the form of reliable books or that he has the necessary training in mechanics enabling him to take counsel with himself and choose the tools best suited to his individual needs, whether in rifle work or other lines of manufacturing.

This chapter is intended for those men who are preparing themselves for the beginning of an all-around knowledge of the gunmaker's experimental stages of mechanics and also for those who may not have had an opportunity to learn. It may give that keynote for the development of talent which has long lain dormant. Some may express their wish to learn a trade, tho they have found their start or even their life's work in one of the special divisions of the metal working industry which have grown out of modern ideas of mass production.

Screw Machine — Early in the development of the machine-shop industry, in the United States as well as in European countries, it became evident

to alert and progressive mechanics that an unnecessary amount of labor was involved in continually changing the cutting tools during repetition or production work on various kinds of lathes. This led to the adoption of devices to avoid the loss of so much time and effort through makeshift contrivances. Then came the development of an idea — the turret lathe principle and the screw machine. Today these may be divided into two general classes; namely, bar-stock machine and chucking machine. The former, commonly termed "hand-screw" and "automatic machine," is used for manufacturing screws, and also for machining any part that can be turned from bar stock or from castings or forgings having a cross-section similar to bar stock. The chucking machine, as its name implies, is used for machining work held in chuck jaws or special holding fixtures, and usually on forgings, castings, or cut stock too large to be a bar-stock product. Machines of the latter class are not used in rifle work, but the former is common in large manufacturing plants.

An inspection of some of the large arms plants will reveal many types of these machines, among them those having a headstock very similar to that of the lathe, and a tool-carrying turret which is designed to swing the cutting tools into position for each successive operation and which may be fed to the work by hand or power, but carries no cross-feed mechanism as a part of the machine. In the large arms plants most of the machines are of the automatic type, but for the small gun shop a hand-screw machine is often an added advantage, particularly for the manufacture of rifle accessories. It is economical to select such a machine as a manufacturing tool, for one piece of work can be finished in less time there than in a lathe; and with two or more pieces making up the part, still greater savings can be made. At times elaborate set-ups pay because the cost in time and money is carried over a large number of pieces and the cost per piece becomes exceedingly small.

I think it well to mention the starting of an unfamiliar machine tool in this part of the chapter. Such advice is ancient history to the experienced mechanic, but to the young man who has not operated all types of machine tools, an advance reminder often saves considerable expense and time. When purchasing or running a machine with which you are unfamiliar, the various controls should be demonstrated by some one who understands them. If this cannot be done, study an operator's handbook such as is furnished by practically every manufacturer of special machinery. These books carry diagrams, descriptions, and cautions regarding particular types of machine. In case neither of these

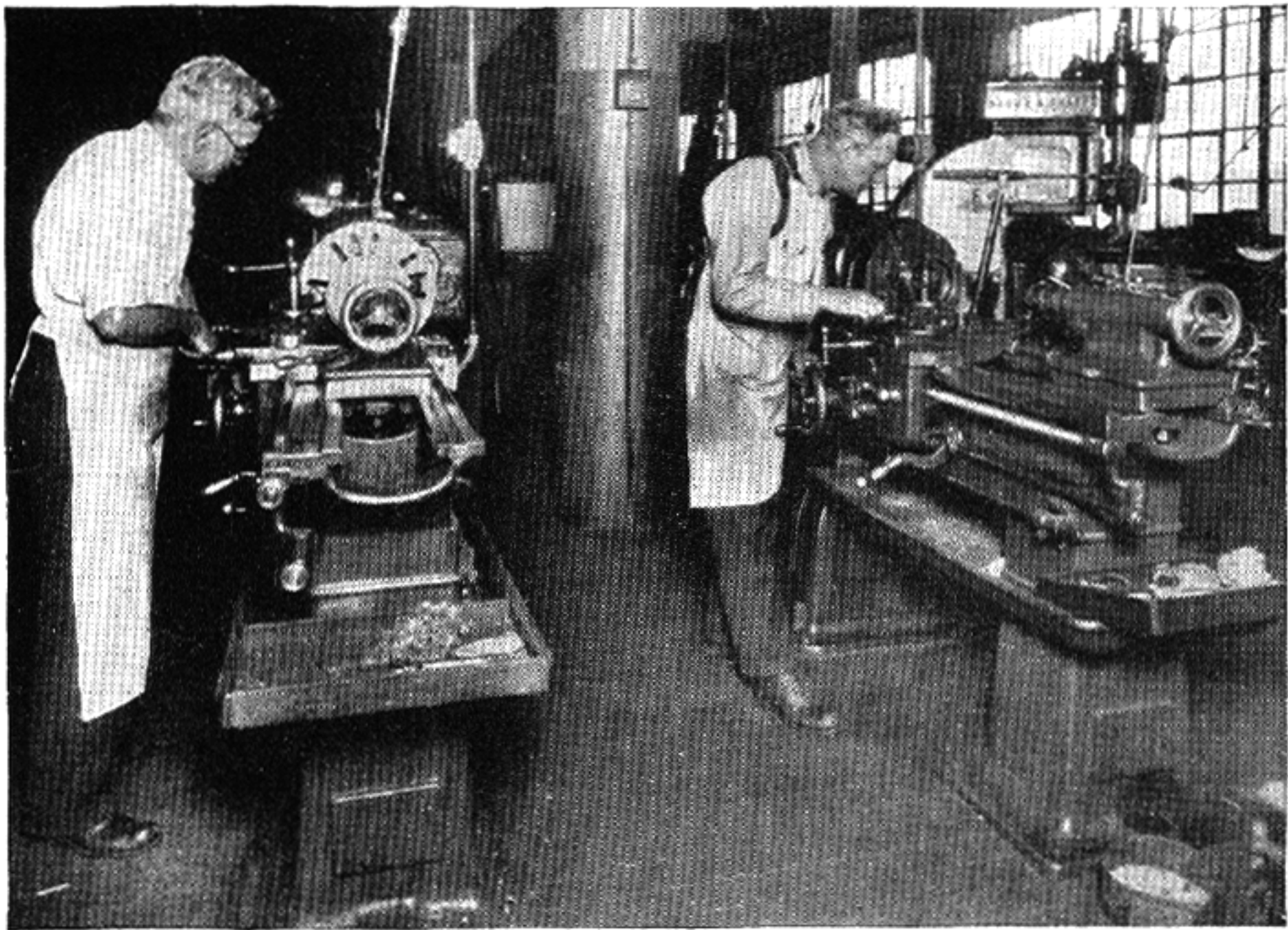


Fig. 3

Engine lathes in operation in the tool room

things can be done, throw off the power, turn the machine over by hand by turning the drive pulley, gear, or sprocket, and try out the various levers, hand wheels, and handles singly and in combinations until you are satisfied as to just what results will follow when certain controls are moved. All cautions necessary for operating any standard machine will hold good for these special machines and some additional ones may also need to be observed.

Lathe — The lathe is one of the most important tools used in the gun shop or in fact any other line of the metal-working industry. The different types of lathes are: engine lathe, turret lathe, bench lathe, jeweler's lathe, etc. The size of a lathe is determined by the amount of swing measured from the centers to the tailstock ways, and the length of the bed, such as 14 in. x 6 ft.—that is, a 14-inch swing and a 6-foot length of bed. Altho the construction of a lathe is simple, it is capable of turning out a great variety of work, as noted throughout the chapters in both volumes. The beginner would do well to learn the names and uses of parts gradually; then he will be quite sure to understand clearly the functions of the parts of the machine and will always remember that a lathe is classed as a precision machine and should be well taken care of. Oil the parts often and you will be better acquainted with each of them.

The main part of the lathe is the bed, which is raised from the floor and supported by four legs. The more modern ones have a chip pan of cast-iron fastened separately to the legs. This type of lathe is used mostly in tool rooms. The height of a lathe is usually adequate for the convenience of the average person. The accurately machined surface of the bed carries the "headstock," "carriage," and "tailstock."

Overhead, if a motor drive is not used, is the "countershaft," which is fastened to stringers from the ceiling to receive the transmission by belt from the main-line shaft and transfer it by belt to the lathe. The bed is made wide and deep to withstand heavy cuts and to give the whole machine rigidity and strength. The upper surface of the bed has "ways" or "vees" which are accurately machined and scraped. The outside ways form a perfectly alined track for the carriage to run on. The inside ways provide a permanent seat for the headstock and a perfectly alined rest for the tailstock, which can be fastened in any position to suit the work.

Lathe Tools — It is very necessary for the beginner to have at least an elementary knowledge of the different tools which can be ground and used in the lathe. Tools required for use on the lathe must usually be ground to suit the particular

type of turning done, and proper grinding of the tools is absolutely essential for the best work. The old method was to forge lathe tools from carbon or high-speed steel bars; they were forged to shape, hardened, tempered, and ground. After many grindings they were again forged and tempered until the steel was too short to use conveniently. The forged tool is very rigid, being made of one piece of steel; however, these are rapidly being superseded for general purposes by the tool holder and high-speed tool bit, and parting tool or blade, because they are far more economical.

The tool holder is a very rigid tool, being made from a drop forging consisting of one piece of metal which has been correctly heat-treated. These tool holders are provided with a square slot into which the high-speed-steel tool bit is inserted and tightened by a set screw. The slot has a slight incline to give the tool a suitable top clearance or cutting shear, thus saving the grinding time and material which would be lost if top and front rake had to be ground on the tool bit. They come in three different types: straight, left, and right hand. The most suitable size is the $\frac{5}{16}$ inch, using high-speed tool bits of the same size. There are also the straight and offset parting tools, using thin blades which may be adjusted for any depth of cut. The same tool may be used for a facing-off operation by inserting a heavier blade for side cutting. There is also a boring tool made to hold different-sized boring bars, but most of the work of boring in the gun shop requires small tools; therefore, they must be made by the gunsmith to suit work of this nature, whether boring or inside threading operations.

There is also a knurling tool holder, which usually carries three pairs of knurls: fine, medium, and coarse. Each wheel cuts a helical groove in the metal, and as the spiral grooves are opposite, a diamond is formed. These tools are used extensively in the gun shop together with small jeweler's knurls for special work such as knurling the heads of thumb screws, etc.

Tool Positions — The position of tools in relation to the work being turned is a very important consideration, and those in the beginners' class who purchase a lathe will do well to study the effect of various positions of the tool, particularly on long turning such as on rifle barrels. Work is often spoiled and in many cases the machine is damaged by lack of foresight on the part of the student. The usual method of elevating or lowering the tool is to swivel the tool holder up or down on the rocker in the rocker rung of the tool post. The tool should never project any further from

the tool post than is absolutely necessary, because the further it protrudes the greater will be the strain on the compound rest and cross slide caused by increased pressure from the last point of support, which is often sufficient to push the tool down, changing its setting and frequently causing it to dig into the work. The position of the compound slide rest, the location of the tool post in the tee-slots provided for it, and the type of tool holder used should all be considered in the setting of the tool. When work is being turned in the lathe chuck, it is easily seen that when the tool post is in a location as near the chuck as possible, the type of tool used will have the greatest influence on the condition of the work. The compound slide or cross slide of the lathe is frequently damaged by a careless mechanic who runs these parts into the fast-rotating chuck, because the tool is not set in the proper position. It is therefore advisable for the amateur to select the best tool for the work he has to do and to place it in position so that it will be rigid and not cause any damage to the work or the lathe.

The advice given for tool positions on the lathe dealt with the position of the tool holder and the tool from an adjusting point of view. It also deals with the influence of the tool position in producing a smooth clean surface on the work. (Refer to Chapter IV, Volume I, for proper grinding of lathe tools.) To explain how the tools should be ground would require too much space and would be of little interest to the experienced mechanic; and I am assuming that the beginner will come in personal contact with the experienced mechanic to teach him correct grinding methods.

Work on a lathe may be carried out in three different ways: on the lathe centers, chucking work, and face-plate work. Various operations may be undertaken in each of these "set-ups." Then, again, a lathe can be utilized to accomplish various other operations in rifle-barrel work. Most ordinary work on the lathe is measured by micrometers and calipers, and the successful use of calipers can only be achieved by constant practise. The calipers are used to obtain many variations of size, and it is only by developing a sense of "feel" that any guaranty of size can be obtained. Many beginners free the caliper over the work, making believe that it is the size to which the calipers are set; but because of the spring in the legs they just spring over the turned surface. It is therefore necessary to develop a very delicate touch to use calipers successfully. Never try to caliper work while it is running. It is rarely accurate and the calipers or micrometers may be caught in the work and broken.



Fig. 4

Gould & Eberhardt shaper in operation

The cutting speed required on lathe work is usually determined by experience before securing the best efficiency from the lathe tools employed upon different types of materials. It is advisable to turn different steels, cast-iron, and brass, to see just what the maximum speed should be. A cutting lubricant should be used when turning steel, to prevent excessive friction and to conduct the heat, thus preserving the point of the tool and producing a smooth finish on the work. Lard oil, which has often been recommended for other work, can be used, or some other cutting compound which can be purchased ready mixed. Lard oil is best for thread cutting.

Shaper — The shaper is used chiefly to produce flat surfaces and to rough out surplus stock on gun parts for milling-machine operations and various tool work such as dies and jig parts. Shapers are very suitable for small work, while a planer is designed to operate on larger work. There are two types; namely, geared shapers and crank shapers. On the geared shaper, the ram is driven by a gear meshing with a rack on the bottom of the ram;

also with a means for a quick return of the stroke. The crank shaper is driven by a crank motion with a means provided for a quick return of the stroke on the ram. The size of a shaper is governed by the size of work the machine can do. A 16-inch shaper, which is the most suitable size, will finish a surface 16 x 16 x 16 inches.

Milling Machine — This type of machine tool is one of the most useful in the gun shop or in any other line of the metal-working industry. The milling machine was first designed by Mr. J. R. Brown of the firm of Brown & Sharpe, for the purpose of cutting the spiral flutes in twist drills, and from that foundation the machine has been developed for a great many other uses. The attachments made for most milling machines are built very rigidly and not like many other makeshift contrivances built to go with machines. Many such attachments answer the purpose for odd work encountered, but in the end special machines must be designed for production purposes.

When the gun shop is equipped with a universal milling machine having all attachments such as a

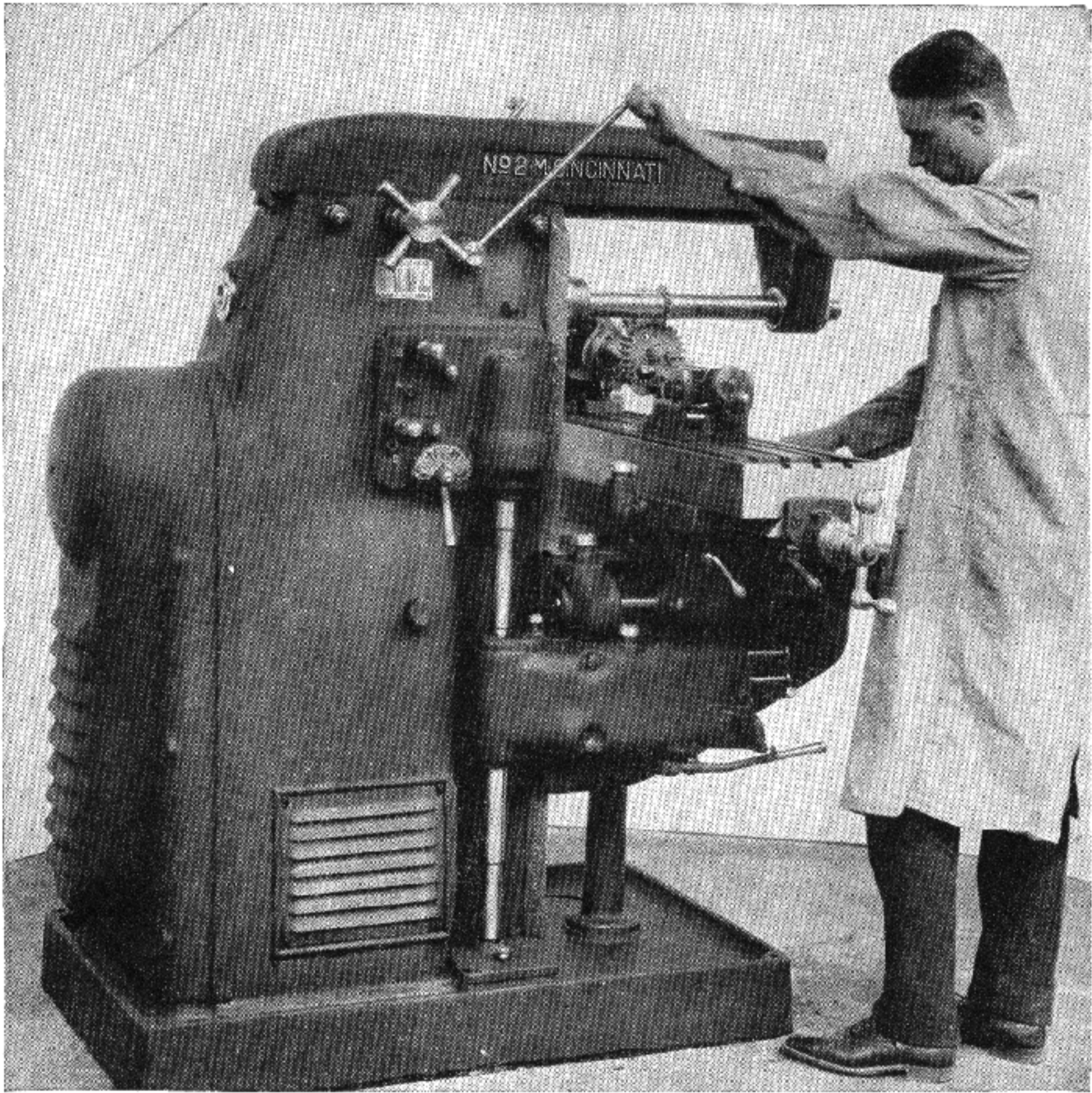


Fig. 5
A Cincinnati milling machine in operation

vertical head, rotary table, slotting attachment, dividing head, center, vise, etc., it is possible to accomplish most of the work encountered on all gun parts. The work is held on the table by various devices and fed against the revolving cutter, which usually has several cutting edges, each tooth cutting away a portion of the material and producing on the work a shape similar to the form of the cutter. The cutters are made in different forms to produce work of regular or irregular shapes, to cut grooves, slots, flutes in taps, reamers, drills, etc. We have already mentioned so many operations which are done on the milling machine that you will understand how difficult it is to operate a large shop successfully without one. The latest machines are usually driven by a motor or directly from the line shaft by belt to the speed cone, and so direct to the spindle through gears similar to a lathe to obtain a further range of spindle speeds.

An endless amount of information could be given on such a machine; for to do justice to a treatise of this nature, a number of tables should be published, together with endless diagrams; therefore I must ask the interested reader to secure books dealing with this type of machine. I have had much experience with machinery, yet I must consult a hand-book continually on certain operations. However, for some of the simple operations, experience has taught an operator or mechanic to use certain cutters for certain work and to know that the table should be fed in the opposite direction to the rotation of the milling cutter. This is done since, if the work is fed against the cutter in the direction in which the cutter is revolving, the cutter will tend to climb on the work and probably be ruined. This is the beginner's problem, and it will be best for him to experiment on a cast-iron block, which involves the use of the plain or universal vise bolted to the table and also the use

of a plain milling cutter of sufficient length to cover the widest cut. I shall assume that the reader is interested enough to complete a study of this machine, for it is one of the most essential in shop practise for producing articles and parts of firearms.

Grinding Machines — Grinding has developed in a comparatively short time from a simple operation involving the use of an ordinary grindstone to intricate work in the finishing of machine products requiring the use of elaborate precision-grinding machines. Grinding is an operation used so extensively in gun work that a good knowledge of it is absolutely necessary. The reader should follow up the work shown throughout the chapters and also study abrasives and their use; also

the manufacture and selection of grinding wheels.

Grinding machines are similar to the milling machine, except that their operations are not so complicated. Still, grinding operations have been used on all classes of work, and when one studies the subject there is an endless number of special machines for such purposes. There are two distinct methods of machining work by grinding, namely, hand grinding and machine grinding, and in both methods grinding machines are used.

Three types of machines are employed in gun work: a cylindrical grinding machine for tool work, a surface grinding machine, and an electric bench grinder for hand tools. The latter has been discussed in Chapter IV, Volume I. Machines for precision grinding are usually classified under the following groups:

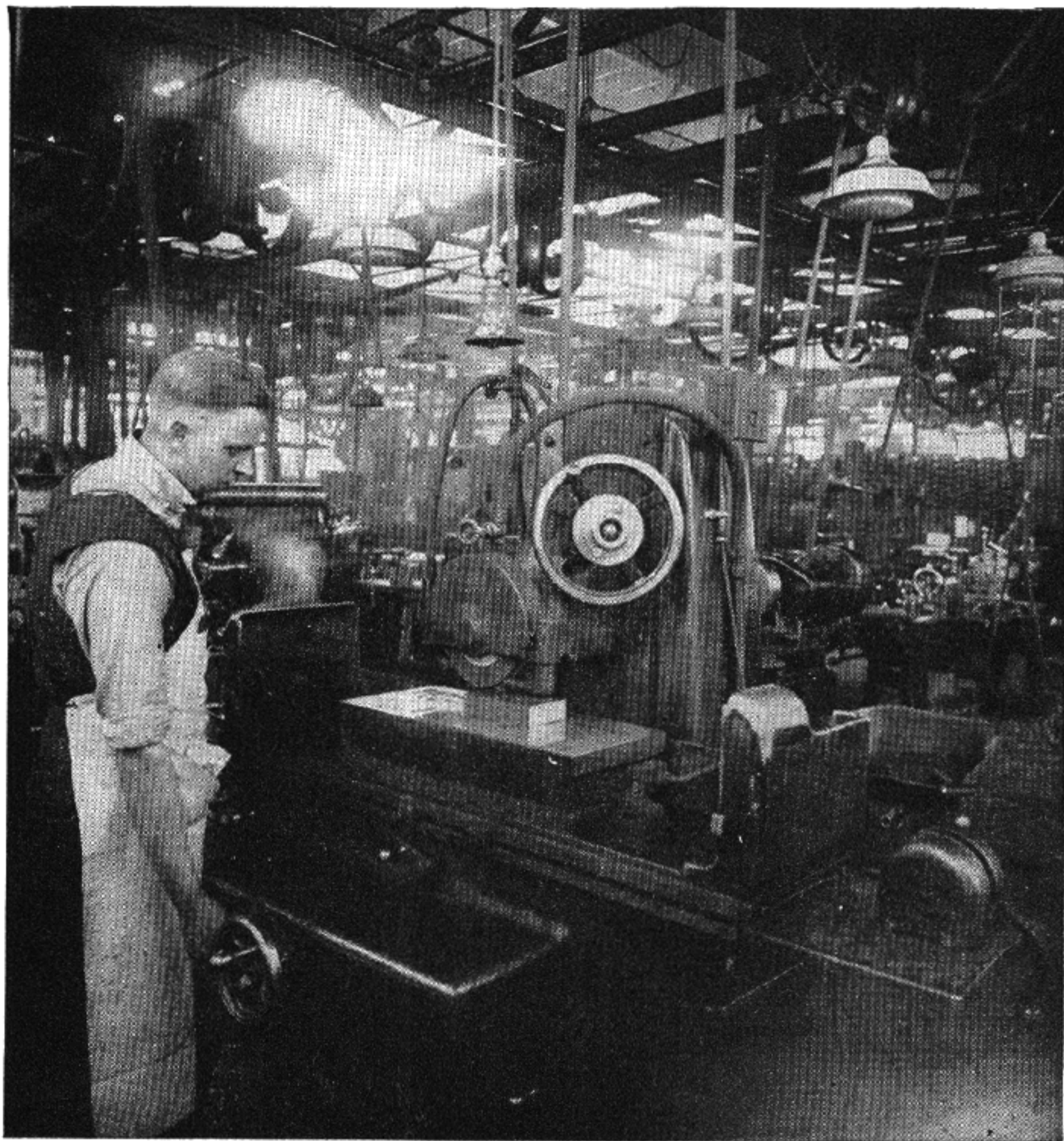


Fig. 6
Surface grinder in operation. Very little use is found for this in the small gun shop. In the larger tool room, however, it is essential

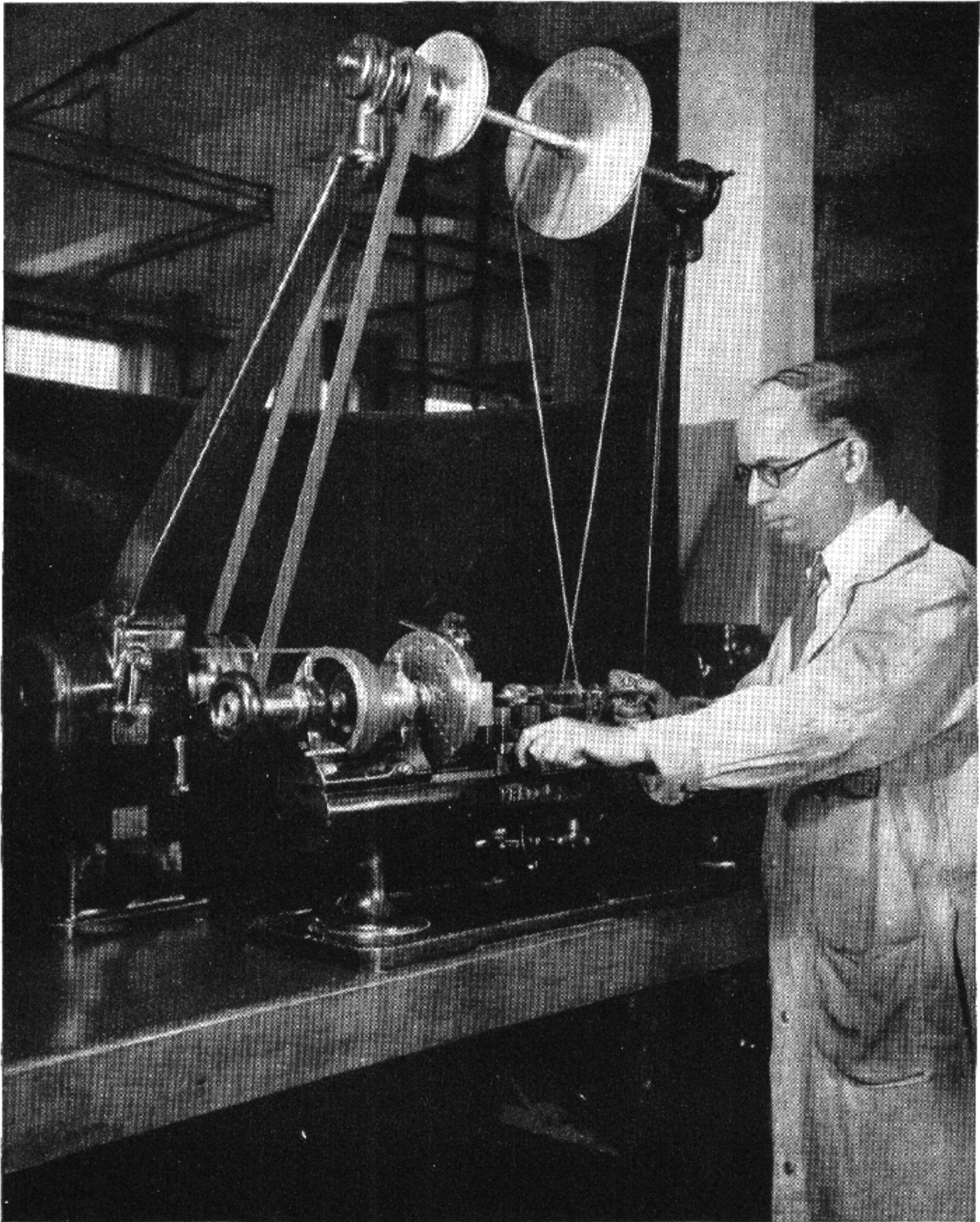


Fig. 7

Pratt & Whitney bench lathe: Internal grinding attachment in operation

A. Machines for grinding milling cutters, machines for hand reamers, counterbores, taps, and work of a similar nature to keep production tools in order.

B. Machines for grinding cylindrical and conical surfaces, both internal and external. Under this group a machine is used for grinding barrels, reamers, rifling heads, etc. A bench lathe equipped with both internal and external attachments is used to great advantage in small-tool work to manufacture rifle parts. Also under this group may be classified the Universal grinding machine, which can grind external cylindrical and conical surfaces of discs, the teeth of milling cutters, reamers, rifling heads, counterbores, and plain surfaces having small areas.

C. Machines for grinding plain surfaces such as the

surface grinder with magnetic chuck for grinding a special tool with flat surface.

D. Machines for grinding work of a special nature. This group includes the drill-grinding machines, portable machines usually having a motor-driven spindle and used on a lathe, milling machine or shaper.

Most cutting tools are simply made with an angle entering the material by the sharpness of their edges and forcing it open or separating it by the gradual increase of thickness it encounters with its angle-like form. A thin-edged or sharp-angled wedge tool cuts freely because it generates less

friction than a thick or abrupt angle tool. A common ax is a simple example of the wedge principle, and every one reared in the country is familiar with the tremendous power of an ordinary wedge when splitting logs. If a wood chisel is forced in a piece of wood, the chisel tends to follow the direction of the side nearest the material, and as it penetrates deeper it requires more power to push it owing to the increased amount of material it is removing. If the chisel were held in a vertical position, as in stock work, the wood would be pushed and scraped off and the edge rapidly become dull. Grinding and stoning operations should be continually in force to keep all tools in their sharpest condition, and on other work a true and even surface retained which cannot be achieved with turning tools alone.

Selection of Grinding Wheels — Selecting a suitable grinding wheel for a given job is a comparatively simple matter for the experienced mechanic when he knows the condition of the machine, the material to be ground, and the shape and size of the work. His knowledge and skill in grinding tell him how to true the wheel, what speed of work and transverse to use, and what depth of cut to take in order to make the wheel cut freely and to produce the desired surface finish in the shortest possible time. However, correct wheel selection is dependent upon proper machine manipulation. The operator should always keep in mind the thought that an apparently poor-cutting wheel can be changed into a good-cutting

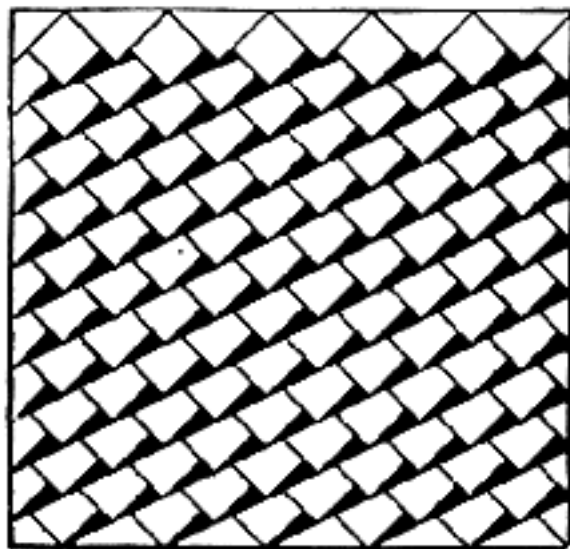
wheel by changing any one of several things: work speed, wheel speed, depth of cut, or manner of truing the wheel. When a wheel is "too hard" it shows a glazed surface very quickly, and when a wheel is "too soft" it does not hold itself together; the logical thing to do is to select a wheel recommended by the manufacturer for the class of work being turned out.

Nearly all the grinding operations are confined to the tool operation, and a medium grade is usually correct.

Wood-working Tools — Wood-working tools for the gun shop enable one to manufacture stocks very economically, but for the small gun shop or the home workshop I can only recommend some of the small wood-working units put out by a few manufacturers. To my knowledge one of the best is the "Delta," made by the Delta Specialty Co. of Milwaukee, Wisconsin. They make complete combination work shops which can be used by the beginner for nearly all roughing-out operations on gun stocks.

There is great pleasure and fascination in making things from wood yourself. Every father might well construct a shop for his boy, allowing him to acquire the skill to produce work and to learn the use not only of his hands but of his head as well. Such investments often pay greater dividends in a boy's education than any other. The tools placed on the market are practical and their catalogs list reasonable-priced tools for wood-working purposes.

CHAPTER II
Special Gun-shop
Tools and
Accessories



Special Gun-Shop Tools and Accessories

THIS chapter is written to assist the advanced mechanic in laying an intelligent foundation for the more highly specialized fixtures used in gun work. It does not concern the special tools and appliances used in large manufacturing plants devoted to gun work, but to the needs of the individual, for methods of mass production would be of no interest to him. He is chiefly concerned with practical problems pertaining to a more highly developed practise and given to those who will cater to the needs of men who seek something just a little different from that turned out by set industrial rules here in America. Ask some of the British gun makers for something out of the ordinary that they do not manufacture; you will find them only too willing to supply your needs. In this chapter specific tools or parts of the equipment are set aside and dealt with practically.

At the conclusion I know that the difficult problem of solving the drawings will only be difficult because the beginner does not approach the problem in easy stages. Most of the drawings are explained in detail, and I shall take it for granted that he will help himself in many ways. These drawings exhibit a very high development of engineering skill, and I cannot neglect those who have devoted years of study to mechanical engineering for the man who cannot read a drawing. The man in the latter class should study the drawings and then construct a part from them to suit his particular needs. The time will be well spent for the interested person. Sometimes apparent things are quickly forgotten, and in practical work the need for a quick and accurate solution is imperative. If a solution to a problem appeals to your reason as being right, it usually is right. Unfortunately it is seldom that another man's device or method, or even his parts, can be used exactly as you used them. Either the work itself is somewhat different or the shop equipment is not the same; unless all conditions are similar you cannot use the other man's device in its entirety for your work.

The field of special gun-shop equipment and tools is so wide that no one book can cover it, but the experience gathered here can be of great assistance to the ingenious mechanic in suggesting methods of simplifying some of the troubles en-

countered and leading to the adoption of various accessories to overcome the difficulty and effort caused by makeshift contrivances often seen in small shops. If practical application is made of these illustrations, I am confident that those who follow the ideas will benefit thereby. All drawings presented here and elsewhere in these volumes have been proved from practical experience and nothing has been taken for granted.

The same subject may sometimes be treated several times, as in the case of the checkering cradle, adjustable tool grinder, and rifle holder for testing; but each time it is treated in a more advanced manner, according to the increased understanding of the reader.

Checkering Cradle — Figure 8 illustrates an all-metal checkering frame and bench made practical by a rigid foundation and quickness of adjustment. This frame would only be practical in a large manufacturing plant and I would not advise the novice to construct it unless he wishes to acquire experience in the construction of some of the advanced stages of mechanics. The two advantages of such a frame over the other simple ones, shown in Volume I, are the ball socket and the manner of clamping the work between centers. After the reader studies the drawing very closely the simplicity of its construction is quite apparent. The frame *C* is made from $1\frac{1}{2}$ x $2\frac{1}{2}$ inch angle iron with a $\frac{1}{4}$ x $1\frac{1}{4}$ ratchet piece *B* and these are riveted together, using the blocking *E* in the center when the plates *F* come together. The blockings *D* at each end are riveted, using $\frac{5}{16}$ inch rivets for that purpose. End stocks *A* are also made of angle iron measuring 4 x 6 inches, with a piece of $\frac{5}{16}$ x 1 bolted on the end. The bottom is bent at an angle of 22 degrees and 30 minutes, which engages the ratchet piece *B*, and when the bolts pull the end stock against a piece clamped between centers a considerable leverage is possible. The ball *J* is set on the end of the elevating screw, which makes it possible to turn the cradle at any angle in the act of checkering and is a feature often needed. The clamping bolt may be adjusted to any degree of tightness desired. The large elevating screw makes it possible to carry

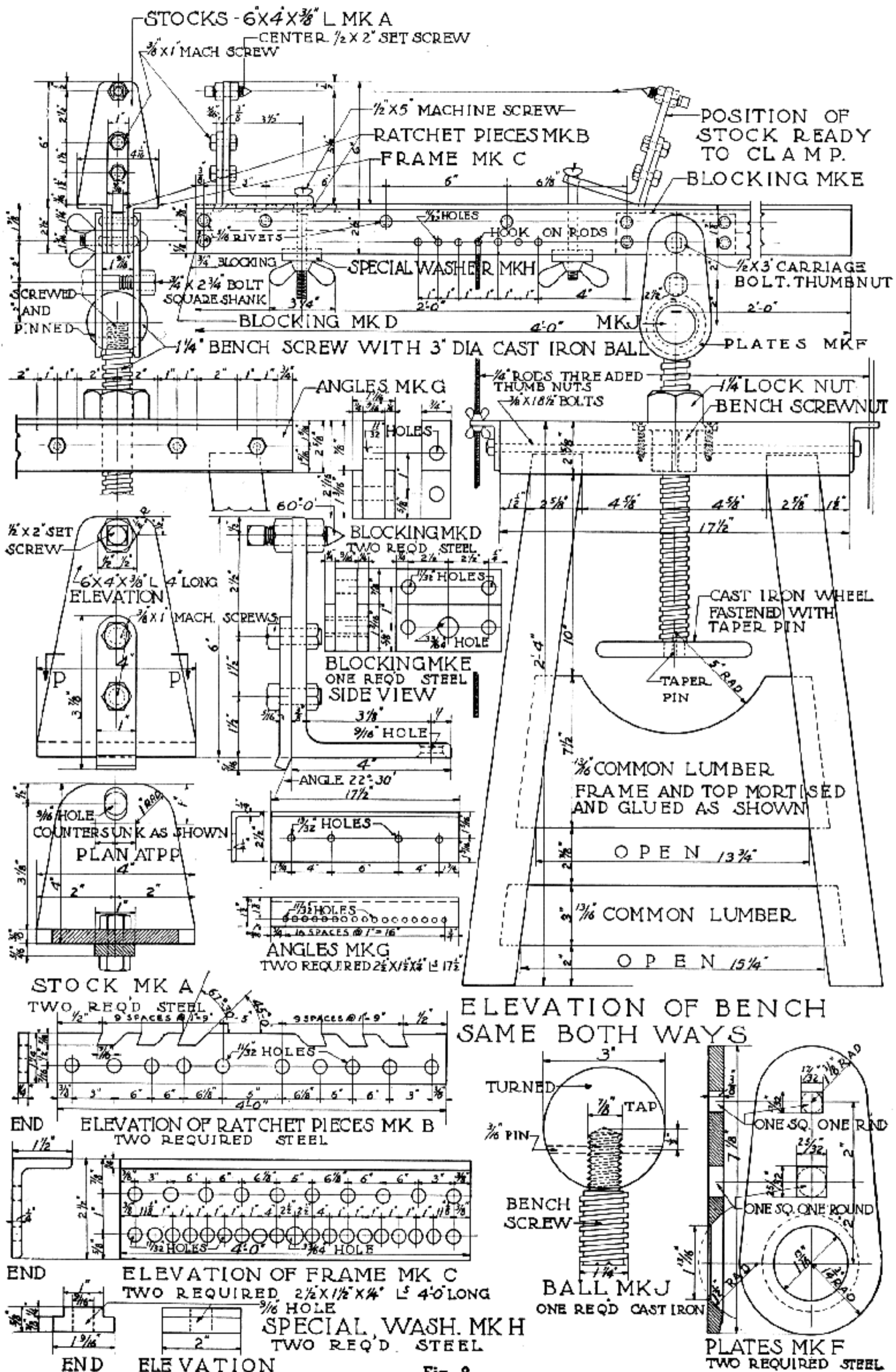


Fig. 8
 Steel checkering cradle and bench

the height so that any build or height of person can adjust it to his stature. The two locking rods shown on the end of the bench and connected to the cradle are optional, and only an added feature in case the work is clamped between the centers requiring an extra-rigid clamping arrangement. The bench which supports the cradle can be made in any manner seen fit.

The pointed set screws, which are shown, can be used for polishing rifle barrels between centers when a barrel and chamber plug are employed; but for the purpose of checkering a stock, a cupped set screw should be inserted in place of these, as it does not have a tendency to split a piece of wood, as does a pointed screw.

Adjustable Tool Holder — Figure 9 illustrates a highly improved tool holder to be used in connection with the bench grinder, and is one of the most practical tool holders for the purpose of grinding flat wood-working chisels, plane bits, etc. The detailed drawing looks rather complicated, but it is really one of the most simple of devices to make. The saving in time pays the wood-working department to install such a tool-grinding fixture. The square rod *E* is the slide with *B* adjusted and the two small angle blocks, so it will just have a free sliding fit. *H* and *F*, two spacing tubes, and the adjustments for different angles are effected by bolts *G*, and any desired adjustments may be made so that any angle can be had by moving the arms *J* and *K*. When the desired angle is obtained, the bottom bolt is tightened and the center bolt is only made friction tight. The square slide rod *E* must be turned and changed each time a new angle is set and then retightened, and only the center bolt employed to control the amount of material to be removed. The center can be clamped tight and the square rod made so that any amount of material can be removed from a tool; therefore, either one serves a double purpose.

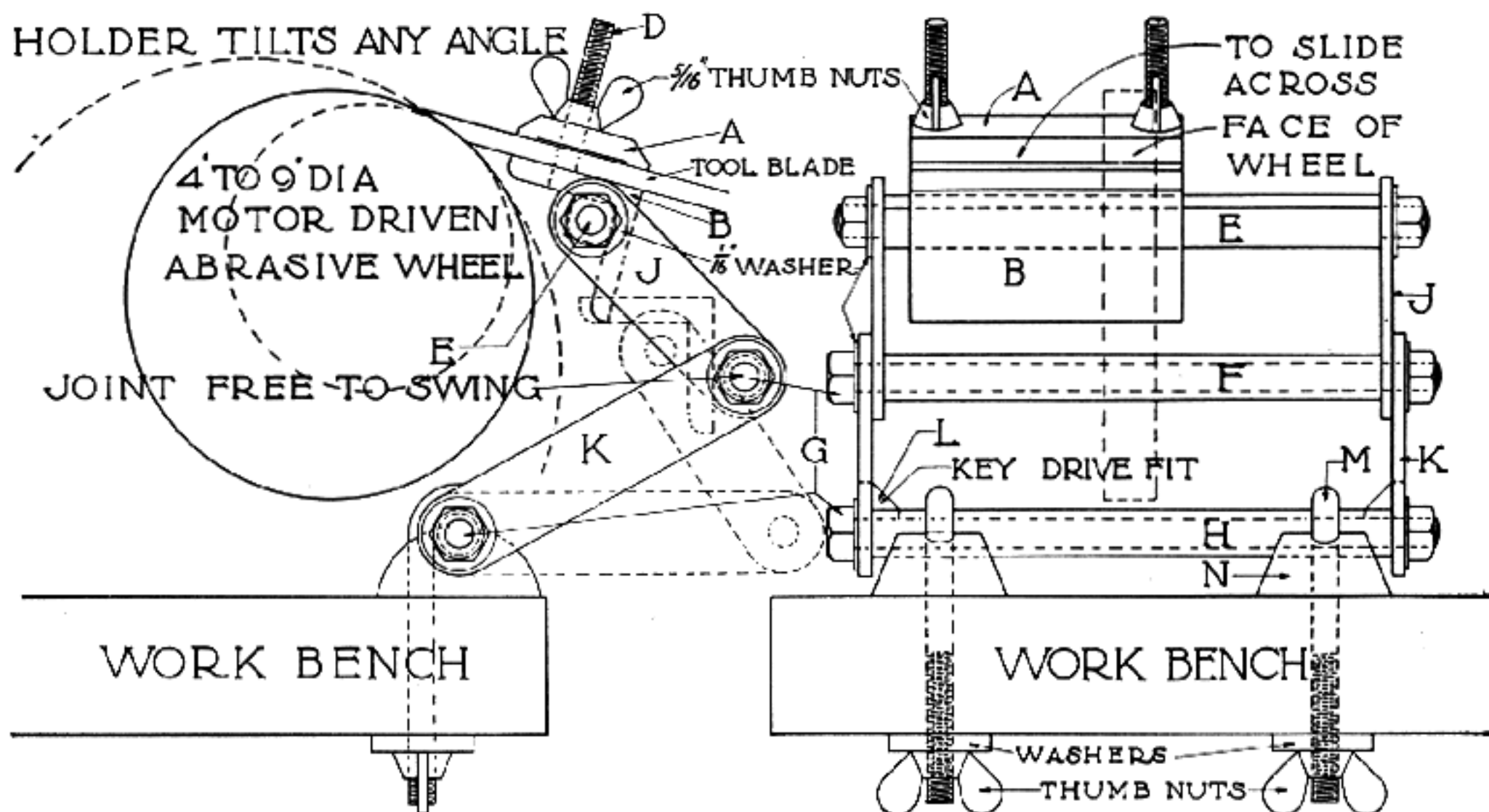
The tool rest *B* is very simple in construction; a 2 x 2 inch angle iron is shaped for this purpose and made wide enough so that any plane bit can be clamped to its surface. Two pins or plugs are set in such a position that a plane or chisel can be set against their sides and they will come at right angles when ground; accordingly, the completed fixture should be set upon the bench at right angles. Many have expressed a desire for such an adjustable tool holder, particularly those who are just starting out in the shop; they find it rather difficult to keep a wood chisel or plane bit at the proper angle on a grinder, but with either this tool or the simple wooden one illustrated in Chapter II, Volume I, it is possible to control the grinding and

at the same time produce a perfect cutting bevel. Too much care cannot be exercised in the use of such a holder so that tools will not be burnt; but since wing nuts are used for clamping purposes, the tools may be very quickly removed and dipped in a can of water which should be close by; or water may be freely sprayed on the tool in the act of grinding.

Barrel-cleaning Tools — In order to keep a rifle or shotgun barrel in perfect condition, suitable cleaning rods should be made, combined with all the strength possible to make the labor of removing residue or other harmful agencies a pleasure. Figure 10 illustrates two cleaning rods and a water cleaning tube and funnel. The construction of the rods shows the best design I know of, and the rods are durable and strong enough to withstand hard usage. The parts shown in the drawing, Colonel Whelen and I worked out a number of years ago; and I know that those who were fortunate enough to own any which were made while I was in Philadelphia understand the merits of its construction. The illustration gives the details of a caliber-.30 cleaning rod, which is one of the most popular calibers.

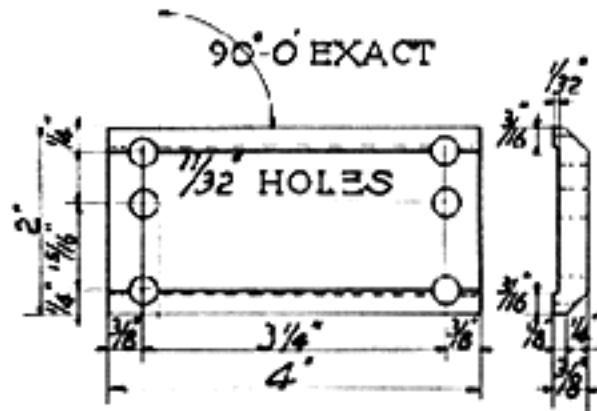
By showing a large detail of the joints the reader can readily see where the strength of joint lies. The male end should be threaded in a true-running lathe collet, and this is done in a sequence of operations on all the sections. First set the lathe tool to remove a roughing cut, leaving 0.020 inch for a finish cut, and at the same time form the radius. All sections are roughed to the correct diameter and stated length on one setting of the lathe tool. The second operation finishes these to size and forms the corner radius, also on one setting of the finishing tool with the correct radius ground on the corner. The third operation places the round recess at the end of the threaded section for the threading to free itself from the metal. The fourth operation is the threading of the ends, which is also accomplished in the lathe with a threading tool and the lathe geared up for the correct thread. The thread is chased within 0.005 of size and then finished with a finishing die similar to those used to finish a tap to a given size as explained in Chapter III.

The operation on the female end is also achieved by similar operations. Each section is centered with a combination center drill, and then comes the second operation, drilling to the correct depth with a standard tap drill. The third operation is to ream the recess and at the same time form the radius on the inside to correspond to the radius on the male section; a special tool should be made

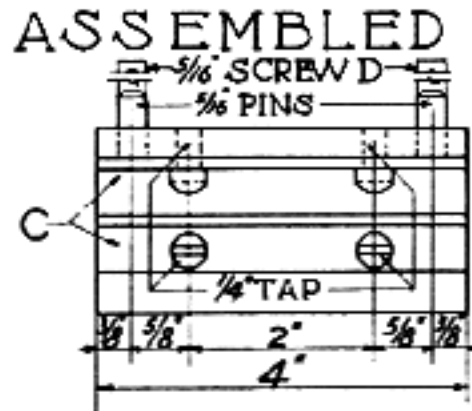


SIDE ELEVATION

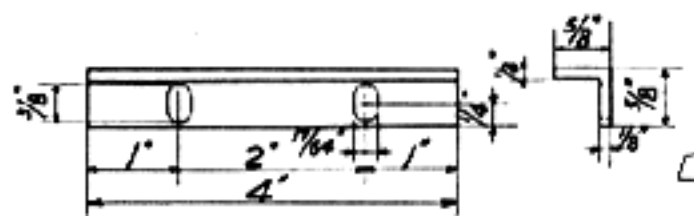
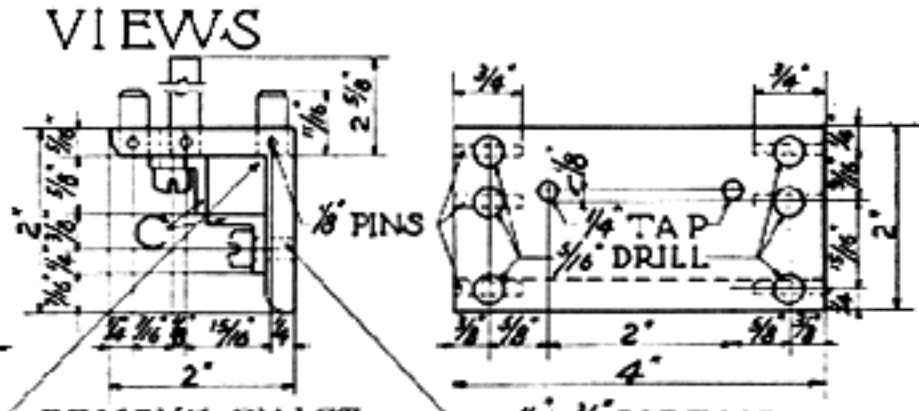
FRONT ELEVATION



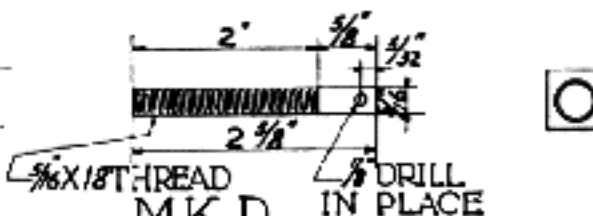
CAP MK A STEEL
ONE REQUIRED



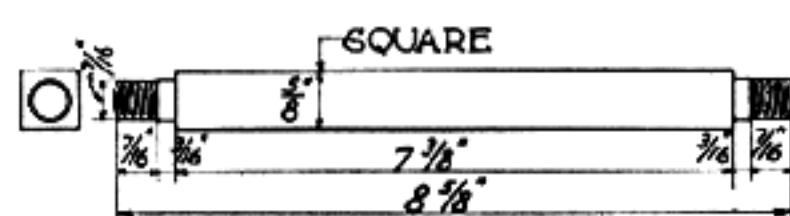
TOOL REST MK B STEEL
ONE REQUIRED



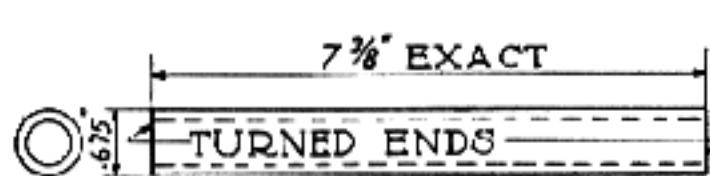
SLIDE CLAMP MK C
TWO REQUIRED



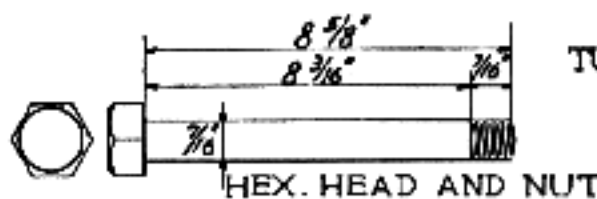
CLAMP SCREW MK D
TWO REQUIRED



SLIDE ROD MK E
ONE REQUIRED



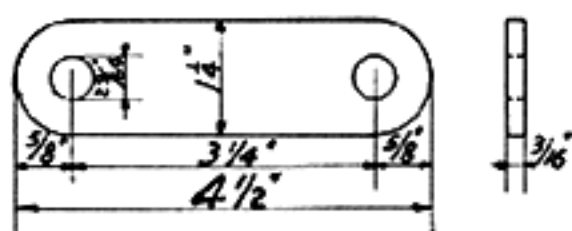
SPACER TUBE MK F
ONE REQUIRED
3/8\"/>



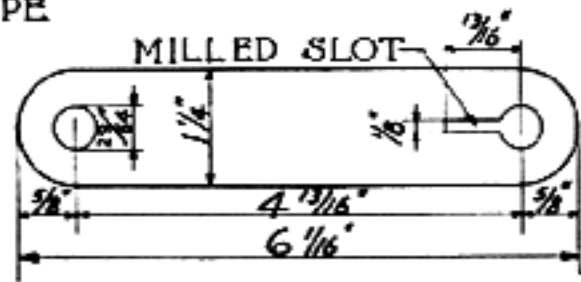
BOLT MK G
TWO REQUIRED



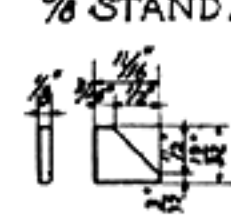
SPACER TUBE MK H
ONE REQUIRED
3/8\"/>



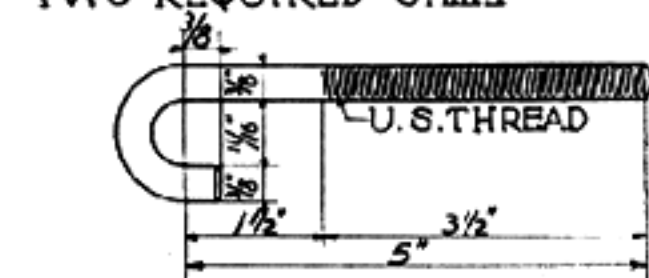
ARM MK J
TWO REQUIRED STEEL



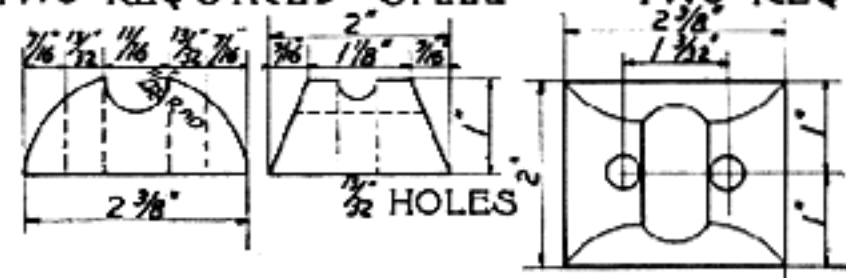
ARM MK K
TWO REQUIRED STEEL



KEY MK L
TWO REQ'D STEEL



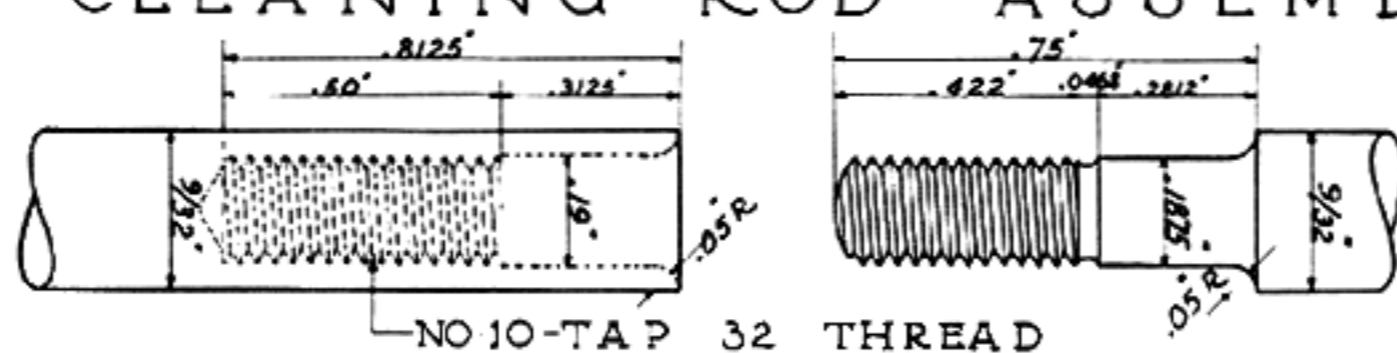
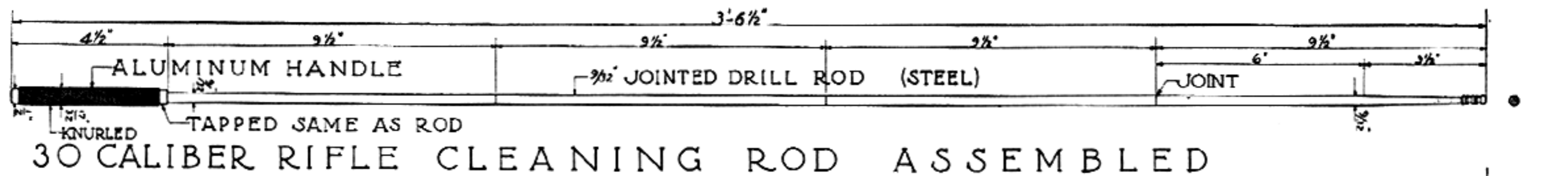
HOOK BOLT MK M
TWO REQUIRED STEEL



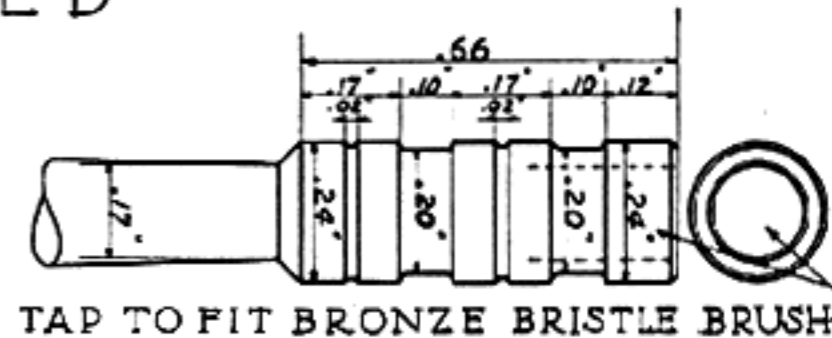
SADDLE MK N
TWO REQUIRED CAST IRON

Fig. 9

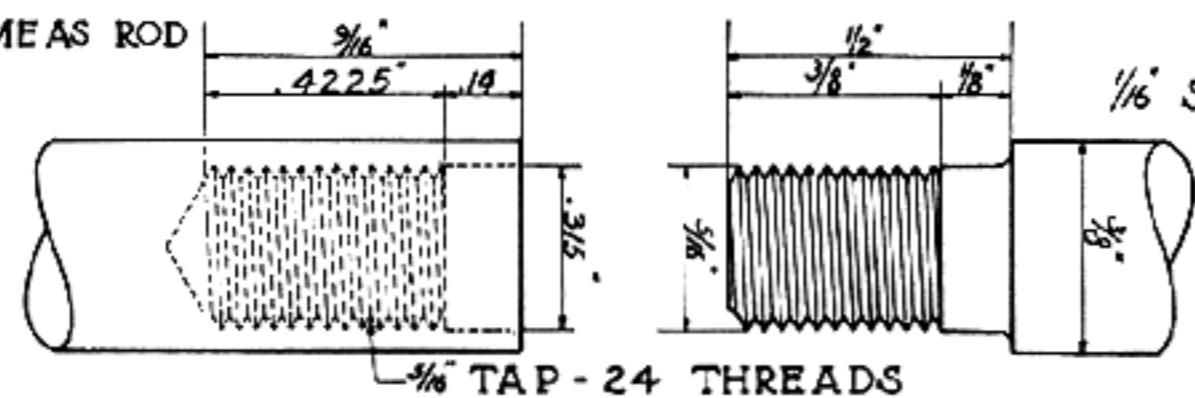
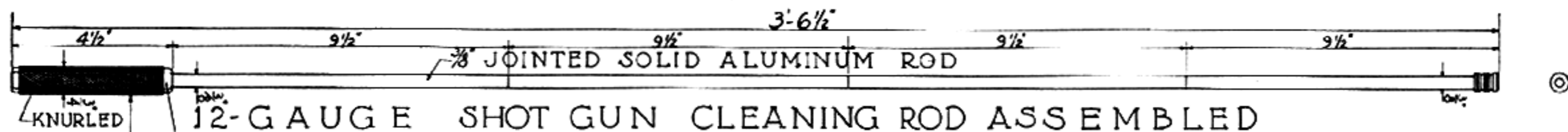
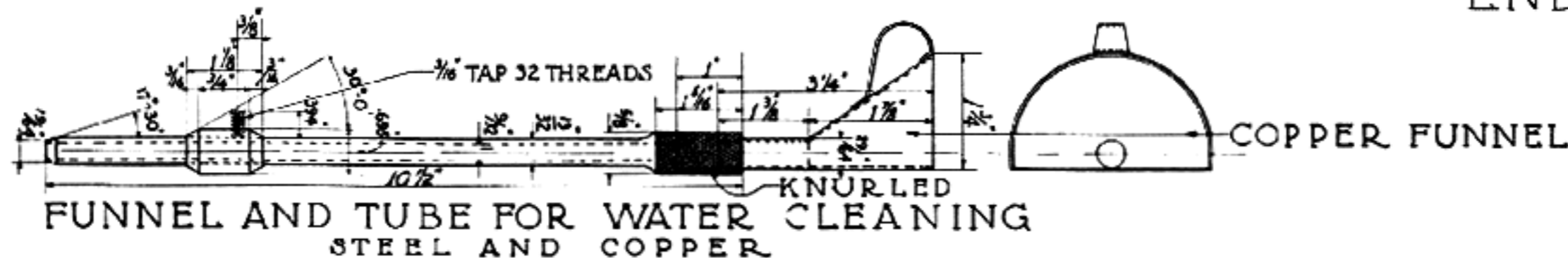
Improved adjustable bench tool grinder



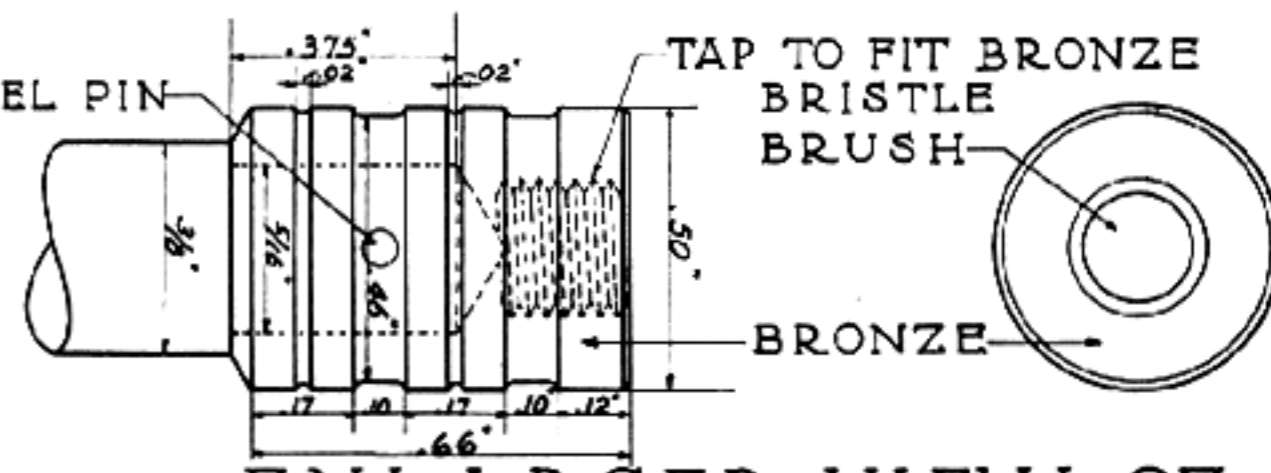
ENLARGED VIEW OF JOINTS



ENLARGED VIEW OF END OF ROD



ENLARGED VIEW OF JOINTS



ENLARGED VIEW OF END OF ROD

Fig. 10
Barrel cleaning accessories

for this purpose which will ream the recess to the proper depth and at the same time form the radius when it reaches that point. The fourth operation is to tap all the sections; this also is done by holding them in the collets of the lathe and using a true-running tap; white lead should be used as a lubricant, and as the tap is started the lathe should be revolved by hand to check the tap to see if it is running true or given a true start for which it must continue the full depth of the tapped hole. After the ends are finished they are washed in gasoline to remove the chips.

The turning of the ends or tips is the next operation, and then drilling and tapping the tip for the bronze bristle brush. The operation of turning the end and planing the taper back from the tip is a regular lathe operation requiring no explanation. The handle may be made from either aluminum or cold-drawn steel. If steel is used, the center may be drilled out to remove a considerable amount of weight and then case-hardened, only allowing enough metal on the end to form the tapped hole.

When making cleaning rods for other calibers, the corresponding size of drill rod should be used: .22 caliber, $\frac{3}{16}$ -inch rod; .25 caliber, $\frac{7}{32}$ -inch rod; 7 mm. or .270 caliber Winchester, $\frac{1}{4}$ -inch rod; caliber .30, $\frac{9}{32}$ -inch rod; .350 and .375 caliber,

$\frac{5}{16}$ -inch rod. Rods for larger calibers can be made of drill rod or duraluminum, the same as shotgun rods, to reduce weight; or larger tips could be placed on the $\frac{9}{32}$ -inch rod according to the caliber the rod is intended for.

Six-inch short jointed cleaning rods are made similarly. For caliber .30, a $\frac{7}{32}$ -inch drill rod is employed, and for the handle end a $\frac{1}{4}$ -inch length of drill rod is used, turned up to $1\frac{1}{2}$ inches on one end to a $\frac{7}{32}$ -inch diameter and then the $\frac{1}{4}$ -inch size is knurled. Six of these lengths are used, and the very neat and compact rod, when finished, can be conveniently carried in the butt stock under the butt-plate trap.

A complete description of the caliber-.30 cleaning rod has been given; therefore one will not be necessary for the shotgun rod as illustrated in Figure 10. The same-sized rod may be used for all gauges, except that different-sized tips must be made for the ends. The cleaning tube and funnel illustrated in Figure 10 is rapidly losing the favor it had a few years ago, because of the use of the new primer mixture; but many still include this among their equipment. The tube is made from a piece of heavy tubing measuring $\frac{1}{4} \times \frac{5}{8}$ inch, and the hole is enlarged to $\frac{9}{32}$ inch for a .30 caliber; one end is knurled and then drilled out to take the end of the funnel. An adjustable locking collar is

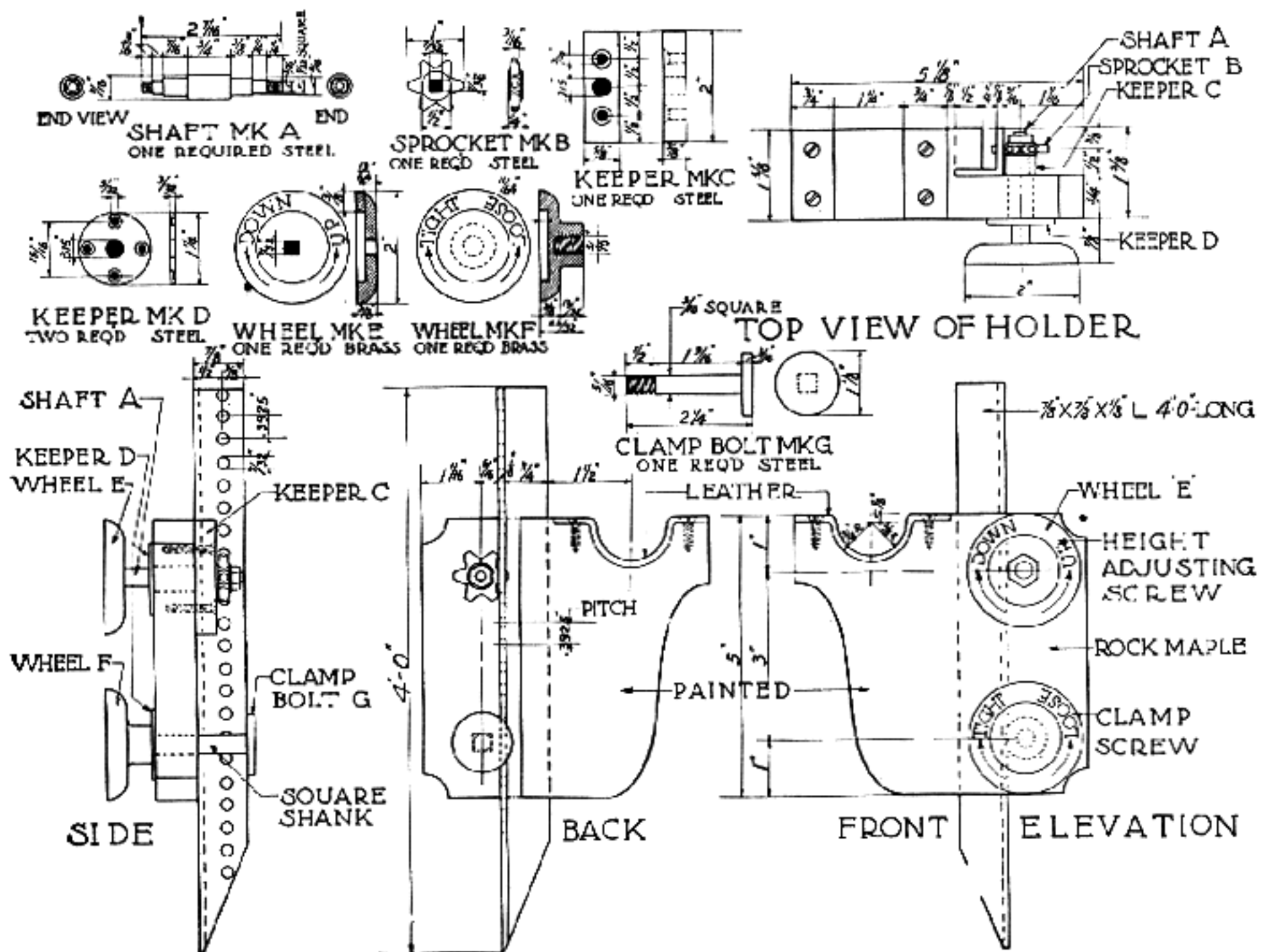


Fig. 11
Improved rifle holder for testing purposes

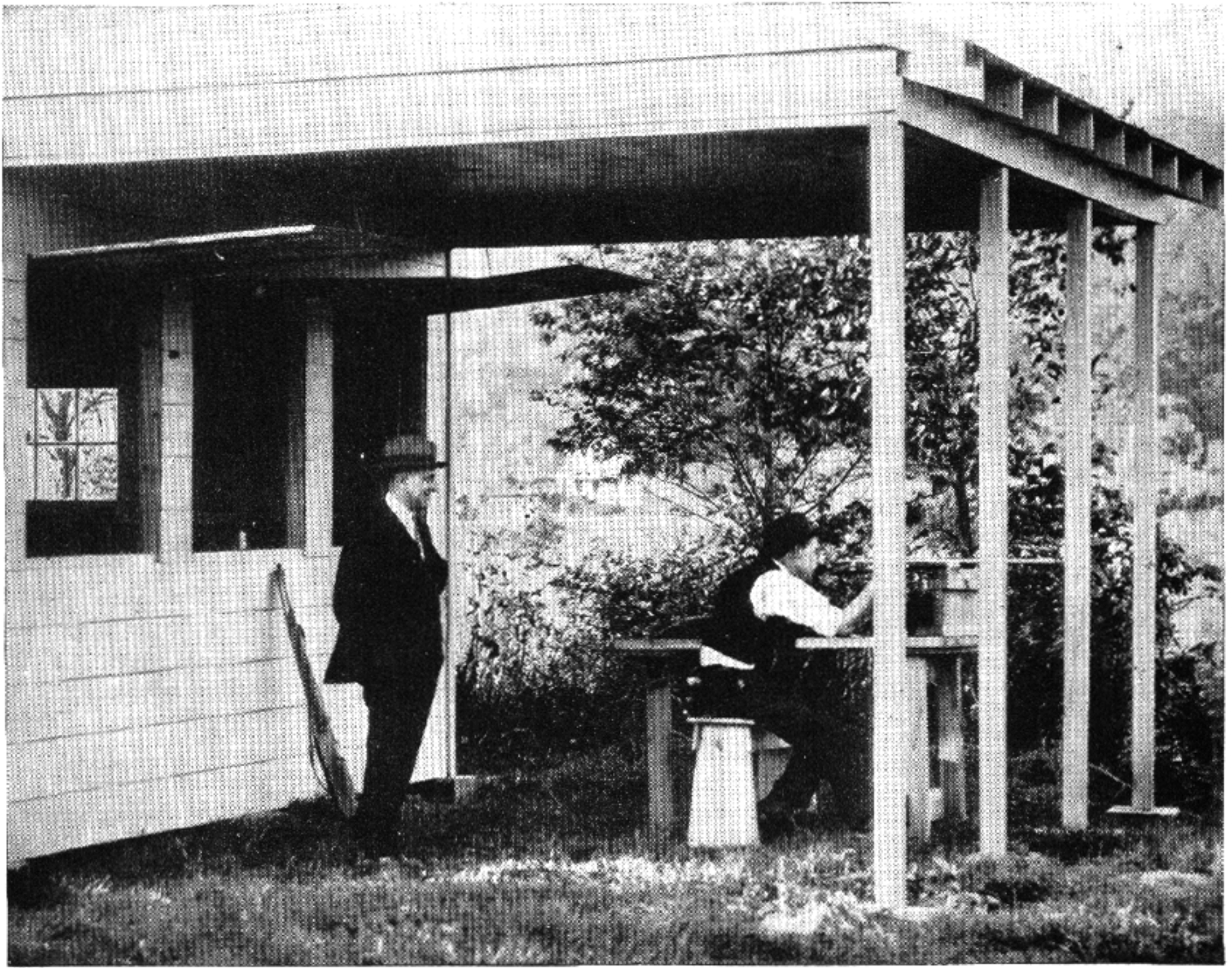


Fig. 12

A model testing house with shooting bench made so that the user can fire from either right or left side

made with a screw; this is used for two purposes—to lock the collar in place, and to keep the tube in position when it is inserted in the receiver and turned into its locked position.

The funnel is made from copper, which is cut out, formed, and the seam soldered, as shown in the drawing. A caliber-.30 cartridge case is cut off and soldered to the bottom, and because of the slight taper in the case a very tight fit is possible in the drilled and tapered end hole. Different designs may be made to suit any rifle, and since the foundation has been laid I suggest that the reader construct such a device even if he uses a cartridge case with the end drilled out and a tube soldered to it.

Rifle Holder—Figure 11 illustrates an improved rifle holder for targeting and testing purposes. Chapter II, Volume I, shows a simple form of holder, but those who wish something a little different from the ordinary can construct one of these. The holder may be made from an

aluminum casting instead of a piece of maple, and the stake from a piece of $\frac{7}{8} \times \frac{7}{8}$ inch angle iron. A series of holes are drilled on one side so the sprocket *B* can work in these to secure the “up and down” movement. Very close adjustment is possible by holding the clamping screw just friction-tight, and when the correct position is reached the block is tightened into position. The face of the radii is covered with leather, glued, and screwed into position.

Every rifleman should have one of these holders; it not only enables him to secure perfect groups, but it proves the only means of securing the proper sight-setting on a rifle. It is used in the sitting or prone position, and when an elbow and muzzle rest is required, a shooting stand should be made like that shown in Figure 12 (the form of testing bench used at the range). A right- or left-hand shooter may also use this table. The top of the upright is padded and a leather covering is put over the material used under the leather. Hair used to pad furniture is good for the padding.

Rifle Machine-rest for Accurate Shooting—The object of employing a rest when testing ammunition for accuracy is to minimize error and to stabilize the best methods of bullet manufacture. With the very best rest it is possible to eliminate any source of error to a great extent, but not entirely, in some designs. Many factors enter into their operation, and in the final analysis the human being who operates a machine rest, no matter how well designed, can always make a mistake, even tho it is a minor one.

At the Frankford Arsenal we came to the conclusion that the Mann form of mechanical rest was the only one worth considering; that is, if the greatest possible accuracy was to be expected. The Mann rest is the six-point rest with the best-located set of six points yet devised for testing ammunition only. Before any description is given of other forms of machine rests, it must be remembered that every experimental type of rest may have its own peculiarities, and that the sighting to give a central impact of shots with one type may give a very wide group with another form of design.

This is due to the fact that every rifle barrel vibrates when fired, and that any particular control of the barrel interferes to a certain degree with all vibrations, and consequently with the line of departure. Slide rests and similar mechanical devices requiring a means of clamping the rifle are not altogether satisfactory. The most usual example is the Frankford Arsenal rest, in which the rifle is clamped at various points, pressure being applied by winged nuts, and the whole mass of metal recoils in a solid V-shaped slide. After each shot a heavy spring returns the rest to its firing position in the V's ready for the next shot. These rests are known as fixed rests.

There are two serious objections to the Frankford Arsenal rest: first, a highly skilled mechanic must bed down the rifle and watch it continually; secondly, the resulting groups are not the exact results of a perfect barrel, of a perfectly designed bullet, or of a rifle in its own stock.

The rest designed on the principle shown in Figure 13 proves the true accuracy of a rifle fairly well; still, a number of experimental factors can be considered, and one is the clamping at the muzzle. Instead of a three-point screw bearing, plungers could be used with springs, having screws for the correct pressure on the plungers to allow for vibration.

There remains the true geometric method attained by Dr. Mann's six-point rest, which is the most perfect for testing the accuracy of ammunition. When six definite separate points control

the position of the rifle barrel, it can be replaced on the rest time after time in exactly the same position. Naturally it is essential, in order to achieve this, that the points should rigidly maintain their relations to one another and to the concrete base to which they are fixed, while the cast-iron base itself must be bolted to it so that adjustments are possible for elevation, depression, and windage. The reason for these six definite points is that every body has six degrees of freedom: three of translation and three of rotation.

Dr. Mann solved the problem by locating the six contacts in the best manner for testing the accuracy of a cartridge. At times it is found essential to test the cartridge alone. For this purpose Dr. Mann used a barrel weighing, with its action, nearly fifteen pounds. By preference much of the weight was placed in the barrel. The barrel was mounted in two concentric rings of solid metal, one near the muzzle and one near the action. Any convenient action was fitted to the barrel and the whole was set on a heavy casting with a large V, capable of being elevated and traversed. The V carried a front stop up to which the front ring was set and also a lateral stop for revolutions to insure that the trigger guard or the action was always revolved to the desired location—12, 3, 6, or 9 o'clock. Very little effort is required to release the trigger without moving the gun, and the actual defects can be checked in the ammunition. The shooting of such a rest must be seen and used to be appreciated.

Machine Rest—Many riflemen and gunsmiths have expressed a desire for a machine rest for testing purposes. The machine rests we had at the Frankford Arsenal would be too elaborate in design and far out of reach of the average rifleman or gunsmith. Figure 13 illustrates one of simple design which is very easy and economical to construct. It is made on the same principle as the rifle vise shown in Figure 87, except that the vise is clamped to a heavy back plate and this is clamped to a heavy piece of angle iron which is bolted to a 2-inch piece of cast-iron set upon or in a concrete foundation. A simple method of adjustment is possible in any direction by set screws. The nuts are left friction tight, adjustments made for a few trial shots, and then the clamping nuts are made tight. Suitable bushings must be made as shown on the barrel-vise drawing to fit the barrel ahead of the receiver, and when once the barrel is clamped as it can be in such a vise, the most severe recoil will not move it. An inclinometer may be placed upon the barrel

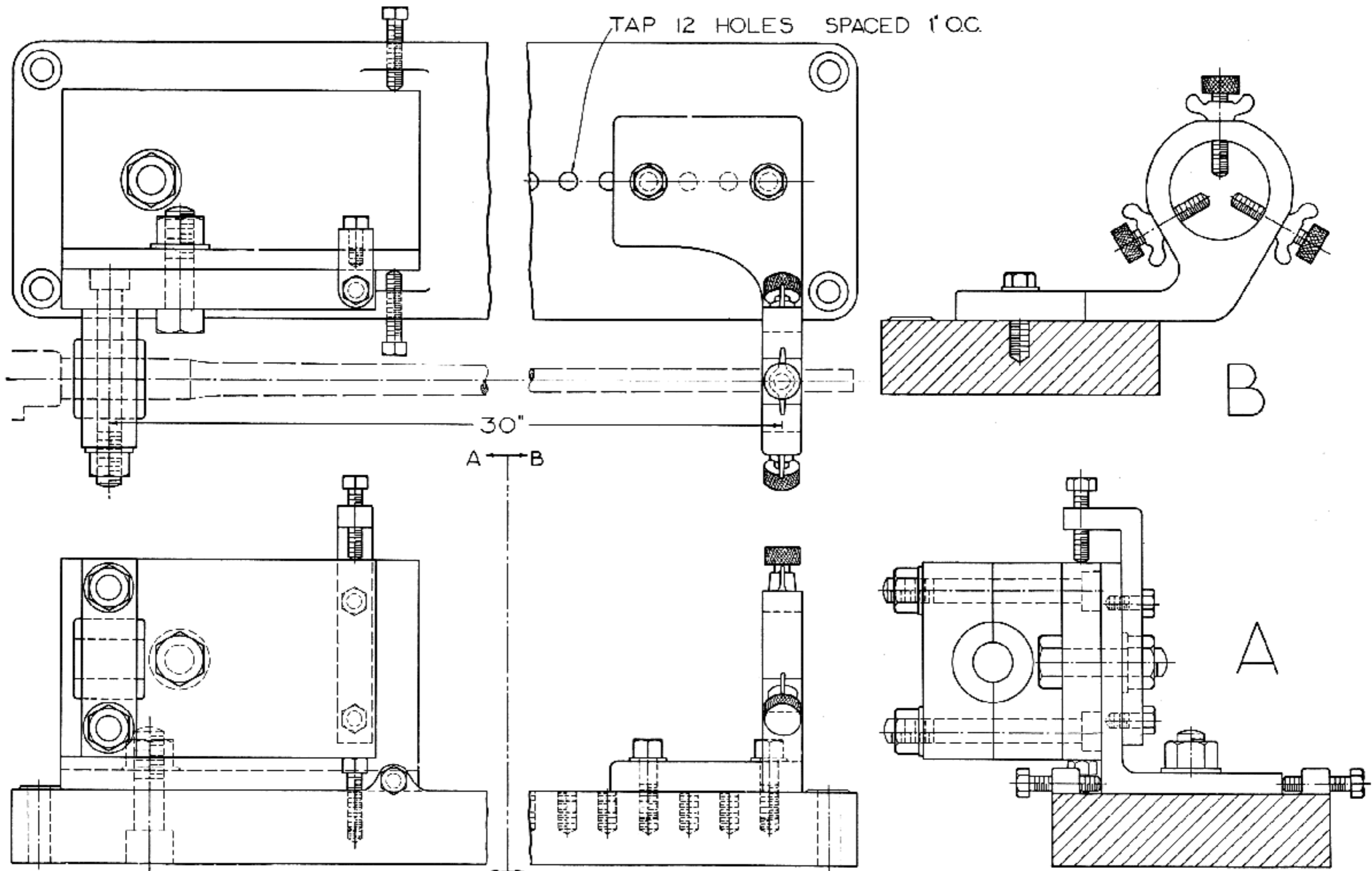


Fig. 13
Improved machine rest design for accuracy trials

wise, providing all parts are at right angles and level, to check the angle of departure of any ammunition used.

The concrete foundation should extend in length to take the longest barrel made, which is 30 inches; the shortest may be 18 inches. One set of clamping bolts must be placed in the proper position to bolt down the forward bracket, which is shown in the same illustration. The muzzle clamping bracket is of cast-iron with three adjusting thumb screws. Standard set screws may also be employed, but because a fine and light clamping effect is necessary at the muzzle of any rifle barrel, thumb screws are preferred. By drilling a series of holes in the base of the casting, the bracket can be moved to take a long or short barrel; or by placing it in the holes drilled close to the upright part, a difference of a two-inch adjustment is possible. The front bracket should be in such a position that it clamps the muzzle between two or three inches from the end of the barrel. The thumb screws should be adjusted so that they just touch the barrel, and then the thumb nuts should be locked in position so that the screws will not jar

loose in the act of firing. Those who wish to construct one with a recoil cylinder to take up the recoil could have a cast-iron plate made and also a base to place all these arrangements on. The base and plate have a V-form of groove with top gibs to take up any lost motion and yet leaving it free to move when recoil takes place. A cylinder or a spring could be provided in the center to return the rest back in position after the shot is fired. This construction, however, would require a considerable sum of money.

Screw Head Polishing Fixtures — Figure 14 illustrates two methods of holding screws to a disc grinder for polishing the heads of rifle, revolver, or shotgun screws requiring true flat heads. Holding a screw with the fingers is very unsatisfactory for polishing or disc-grinding them. The square blocks shown naturally require a large number for all the different screw heads encountered in the repair of different firearms; therefore an adjustable feature is used. A small drill chuck is purchased for this type and made over to take

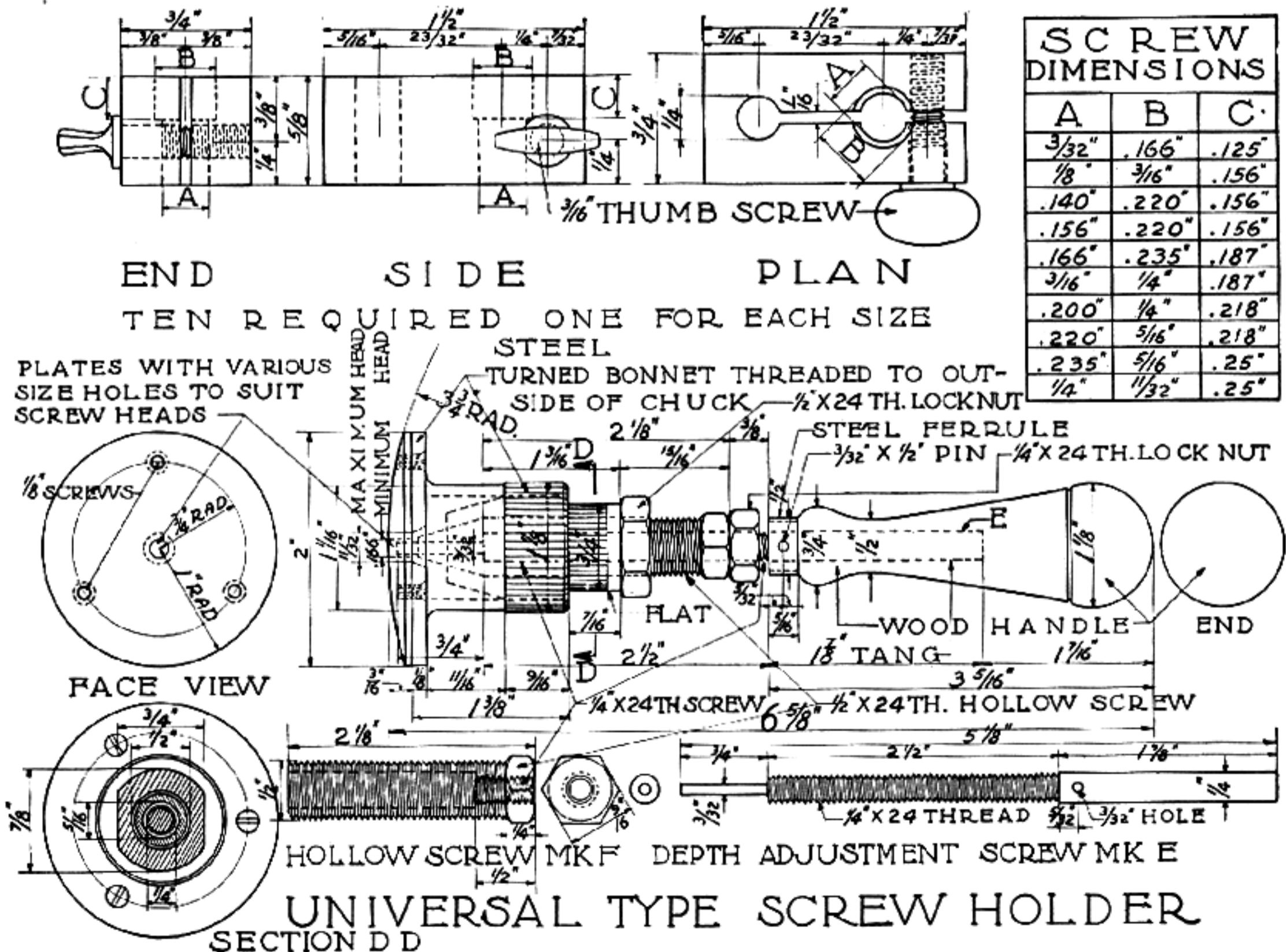


Fig. 14
Disc polishing holder for flat screw heads

any screw. The chucks cost about twenty-five cents. The two-inch bonnet is threaded to the outside of the chuck, and on the end a plate is made to take the different-sized heads encountered or as given in the table of screw dimensions. The depth-adjusting screw *E* is fastened to the wooden file handle with two locking nuts which lock the screw at the correct length; very close adjustments are possible.

The $\frac{5}{8} \times \frac{3}{4} \times 1\frac{1}{2}$ inch steel blocks are a simple means of holding screws, and they can be made as needed. Close adjustments are possible with these blocks, and after all the machine operations are completed the blocks should be hardened, or they can be made from cold-drawn steel and case-hardened. If tool steel has been used the end should be drawn to a blue to insure considerable spring. A wedge should be driven in and wired in position so the blocks will not close in when hardened. Any one attempting the construction of either the blocks or the universal type of screw holder should not find difficulty in their making.

Telescope Holder — Figure 15 illustrates a holder for a spotting telescope very simple to make. The jointed rods are made from cold-drawn steel. The end of one rod is bent to hold the

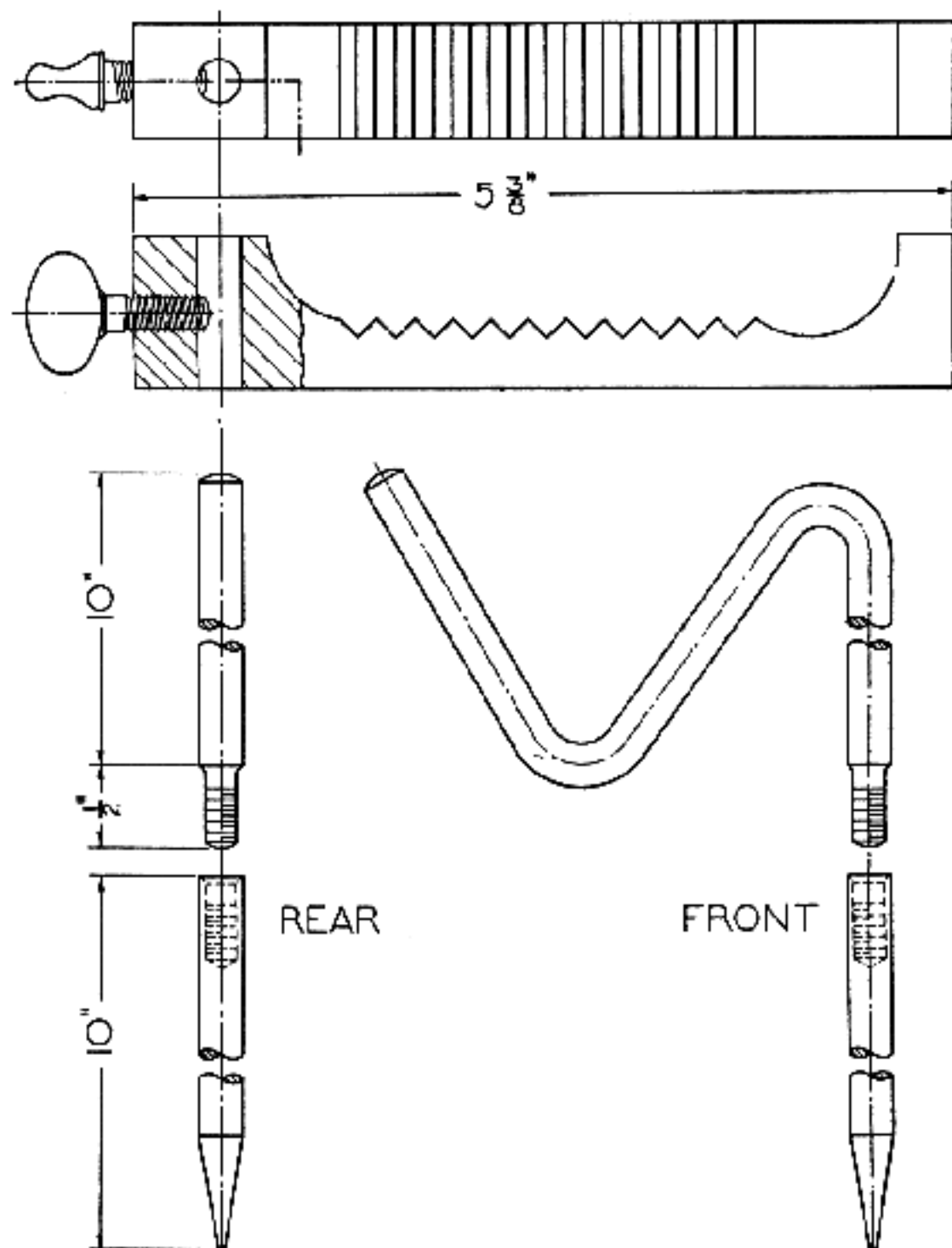


Fig. 15

Whelen spotting telescope holder: Very simple to make

front of the telescope while the other is straight to fit the aluminum notched holder, and is adjusted by means of a wing nut. The notches are placed a certain distance apart, making it possible to adjust the telescope on a horizontal plane, and other targets may be seen as well as your own.

This holder was gotten up in the days when we were shooting on the Frankford Arsenal rifle team. Charles Hogue, one of the members, originated the idea and I developed it. It has proved to be a good holder that can be constructed at a reasonable cost, and at the same time is one of the most compact when disassembled. After it was completed and a pattern made, it was given the name of the Whelen telescope holder, as Colonel Whelen was the organizer of the Frankford Arsenal Rifle Club at that time, and he also gave some valuable suggestions for its construction.

Bolt-bending Fixture — Figure 16 illustrates a vise block and a handle to bend the bolt handle on Springfield, Krag, or Mauser bolt-action rifles. The bending of any bolt is not advisable without a fixture of this kind. It is often necessary to bend and also grind a Springfield bolt to clear a telescope sight. The bending wrench is made from a piece of cold-drawn steel measuring $\frac{3}{4} \times 1\frac{1}{4} \times 12$ inches and notched to fit over the tapered part of the handle. The bolt is clamped between split blocks in the vise, and a wet cloth is placed over the top, making it impossible to anneal the end of the bolt at the clamping point. Considerable heat is required, however, before it runs down to the bolt proper. An acetylene torch is necessary to heat the bolt at the desired point of bend. The bolt at that point should be heated cherry-red. When the required heat has been reached, place the notched wrench in position and bend the handle. The bend in the handle should not be short, but straight and continuous. When bending a bolt handle, the under side of the round knob is usually milled off. To do this it is necessary to anneal the knob before a milling cutter will touch it. It is never necessary to reharden the handle after these operations. It need only be highly polished again or the entire bolt reblued. Some very clever alterations have been made on bolt handles to suit some special requirements or individual ideas, but I only advise the round knob for quick handling and operation, as it fits the position of the hand best.

When using the vise blocks it will be well to turn up a special steel plug to fit into the end of the bolt so that there will be no danger of crushing in the end when pressure is exerted. Some men

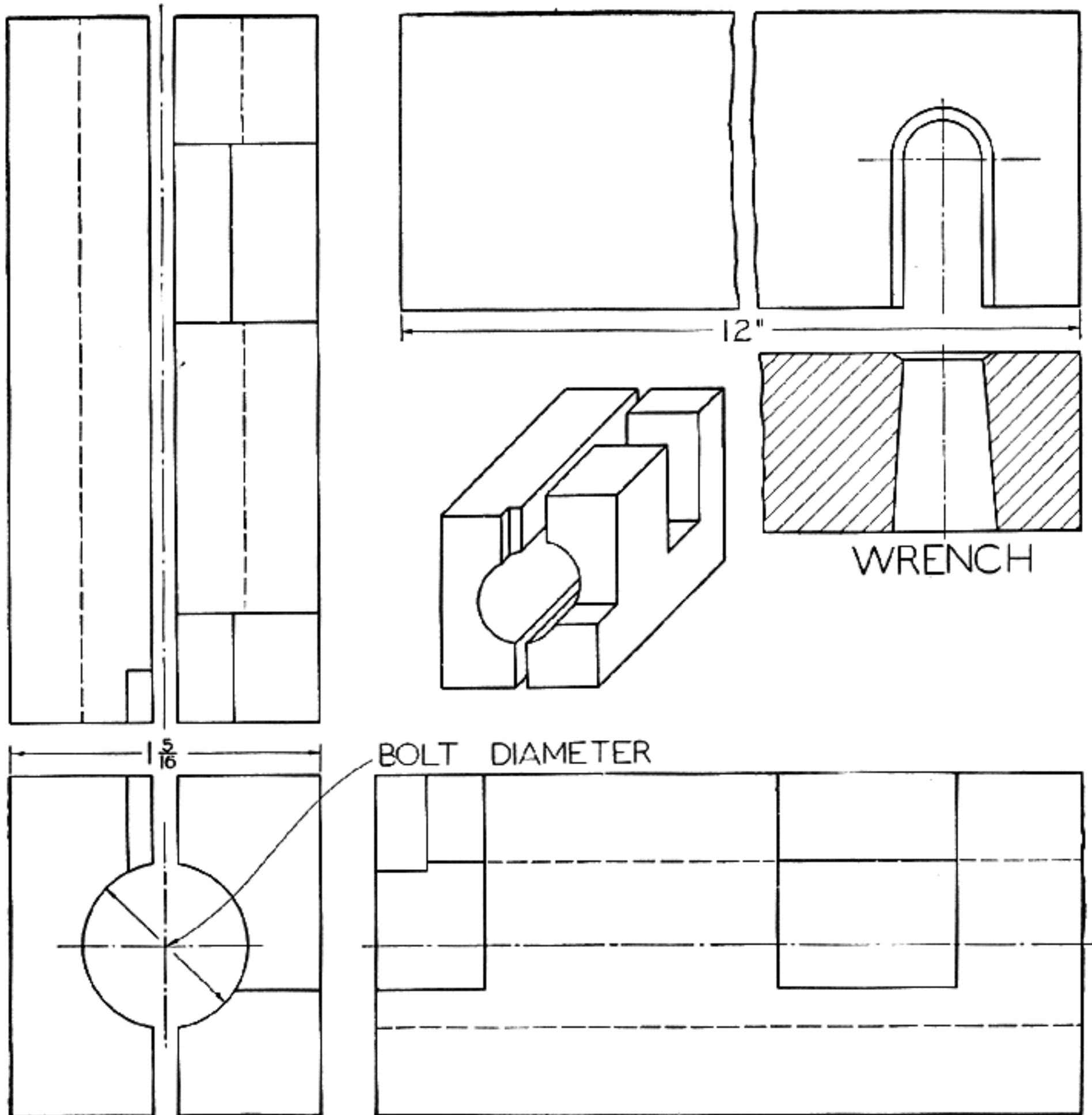


Fig. 16
Bending fixture for bolts, such as on Springfield, Krag, Mauser, Winchester Model 54, or any other bolt-action arm

use a hammer to knock over or bend it in the desired position, but it is not a good method; it only requires a short time to drill and file out a wrench for this purpose.

Bullet-drilling Fixture — Figure 17 illustrates a bullet-drilling fixture for drilling the ends of bullets in fixed ammunition, particularly the Frankford Arsenal caliber-.30, Model 1906, 172-grain boat-tail bullets or any other full-metal-patch projectiles. A similar fixture was made at one time for Colonel Whelen which proved very successful. The same fixture can be made for any other cartridges when the points of bullets are to be drilled. It may either be used in a drill press or by hand if no form of motor or drill press is available, or if one only has a small bench to work on.

Drilling into the ends of bullets has been rather

disparaged in late years by different writers. Such advice is well grounded, but if one uses good judgment in drilling, he need not be alarmed. I have made extensive tests of bullets drilled with different-sized holes in the ends, measuring from $1/16$ to 0.20 inch. The tests were made on a hydraulic press to see just what pressure was required to start the lead through the holes that were made in the bullets' ends. Holes between $1/16$ inch and $1/8$ inch took between 70 and 150 tons of pressure to start the core through the small openings made, which proves that it requires between three and six times more pressure even to start the core than the pressure developed with the explosion; therefore, if it only requires 2200 pounds to push the tightest bullet through a barrel, the margin of safety is very great and to obtain the desired results upon game, a drilled pointed bullet of the

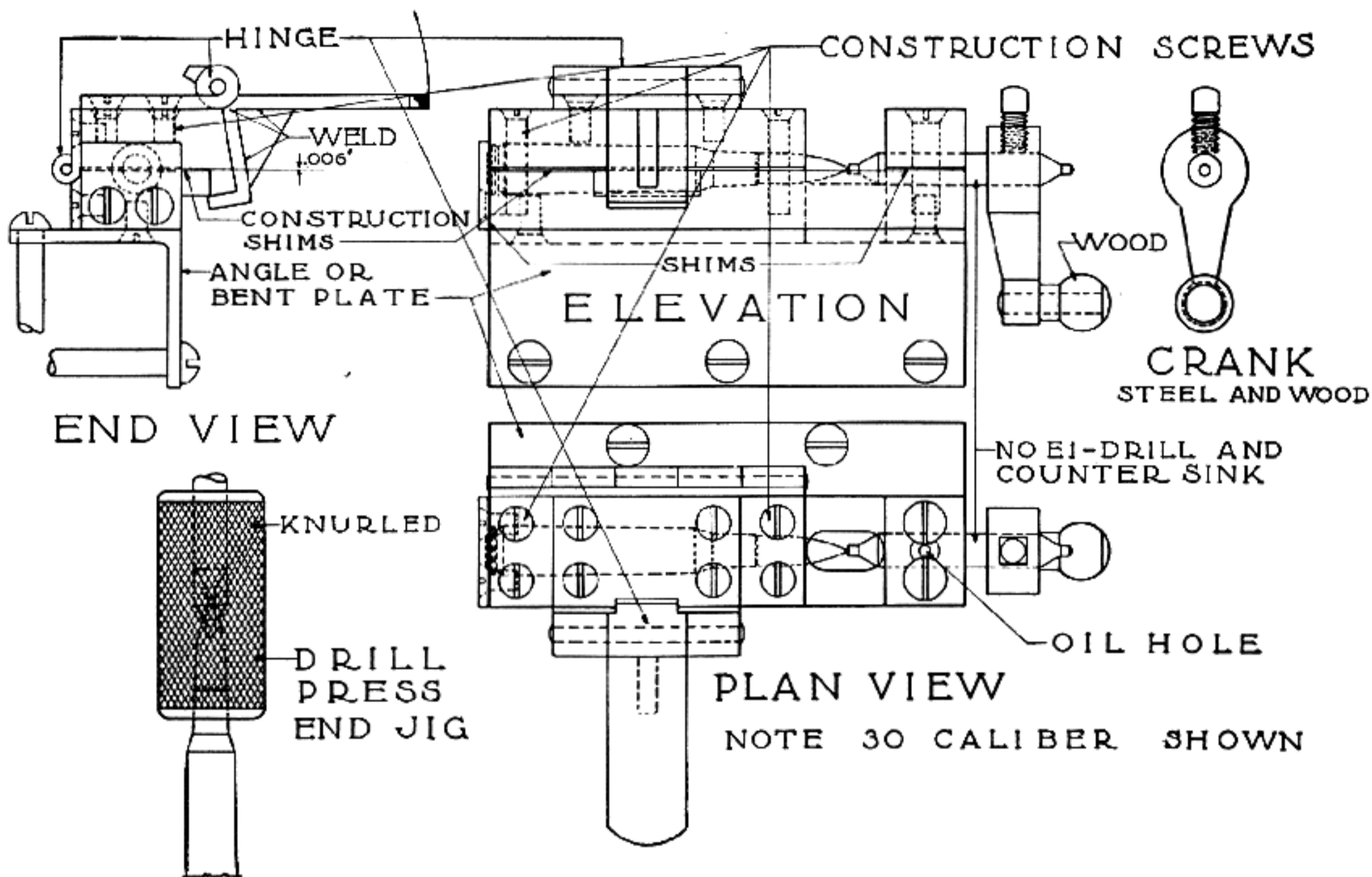


Fig. 17

Drilling fixture and drilling jig to drill points of bullets in fixed ammunition such as the caliber .30 Model 1906 or any other types of ammunition

Frankford Arsenal make, particularly the new boat-tailed ammunition, will give the results always looked forward to in the game field. I not only use these myself, but recommend them to others; it has been proved that it is the only practical ammunition to use.

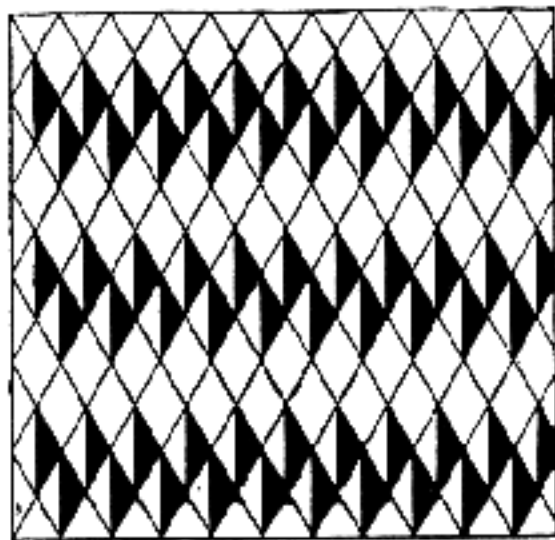
The ideal diameter of hole drilled in a bullet for quick killing effects is between $\frac{3}{32}$ inch and $\frac{1}{8}$ inch to a depth of $\frac{3}{16}$ inch in the end. Use a combination center drill and allow the countersink of the 60-degree angle to open up the end; which proves a better means of expanding the bullet as it strikes an animal. There are so many conflicting reports of the effects of bullets upon animals that it is difficult to accept any except from those who have conducted various experiments with all kinds of ammunition, proving without a doubt what one particular kind of ammunition will do and then extending experiments to the drilled-pointed bullets to prove even superior results with a well-defined combination to carry ammunition which will drop any animal in its tracks instantly.

The illustration of the bullet-drilling fixture is favorably shown so that any one can proceed to make one with only the parts as they are drawn,

and I do not believe that any further information is necessary. This is one device that every one should have, especially those who do very much hunting and need ammunition which can be depended upon. Some of the following suggestions may be of benefit to those wishing to make one of these fixtures. A pattern is made and the entire part fashioned from an aluminum casting. A standard chambering reamer is used to ream out for the cartridge case to a depth where the bottom of the case will come flush with the bottom. Allow the bottom plate to fall in place, and when it is possible, apply a little pressure on the thumb screw to keep the cartridge in position while drilling takes place. If it is made for hand drilling, a bracket may be combined with the body so that it can be screwed to the side of a bench, table, or even a convenient upright so that it is possible to turn the crank and exert enough pressure to drill the hole. Drilling the ends in a drill press or with a small motor would be a very simple operation compared with the use of the hand drill, but the hand fixture is very welcome as long as holes can be placed in the end of a bullet to render the desired results.

CHAPTER III

Tools and Methods of Tool Making



Tools and Methods of Tool Making

BEHIND the development of firearms—in recent times a constant evolution—stands the tool maker. Hand tools were made first, and then with the building of various labor-saving machines came the creation of tools necessary to go with them; for this reason a higher refinement traveled with that evolution until today we carry out some very precise measurements to make tools perform to a given standard set by natural law and understanding. The gradual development of machine tools and methods of manufacture brought an eager increase in the required accuracy and refinement of workmanship. The demand upon a tool maker is for more precise methods and greater skill. Today, therefore, the large body of tool makers represents the most skilled, the most inventive and the most intelligent element in the army of the mechanical trades; their work forms the great backbone of our immense industries.

The fundamental requirement of a tool maker in rifle work is *accuracy* in all vital measurements. The introduction of high-speed steels many years ago demanded greater skill in the construction of the tools and the correct heat treatments, simply because the pressing demand for higher velocity in rifles and the hardness of steels used in their construction necessitated cutting tools which would maintain their cutting edges. The design of efficient and complete sets of barrel tools requires a highly developed knowledge of various machine methods and a thorough understanding of the machines for which such tools are made.

It is usually understood that a tool maker is a machinist who has developed greater knowledge of his trade than is merely sufficient. Many a tool maker should still be a machinist and many a machinist should do his best to advance to that higher plane of mechanics where he may make such tools, gauges, or gun parts as will decide the accuracy of a firearm.

The man advancing in general knowledge of this subject should be familiar with the accurate reading of all measuring instruments such as the micrometer, vernier (as applied to the vernier caliper), vernier depth gauge, and vernier height gauge. He must not take anything for granted when accurate measurements are necessary. A barrel reamer

should always cut to an exact size, but experience has proved that invariably it does not do so when first made. It must be stoned and regulated until the gauge or micrometer size is secured. While extreme care should be exercised when accuracy is essential, there are parts of many tools in gun work where approximate measurements will suffice. If within 0.010 inch is sufficiently exact, then it is folly to spend long hours to get a size within a limit of the 0.0001 of an inch which is often seen upon arsenal drawings.

Approximate measurements are those made with the aid of calipers, dividers, surface gauges, etc., set to a steel scale. Precision measurements are obtained by the aid of the various measuring instruments graduated to read very small fractions of an inch or millimeter; also by the use of Johansson reference gauges and standard test bars which are often accurate within a limit variation of 0.000008 of an inch. In using the micrometer, the vernier, or any of the instruments which should give accurate readings, it is necessary to use the greatest care in setting the tools—above all, the vernier. In setting the latter, a powerful magnifying glass should be used so that no error will be made. In the use of the micrometer a touch should be developed much finer than the ratchet stop is capable of.

Necessary Instruments—If the interested reader will secure two catalogs of tools sent to any address for the asking—the Brown & Sharpe and the L. S. Starrett books of machinist tools—he can pick out the tools as they are named. The vernier height gauge is a very useful instrument for laying out templets, setting sine bars, checking various steps in various-form gauges by the use of Johansson blocks and other tools requiring very accurate height measurements, and for locating working points, holes, etc. The fixed base is of sufficient thickness to allow the gauge to stand upright. An extension attached to the movable jaw can be used to scribe lines when laying out measurements. In the absence of a height gauge, the regular vernier caliper may be made to answer the same purpose by making a base which may be attached to the fixed jaw. The vernier caliper is a very useful tool for taking length measurements; one of nine or of

twelve inches is the most convenient to use. The vernier depth gauge and micrometer depth gauge are two very useful tools to secure depth measurements in recesses, flanges, etc. Either one of these instruments is a matter of choice among tool makers, but the vernier depth gauge is the one usually preferred.

Micrometers — These measuring instruments are well known and do not require any introduction. The 1-inch size is the most used; therefore, two should be included in all tool makers' kits; one with a vernier reading to 0.0001 inch to be used for precise measurements and the other just a plain instrument reading to 0.001 to be continually used for all rough measurements. A lapping block should be provided for lapping the spindle, as illustrated in Figure 18. These must be made as they cannot, to my knowledge, be purchased. The lapping block is made from cast-iron with two small knurled handles, and the face of the blocks is charged with diamond dust prepared as explained

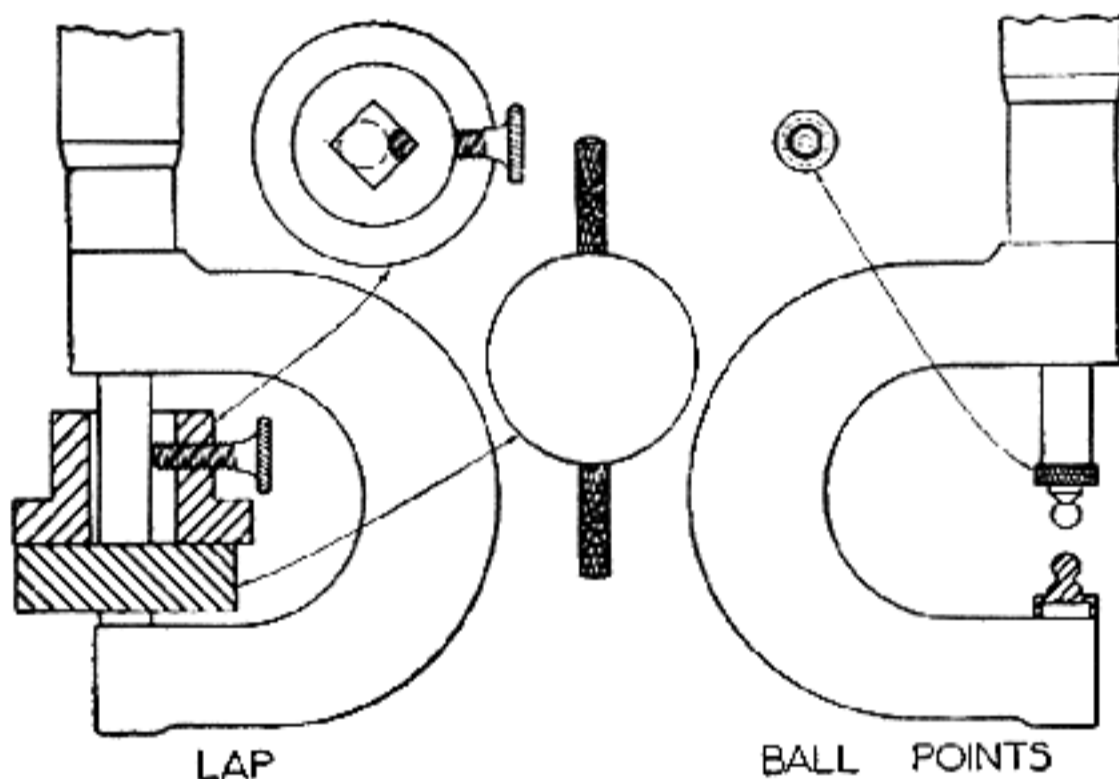


Fig. 18

Micrometer ball points, lapping fixture for spindle, and anvil of same. Ball points are for the purpose of taking measurements on rounded surfaces

in Chapter IV, Volume I. The spindle face plate is made from tool steel, hardened and accurately ground. A square hole is filed or broached in the center and a small thumb screw is set in the center opposite a V. After the hardening of the plate it is clamped on an accurately ground arbor by the thumb screw and the face ground with the edge of the wheel on a cylindrical grinder, and then the face of the plate is lapped to remove all grinder marks.

Bevel Protractor — This instrument is in almost constant use by the tool maker working on rifle or cartridge tools; therefore, the best should be procured with the vernier scales to read minutes of

angles. These instruments are very accurate, finely made, and capable of checking any angle; or they can be set for any angle as it is turned or ground on a machine.

V-Blocks — A pair of accurately hardened and ground V-blocks is a necessary part of every tool maker's kit. The best will be the ones made by yourself, as Figure 19 illustrates. Naturally, you can procure a very accurate pair from Brown & Sharpe, but the ones made by yourself will be the more highly prized. They are first machined from

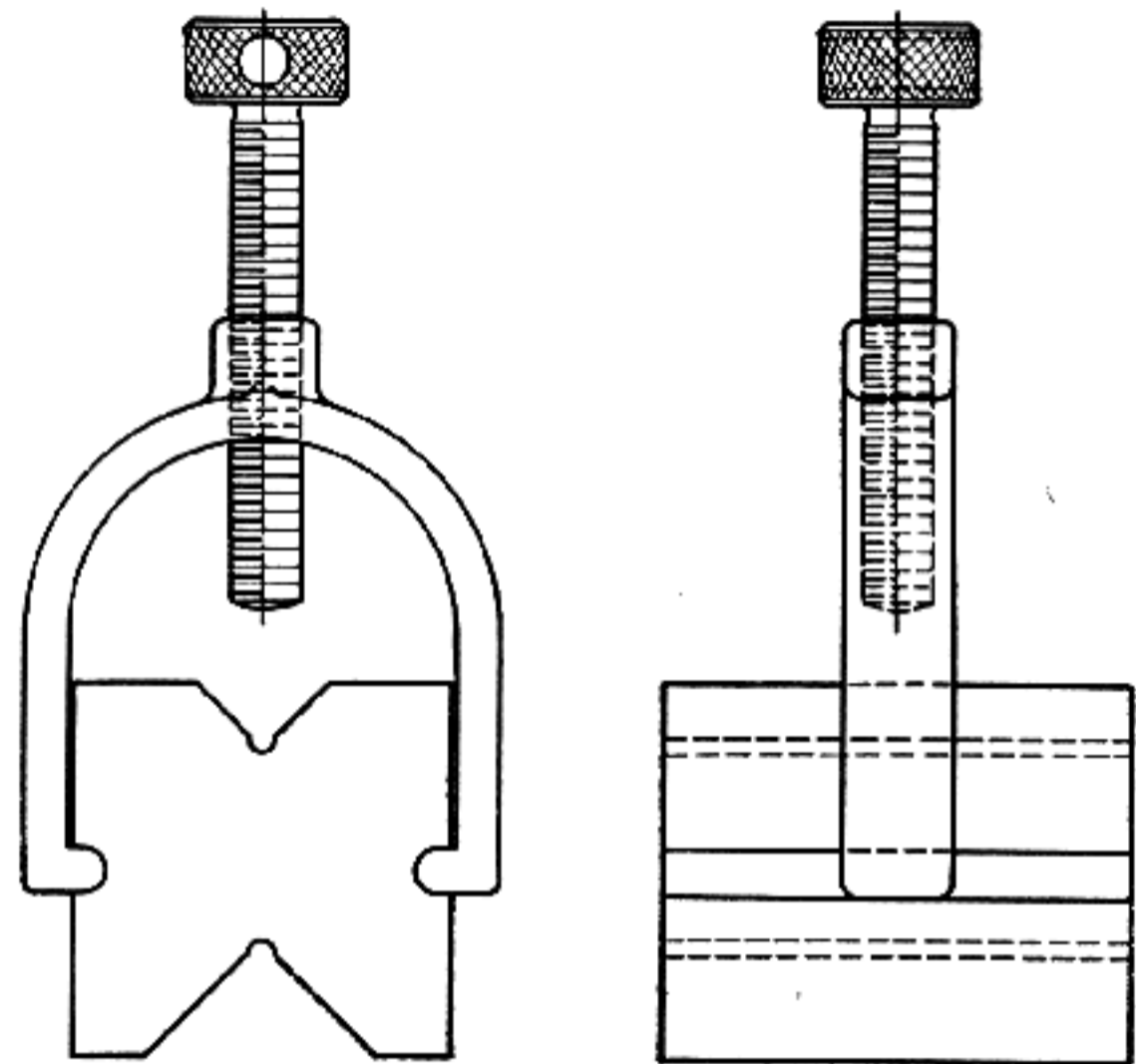


Fig. 19
V-Blocks and clamp

tool steel which consists of milling machine operations and then they are hardened and seasoned. Refer to Chapter VII for this information and then accurately grind all over on a surface grinder by grinding both together. Both are alike, and after they are ground the grinder marks are removed by lapping on a lead lap. A clamp is also made as illustrated to hold work to drill or to be laid out; oftentimes two are required, but one usually serves the purpose.

Cube — A cube block often becomes one of the most essential tools in gauge work. Figure 20 illustrates one with two plugs used as a sine bar. This tool cannot be purchased; making it requires a considerable length of time. The material used is an oil hardening steel, hardened and seasoned and accurately ground all over. Even the holes which hold the sine plugs are internally ground; therefore, the closest precision work is done to make it as perfect as possible. Holes are drilled and tapped for $\frac{1}{4}$ -inch standard screws on all sides to

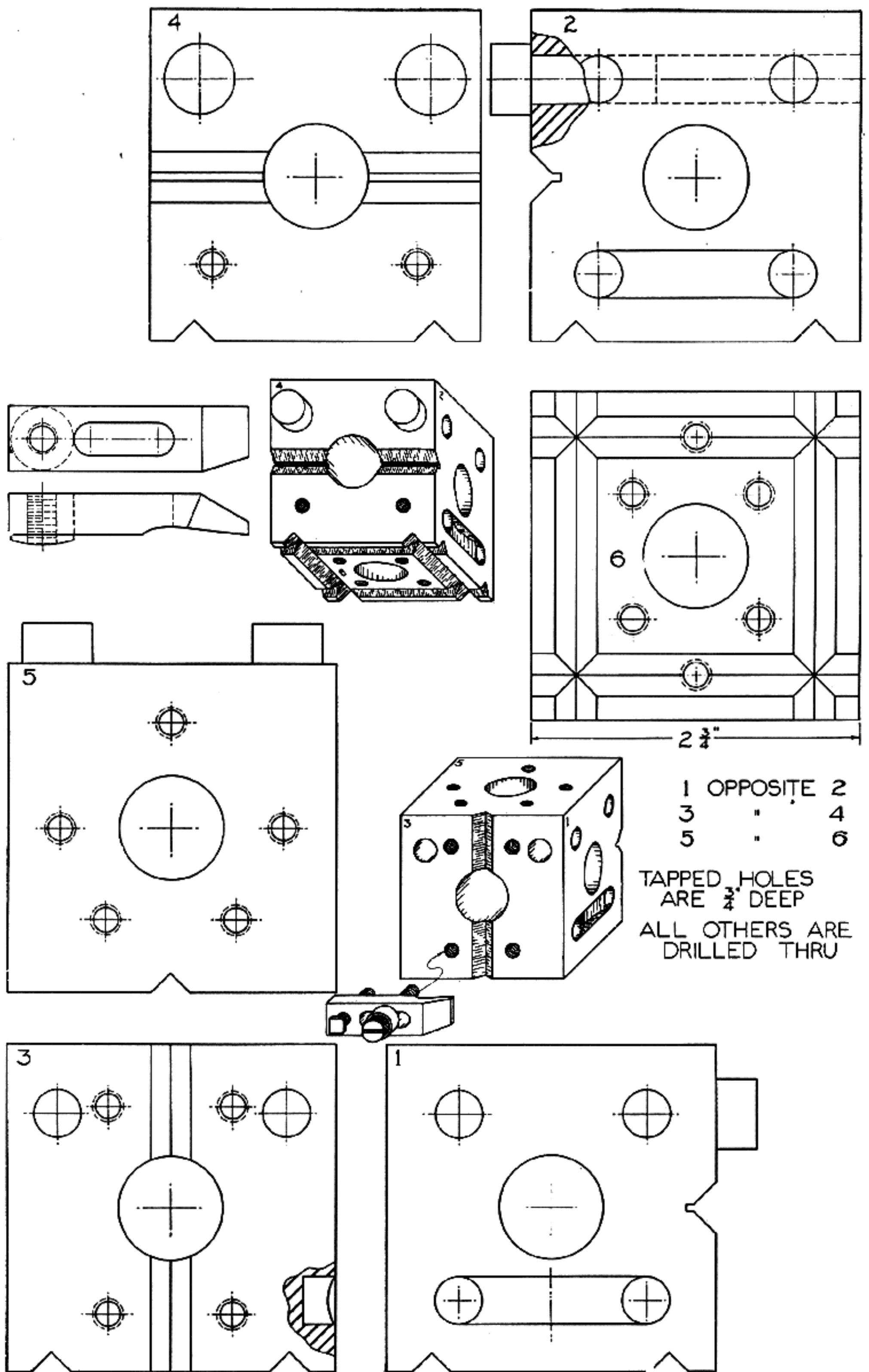


Fig. 20

Cube—an essential tool for laying-out work and making tools for the gun shop

hold the work clamped in various positions. The small shallow vee's which are milled on the bottom are to place cylindrical plugs of the correct diameter in order to secure different angles with the sine plugs. Clamps are also made to hold parts on the surface of the cube, as are shown in the illustration.

Center Gauge — The center gauges sold by the leading tool manufacturers are perfectly satisfactory where accuracy is not important, but for the very close accurate setting of the threading tools we must have instruments that can be set between lathe centers with accurately ground angles; when these discs are placed against the angle of a thread tool, they are known to be on perfect center. Figure 21 illustrates this tool, which can be made in one's spare time, particularly when much thread chasing is anticipated. The thread tools can be set up on the cube and very accurately ground; consequently, extremely accurate threads can be cut with such combinations.

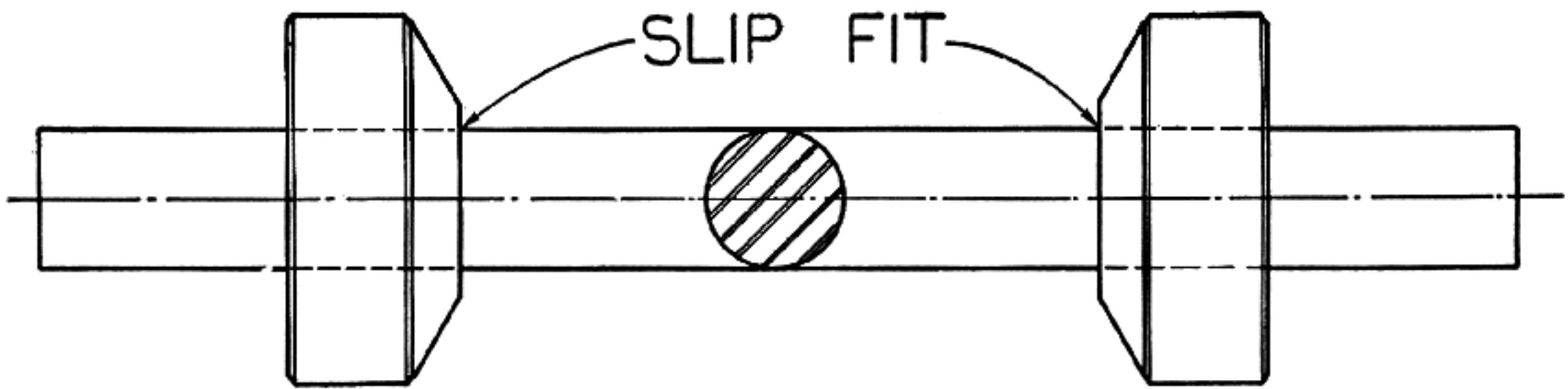


Fig. 21
Thread center gauge: an essential tool for cutting accurate screw threads

Center Test Bar — Figure 22 illustrates a center test bar far superior to the lathe test indicator shown in the tool catalogues. After the bar is hardened it is rough ground and seasoned, and then finished ground. A test indicator is used in connection with one of these bars and the setting of any work whether on the face plate or in the

chuck can be done very rapidly in comparison with a lathe test indicator.

Test Indicator — Naturally, a test bar will call for an indicator, but since there is such a large variety to choose from, it is sometimes difficult to choose the best. I would advise an Ideal indicator, which is, incidentally, the most inexpensive.

Die-maker's Square — Many die makers and tool makers use an adjustable square having three different blades. The narrow blade is used to pass through an aperture in a die. The amount of clearance given to a die is determined by judgment of what the die produces and the nature of the material. These squares are used very much in all types of work.

Knife-edge Straight-edge — A straight-edge is a necessary part of any tool maker's kit, and particularly the knife-edge type. Many tool makers have several, varying in length from one to seven

inches, or even longer. Straight-edges should be kept in a case so that their edges will not become marred. Figure 23 illustrates two straight-edges; one is made from square high-carbon steel and one from a razor blade. The latter makes one of the best known. The former straight-edge is machined, accurately ground, and lapped after being thor-

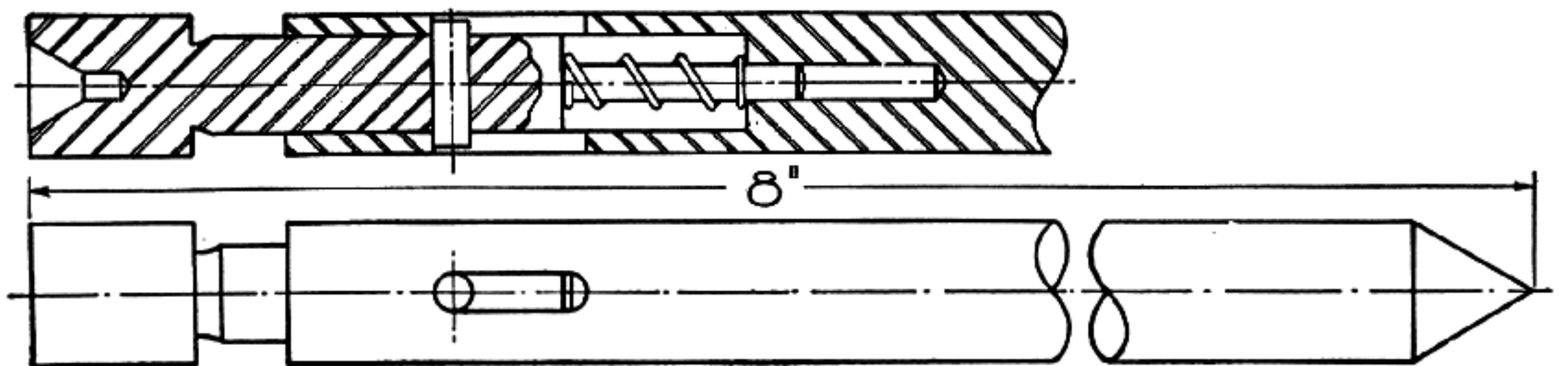


Fig. 22

Center test gauge: Used to true work on a lathe. The back end is held by the dead center while the pointed end is placed in a center punch mark and the work trued with a sensitive indicator

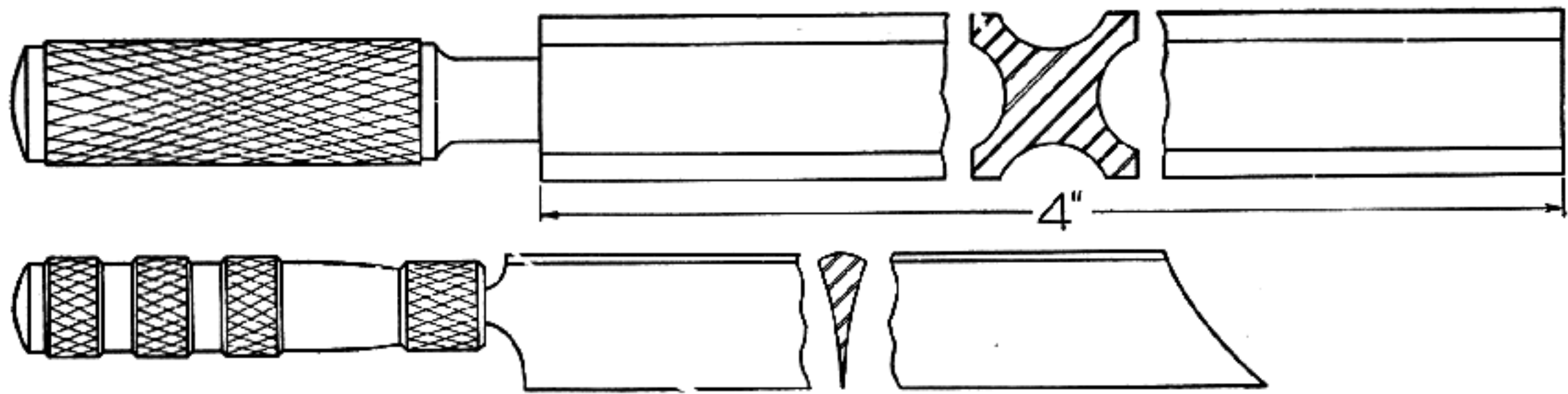


Fig. 23
Knife-edge straight-edges used to check flat surfaces

oughly seasoned. The flat surface should be lapped by hand by following the instructions given in Chapter IV, Volume I. It will be necessary to finish by oilstoning with a fine Arkansas stone to remove any high places that are not removed by lapping. To check straight-edges test on a master straight-edge either of steel or glass.

An endless list of tools and instruments could be given here, but since I have named the foregoing tools I shall assume that the reader has sufficient knowledge of mechanics to enable him to go even farther than I have gone. Remember that it often pays to create your own tools, making some just a little different from those you see in catalogs. They are easy to copy, but try to avoid duplicating tools you see in circulars. Be original in your design and just prove how possible it is to have something better and far more efficient than those that can be procured by money.

One more point to remember is that a tool maker should always have at hand a small bottle of blue vitriol or coppering solution to color the surface on which lines are to be laid out, etc. Chapter XVI contains these formulas. The coppering solution produces a copper-colored surface when applied to polished steel which is free from grease and dirt.

The subjects of steels, their proportions, annealing, hardening, and tempering, have been treated in separate chapters and have been presented to the reader in a way which might seem rather difficult to fathom except for one directly in contact with the treatment of steel. Tool steel is used for tools intended for working metals in gun work or any other hard materials. The tool maker should have a thorough understanding of the different metals and a knowledge of some of their peculiarities in order to work them successfully.

Carbon is the element in tool steel that makes possible hardening it by heating to a red heat and plunging into a cooling bath. A bar of tool steel from the rolling mill or even the forge shop is somewhat decarbonized on its outer surface, and in certain steels to a considerable depth; therefore, this

portion may not harden, the results being far from satisfactory. For this reason, if a tool is to have cutting teeth on its outer surface, such as chamfering reamers and other barrel tools, it is necessary to select stock of a larger diameter than the finished size of the tool so that this decarbonized portion may be removed. About $\frac{1}{16}$ inch additional is usually allowed on stock measuring $\frac{1}{2}$ inch or less; $\frac{1}{8}$ inch for sizes up to $1\frac{1}{2}$ inches; for over this diameter $\frac{1}{4}$ inch will be sufficient.

Tool steel may be procured in almost any form or quality; do not rely upon all the information which catalogs contain, but use some certain steel best adapted to your particular needs. Tests should first be conducted to determine the steels best for your purpose; the cooperation of the steel companies should be secured to help solve your problems.

Both high-carbon and low-carbon steel-cutting tools should be made from a high-carbon steel if the metal is to be forged or hardened by an experienced tool maker. But if the steel is to be heated by an inexperienced man it is not safe to select a steel having a high percentage of carbon. For non-cutting tools, of which there are many in gun work, a low-carbon steel having one per cent carbon or less is preferable, because with this steel there is not so great a tendency to spring in the hardening. In many such cases it is advisable to select alloy steels hardened in oil, and there will be less chance of cracking the tools thus made.

Hammered steel is prized more highly than rolled steel for rifle or shotgun work, but many authorities will not agree with me on this point. It is usually conceded, however, that the best tools can be made from forgings if the heating and hammering have been correctly done. The steel should be heated uniformly throughout and hammered carefully with heavy blows at first. Lighter blows should follow, and when the piece passes from low red to black, extreme care should be used to avoid crushing the grain. Steel properly heated and hammered has a close fine grain.

It is advisable, when cutting a piece of tool steel from the bar, to use a cutting tool such as a saw. It is considered poor practise to weaken the bar with a cold chisel and then break it by a sudden blow. This so disarranges the particles of steel that they do not resume their proper relations with one another when hardened. If it is necessary to cut the steel with a chisel, it is best to heat the bar to a red heat; in this condition the steel may be cut off without injury.

A piece of tool steel that is to be hardened should never be straightened when cold, as it is almost sure to spring when hardened. If it is bent too much to remove all the decarbonized steel when being turned to size, it is best to use another piece of stock; but if the bent piece must be used, heat it to a red heat and straighten.

In order that tool steel may be soft enough to work easily it must be annealed. Steel can usually be purchased annealed much more cheaply than it can be annealed afterwards. Annealing or normalizing removes the strains or the tendency of the steel to crack and spring when hardened. Strains are caused by rolling and hammering in the steel mill or forge shop. To remove the tendency to spring, the piece of steel should be machined somewhere near to size, sufficient stock being left to machine all over after the normalizing operation. See Chapter VII.

The use of high-speed steels for cutting tools has not only revolutionized machine-shop methods, but rifle work as well. The results obtained from the use of high-speed tools in rifle work are dependent in a very large measure on the way in which the tools are made and used. As they are principally valuable for barrel drills, reamers, etc., and also for roughing purposes, it is apparent that they should be made strong and of such shape as to secure the greatest efficiency possible, the hardening to be done in proper furnaces. Burnishing reamers are prized more highly when made from high-speed steel and also other tools of this nature. Many authorities do not agree upon this point, probably because they have only examined tools made through the regular process of manufacture, but if a high-speed cutting tool is given the correct heat treatment and ground and lapped to size or even stoned it will outlast other tools four to one.

Standard Tools—The tool maker is often called upon to make some very odd tools, so he should be prepared to adjust himself to any emergencies which may arise. Special drills are often requested for a form of work where a twist drill would not answer the purpose. For certain classes of work the single-lip drill becomes very useful; it

has but one cutting edge and its action is similar to that of a boring tool as used in a lathe. Before this drill is used a smaller hole is made and the body of the drill, being the size of the hole drilled, insures the cutting of a straight hole, even in drilling work which has been partly cut away. This form of drill does not cut as rapidly as the standard forms and consequently is not used where a twist drill would do satisfactory work. There are many suggestions which could be given in making different drills, but since drills of the twist variety are so reasonable it does not pay to construct your own except for a straight hole.

Taps—The taps measuring $\frac{1}{4}$ inch in diameter and smaller are as a rule made with vee threads whose sides form an included angle of 60 degrees or with round top and bottom threads. Taps larger than $\frac{1}{4}$ inch are made with the United States standard form of thread which has an included angle of thread of 60 degrees the same as the V form, but with one-eighth of the altitude removed from the top and one-eighth filled in at the bottom. The V-shaped thread taps are made in various pitches for each different size but the United States standard has a definite pitch for each diameter.

Taps measuring $\frac{1}{4}$ inch in diameter or smaller are best cut on a Pratt & Whitney bench lathe with a screw-cutting attachment. They can also be cut on any screw-cutting lathe, but better results are obtained on the small precision lathe. If a number of taps are to be made they are best cut with screw dies made similar to a hollow mill. This operation is best done on a screw machine but a lathe can also be employed when a die holder is used, allowing the die to feed upon the blank of its own accord. The method used for gauging the correct size varies in different shops. Some use a thread micrometer while others use the three-wire system of measurement; but for taps of the same size, such as gun taps, a sizing die is used to give the thread the correct size. The threads are cut to within 0.004 inch with the hollow screw die and finished with a sizing die of the same form.

Taps for general use around the shop are often made in sets of three. The first tap to enter the hole is called the "taper tap" because of the long chamfering or taper. The second is known as the "plug tap," which has the first two or three end threads chamfered and is used when the screw is to go nearly to the bottom of the tapped hole. The "bottoming tap" is used when the thread is to go to the bottom of the hole; the end of this tap is not chamfered.

Hand taps are intended for tapping holes by

hand and are usually made in sets of three as previously explained. After being normalized the shank should be turned to size and the square end milled for a tap wrench. The body is then turned to size and the thread cut. Before turning any of the parts to size or starting to cut the thread, be sure that the centers of the lathe are in good condition—the live center should run true. The dead center should also be ground to the correct angle and in good shape. It is advisable to grind the thread tool on the cube set-up to an angle of 30 degrees; first grind one side and then the other, making allowance for the proper clearance. There are various forms of thread-cutting tools, but the standard $\frac{5}{16}$ -inch Armstrong tool holder (using a $\frac{5}{16}$ -inch high-speed tool bit) is as good as any I have found in practise. Instead of having the point of the threading tool come out straight, a slight downward incline is stoned to the point. This simple stoning operation imparts greater strength to the point, and, besides, gives a perfect finish to the threads as the goose-neck tools were employed. The cutting point of the tools should be on the exact center and the tool set to the proper angle by the center gauge described in the first part of the chapter. The dial should be employed on the cross feed when cutting threads, and only a 0.001 to 0.002 inch cut taken on each setting. A cross-feed screw-cutting stock is also a very handy part to become accustomed to using in screw cutting when any adjustments take place. Reference should be made to the graduation on the cross-feed dial.

After the thread is cut to size and the ends chamfered, the tap is ready to be fluted or grooved in the milling machine. The tap is held between centers and the flutes cut with a cutter especially adapted to the size and style of tap. While the grooves are best cut with a milling-machine cutter, it is possible to cut them in a shaper, using a tool of the correct form. Great care should be taken not to stretch the thread by a heavy cut or by using a dull tool.

The grooves cut in taps are ordinarily termed flutes the same as in reamers. A tap that is to run through the work without backing-out can have a flute of a different shape from one that is to tap a deep hole in a piece of steel where it is necessary to reverse the motion of the tap every two or three revolutions to break the chip and also to allow the lubricant to reach the cutting lips.

While all taps up to and including those which tap a receiver are usually given four or more straight flutes, special flutes are sometimes desirable, especially with small taps in gun work. With spiral flutes, it is generally necessary to cut a

smaller number than with straight flutes, and since special taps are not often ground after hardening, there is no objection to giving an odd number of flutes as in the case of a barrel reamer in which three spiral flutes are often cut. A large number of small special-thread taps are used for firearms, but the three straight-fluted taps are the ones mostly used.

When taps are used to tap tubing having thin walls, the tubing between the lands has a tendency to close into the flutes of a tap and is liable to break the tubing or the tap. In such a case there should be double the number of flutes in order to provide enough lands to hold the tubing in shape. For general gunshop work, however, three or five flutes work best in hand taps up to and including those made for receivers for larger sizes of a special nature, and for which I would advocate more. Naturally, the class of work and the material used in the individual shop will determine this.

Steel used for making taps should be of the highest grade, as recommended by steel manufacturers for this purpose. To insure removal of the decarbonized surface of the metal, stock should be selected of a diameter not less than $\frac{1}{16}$ inch larger than the diameter of the tap. When cutting some steels used for taps it is necessary to give them a "board anneal." This process consists of heating the blank to a low red, holding it in a dark place until the color leaves the steel and then placing it between two thin boards. After it burns itself into the wood a short distance it is plunged into a bath of soapy water. Oil may be used, but soapy water is preferred because the finished threads are not so inclined to tear when the threading tool is finishing the last cuts. The making of taps is a higher grade of work than ordinary thread-cutting and special care will be required for it. Good lard oil should be used and the finishing cuts should be just scraping cuts.

The most commonly used form of flute is that which is cut with a convex milling cutter for milling half circles. The advantage of such a flute is that it has a greater chip clearance and a strength which leaves the lands strong. After cutting the flutes, the lands should be backed-off to give the tap cutting edges and a lead, which is usually done with a file. Commence at the heel of the land, file the top of the land and gradually approach the cutting edge, making sure that no stock is removed at that portion. Simply bring it to a sharp edge. The size and number of threads per inch should be stamped on the shank of the tap before the hardening operation.

Taps can be stoned for the lead as well as backing-off the teeth similar to the way a reamer

is stoned. By using this method there is no danger of removing too much metal as with a file, particularly in the hands of an inexperienced person.

Hardening — It is advisable to coat the teeth of a tap with boneblack and heat them gradually in a tube away from the direct action of the flame, or in a lead bath. They should be plunged into a cooling bath a little above the threads and worked up and down and around in the bath to prevent soft spots. For taps less than $\frac{1}{4}$ inch in diameter, an acid bath will be found very satisfactory, and for larger taps, strong brine is advisable.

The flutes of taps should be ground with an emery wheel of the proper shape in order to brighten the surface so that the color will be readily seen when drawing the temper. Grinding also sharpens the cutting edges and breaks the burrs that have been thrown between the teeth when cutting the flutes. The temper should be drawn to a full straw color. Much more satisfactory results may be obtained by heating the taps in an oil bath and drawing the temper to a point from 475 to 510 degrees Fahrenheit, according to the size of the tap and the nature of the material. The shanks of all small taps should be drawn to a blue up to the thread portions.

Threading Dies — The tool maker is often called upon to make round or square threading dies for special screws in gun work. The round button die is mostly employed on such work and the general principles of constructing a threading die of the button type are very much the same as of other dies in this class. The blank is first turned and drilled in a lathe to the double depth of the intended thread, and because of the small size of most of these dies, taps must be used to thread the holes; but when they are of a sufficient size they should be first chased out with an inside threading tool and then a tap used to give the thread the finish and also the proper size. Whenever possible, use an inside threading tool to first cut the threads, and good lard oil as a lubricant. The finishing cuts should be very light and the threading tool for this purpose should be in the best possible condition. When a tap of the right size is available, it would be well to take the finishing cut with this tap; but as the pitch of taps is sometimes slightly altered in the hardening process, the thread must not be cut too near the finished size of the thread tool; in that way fewer tool marks will be seen after the hole has been tapped. Before taking the die out of the chuck the hole should be chamfered back a distance equal to about one-fourth the thickness of the die. The larger diameter of the chamfer should

be slightly greater than the diameter of the screw. It is understood that the object of chamfering the die is to facilitate starting the thread on the screw.

After cutting the thread the next operation is to drill the clearance holes. For small dies three holes are usually employed, and these are laid out so that the least bearing is given to the threads; at the same time strength should be taken into consideration. First, a small hole is drilled and enlarged with a counterbore which may be done in a drill press. After finishing this work, the die is ready to be filed. For general purposes, the back of the cutting edge is given clearance by filing up to the cutting edge. Great care is required in this work to keep the file from cutting the extreme points of the teeth at the advanced edge. The filing should be started at the heel and barely brought up to the edge without touching it. At times it is well to file or "back-off" the heel beyond the chamfered part; that is, through the full length or thickness of the die; then it is hardened and tempered.

While round dies for cutting screws may be made solid for roughing out a thread that is to be finished by another die, the finished die should be made adjustable. When making adjustable dies, the usual instructions given for solid dies may be followed, except that some provision must be made for adjustment. This is done by splitting it at one side; the hole for a small adjusting screw, however, should first be drilled and tapped. To prevent the die from springing out of shape in hardening, it is advisable to cut the slot from the center of the die, holding a thin margin of metal. After the die is hardened this may be ground out with a bevel emery wheel. Often this bevel is used for the adjustment with a screw in the die holder.

Counterbores — These tools are used for enlarging a hole without changing its relative position. For an emergency job and for a small number of holes it is advisable to make as cheap a form as is consistent with the work to be done. Probably the cheapest counterbore that will do satisfactory work is the one with two lips. This can be forged so as to require but little machine work. After forging, it is turned to size, and the necking between the pilot and body should be cut with a tool having the corners slightly rounded to decrease the liability of cracking when the counterbore is hardened. The flat sides of the body may be finish-filed; the edges should be draw-filed and more stock removed on the back than on the cutting edges for clearance. The pilot and body should be hard the entire length or they will wear and become rough so that they cannot cut a smooth hole. Draw the temper to a

full straw color. Unless intended for accurate work, the tool need not be ground.

Permanent counterbores are usually made with four cutting edges as seen in tool catalogs. Counterbores for screw holes are usually made in sets of three: one for the head of the screw with pilot of body size, one for the head with pilot of tap-drill size, and one to enlarge a tap-drill hole to body size.

The following instructions apply to counterbores with either straight or taper shanks. When turning to size, take stock somewhat larger than the finished size of the counterbore. Turn a roughing chip or cut all over the blank, and turn the neck portion between the shank and body to size and stamp the size of counterbore and pilot. Turn shank, body, and pilot 0.015 inch over finish sizes to allow for grinding. In the case of a tapered-shank counterbore, the tenon should be milled.

After the lathe work is finished the counterbore is ready to have the flutes milled to form the cutting edges. One method is to cut them with a right-hand spiral of from 10 to 15 degrees; the other is to cut the flutes straight. The former has the effect of running the chips back from the cutting edges and works very well on all classes of steel used in gun work, while the latter method is considered more satisfactory for brass and cast-iron, altho it also works well in steel. The cutting edges are given clearance by filing. If the counterbore is to be used for brass it is necessary to give clearance to the lands also.

When centering counterbores or any tools whose centers are not to be used after the tool is finished, the combination center drill should be small and the countersinking no larger than deemed necessary for good results in machining. Figure 24 shows a com-



Fig. 24
Drill and countersink combined

bination drill and countersink. If large centers should, by accident, be set in the ends, the one on the end to be hardened should be filled with fire clay moistened with water to the consistency of dough, or with graphite mixed with oil; this prevents steam from forming in the hole and cracking the tool when dipped in the bath. If the piece is to be heated in a lead bath, the filling should be dried thoroughly before immersion.

A very satisfactory way to mill a counterbore having a spiral is with a vertical attachment on the milling machine. This method also may be used for reamers and taps. Having geared the

index head up to the required spiral, and with the blank between centers, the vertical head is set on a 15-degree angle to the left of the right-hand cut by using a 1/2-inch or 5/8-inch spiral end mill with a perfect sharp edge and set about 0.010 inch ahead of center. You will be very surprized to see what a perfect radius a sharp end mill will make at the bottom of the flute. The radius desired is controlled by the angle the head is set over; 15 degrees is the standard for nearly all radii in the bottom of the flutes and desired angle of the cutting edge. Smaller radii may be obtained by bringing the head in closer to the perpendicular. This can be judged best by the tool maker when cutting the tools.

Many times it is necessary to produce a hole of a given taper extending in a piece of work, as in the case of an experimental "cone" in a shotgun where the taper must be in perfect alinement with the bore. At other times it is necessary to produce an impression of a special form which must be true with a drilled hole. In either case, a counterbore may be made whose pilot is the size of the hole and whose body has the form of the desired impression. Since the cutting edges of such counterbores cannot be ground, before hardening they must be backed-off with a fine file and stoned after hardening. Special attention should be paid the hardening to prevent springing. Proper hardening is accomplished by heating in a muffle furnace or in a lead bath, the tool being turned frequently to prevent uneven heating when the furnace is employed. The counterbore is quenched in lukewarm water and the temper is drawn to a full straw color at 466 degrees Fahrenheit. Better results follow when these forming tools are pack-hardened and then quenched in raw linseed or cotton-seed oil. There are many kinds of counterbores made, but for gun work the ones described will be found the best.

Fishtail Cutter — These cutters are used very extensively in gun work, particularly for elongating slots. When such necessary tools are made, much more accurate and satisfactory methods of producing a slot are found with the milling machine. They consist of cutting the slot with a fishtail cutter. Figure 25 illustrates one which every tool maker should be familiar with. When using such a cutter for milling a rifling head cutter or wedge box, the cutter head is held on the centers of the dividing head, and is fed into the blank. The table is moved to produce a slot of the correct length, the operation being repeated back and forth with light cuts until the slot is of the correct depth.

When using this form of cutter, take light cuts and fine feeds, and run the cutter at a high speed

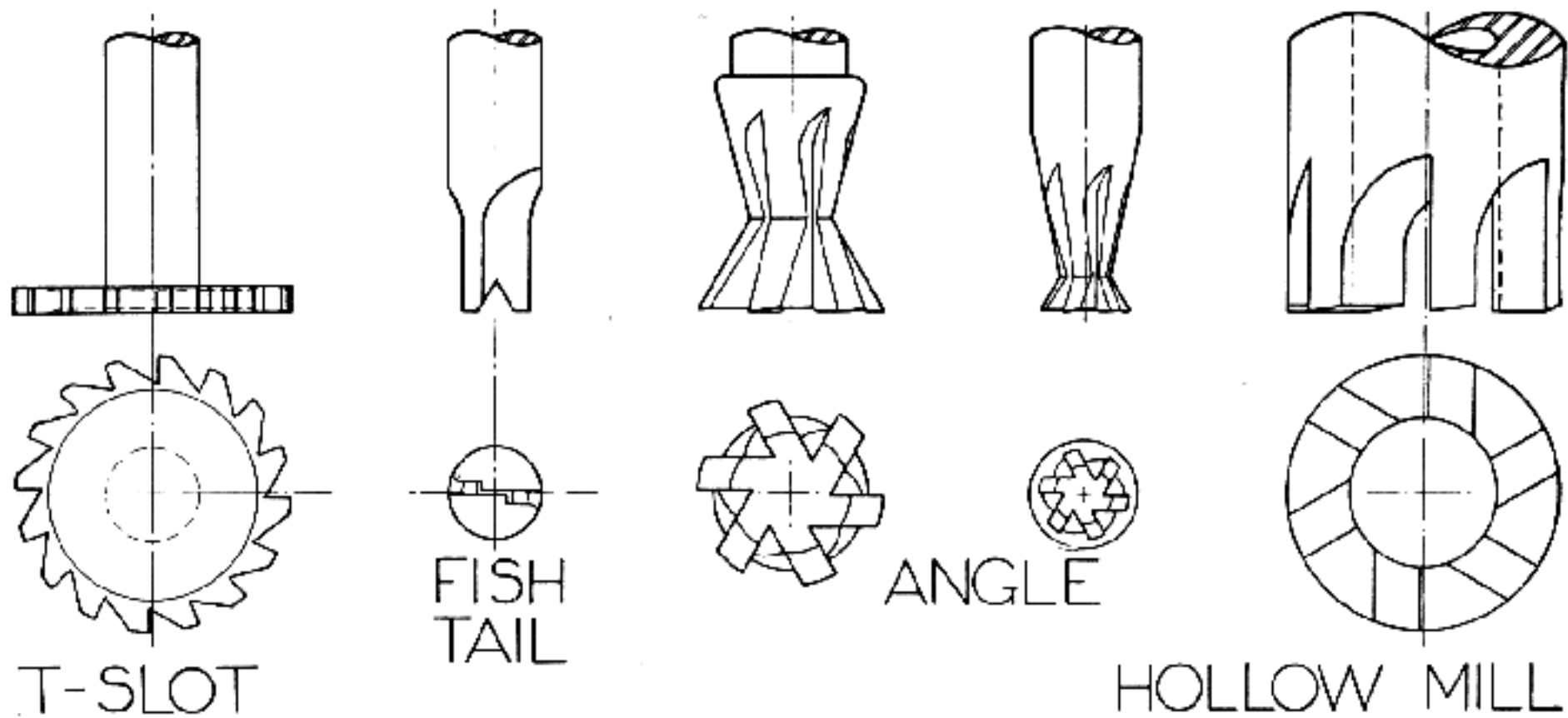


Fig. 25
Special milling-machine cutters, and hollow mill

in the vertical head, keeping it flooded with oil. Before starting, make sure that the cutter is well sharpened and that it has enough clearance at the edges to prevent any deviation from a straight line. When all conditions are right, this cutter will produce a straight true slot in a fraction of the time consumed with a standard end mill. Whenever it is necessary to have the ends of the slots square on certain work produced with these cutters, the holes must be filed or broached to shape after cutting.

Angle Cutters — Angle cutters are used (see Figure 25) to cut out sight slots, dovetailed bases, etc. They are made with straight shanks to fit either in collets or in special holders. Since most angle cutters that are used in the manufacturing of firearms are small in size, a bench miller is employed to cut the blanks. In order to insure teeth strong enough on these small cutters to resist the strain of the full cut, an angular mill should be made which will give the required shape. After the teeth around the circumference of the angle have been cut, the end teeth may be filed, particularly on the small cutters up to $\frac{1}{2}$ inch diameter. For cutters over this size, the end teeth are cut on the milling machine more satisfactorily. When the teeth on the end of the cutter are being cut, the dividing head is turned until the cutter is in a horizontal position. The angular cutter usually used for the end teeth is 80 degrees.

T-slot Cutters — In cutting small slots in various parts of an action a cutter of this form is employed as shown in Figure 25. This type of cutter is used more than any other in special firearm work, as there are various widths and diameters required. Some of the T-slot cutters have teeth cut on both faces, particularly when a T-slot is required in a

certain section or part, but since these cutters are only used for cutting on the circumference, teeth then are only necessary on the diameter; therefore, the sides are given a slight angle inward for clearance so that the cutter will not bend in the slot. It is advisable to harden the cutters which have just been described the entire length of their shanks, especially if they are of a small diameter; otherwise they will be very likely to spring and break while in use. After hardening, the neck should be drawn to a straw color up to the cutting section.

If very accurate results are desired, the shanks of these cutters are ground, but for the usual run of work they can be turned and milled, the clearance filed on the teeth, and stoned after the hardening and tempering operation. End mills can be secured from the manufacturer at a reasonable price, as Figure 26 shows. Many times, however,

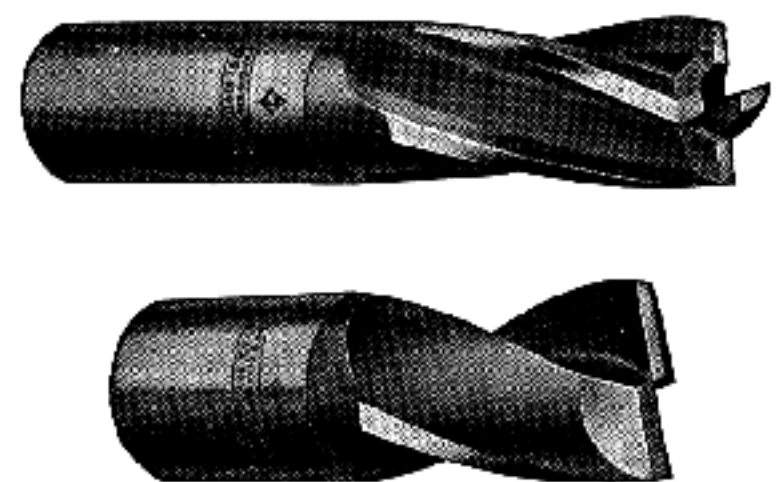


Fig. 26
Two- and four-fluted end mills

special mills must be made; I will assume that the tool maker is familiar with them, for they are commonly used for special jobs and to get into places impossible with standard end mills. Wood cutters also come under this head and are used in various machine operations for grooving and turning special forms.

Hollow Mills — These mills are mostly used on screw machines for roughing down and finishing, and also for screw cutting. They are also used in a drill press for finishing a projection which may be in some given position on a part of an action. In the latter instance they are usually guided by a bushing in a fixture to bring the projection into the correct location. For roughing-down work on a screw machine, solid mills having strong stubbed teeth are preferred because of their solid construction. For finishing they are made adjustable in order to secure the exact sizes, and for small hollow mills three cutting teeth are advisable.

Figure 27 illustrates a hollow mill showing its rear end, bored somewhat larger than the cutting end which allows it to clear on long cuts. The cutting end must be relieved or it will bind on

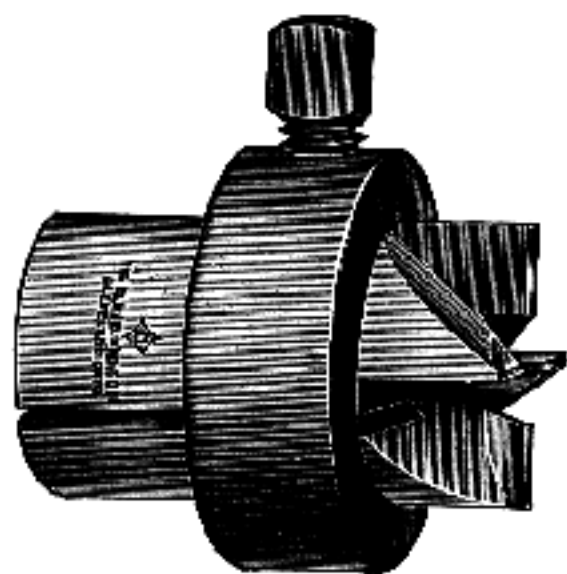


Fig. 27
Hollow mill with clamp

small work, and probably twist it off in the mill. There are several methods of relieving hollow mills; the most common is to ream the hole with a taper pin reamer from the back; another is to file back the cutting edges. Having thus prepared the mill, the teeth are ready to be cut. If four cutting edges are to be given, an end mill may be used of a diameter about double the diameter of the mill, the blank being held in the dividing-head chuck. For a strong tooth the dividing head should be set at a slight angle, or when considerable stock is required for a strong tooth, it should be set on such an angle that the cutter can be fed through the blank. If a deeper tooth is desired, the dividing head is set in a vertical position and the milling cutter fed in until the desired form and depth of tooth is obtained. Adjustable hollow mills may be made by following the instructions given for plain hollow mills except that the mill must be split to allow for alteration in size.

There are two methods of adjusting the mill; in one the outside of the cutting end of the mill is tapered and a collar having a corresponding tapered hole is forced on the mill. The collar closes it and causes it to make a smaller cut. The other

method is to turn the outside of the hollow mill straight and close it by means of a clamp collar. Adjustable hollow mills are usually employed for finishing cuts and do not remove very much metal; therefore, the teeth may be made finer than those of solid mills used for roughing purposes. If the teeth are nearer together, they will finish a cylindrical piece of work more accurately than if the teeth were cut farther apart. It is customary to give adjustable hollow mills which are to be used for finishing from six to eight cutting teeth. The cutting edges should be radial for most work. Better results will be obtained if the hole in the cutting end of the mill is left 0.005 of an inch small and ground to size after the mill is hardened. The hollow mill, whether it is solid or adjustable, should be hardened a trifle farther back than the length of the teeth and drawn to a straw color. The mill is sharpened by grinding the end of the teeth.

Forming Tools — Forming tools are principally used when several pieces are to be made of exactly the same shape. They are particularly valuable when making special bullets, special forming cutters and similar tools, and in duplicating a given shape on work produced in the screw machine. Forming tools are made flat and circular in shape. When used in the lathe for forming such tools as formed milling-machine cutters they are usually made flat; for backing-off formed milling-machine cutters they are always made flat, but for screw machines in duplicating a given shape they are made flat and circular.

The flat forming tool is often made as a solid tool but to save steel a special holder should be made with one or two hold-down screws. When only one tool is made, the former will be found to be inexpensive, but for making many tools it will be much cheaper to adopt the latter. On certain classes of work it is advisable to use a forming tool on a spring holder; because of its design it may spring slightly when used on heavy cuts, thus reducing the tendency to chatter. It is necessary to make these holders of tool steel, giving them a spring temper at the point of the goose neck, which allows the forming blade to spring away from the work when under heavy strains.

So that a forming tool will cut readily it is necessary to give the cutting surface a sufficient amount of clearance. For tools to be used for forming milling-machine cutters or similar tools, a clearance of from 10 to 15 degrees will be sufficient; that is, the angle should be from 80 to 75 degrees, but if the tool is to be used for backing-off the teeth of formed milling-machine cutters, it is then necessary to give a clearance of from 18 to 22 degrees.

Before starting to make an odd-shaped forming tool, accurately ground gauges should be made from $\frac{3}{32}$ -inch Brown & Sharpe ground gauge stock. In one large manufacturing plant where I was working in the gauge department, when a forming tool was designed, the gauge department first made the male and female gauge before the form tool department was allowed to begin its work. When the work was produced from the tools it came out perfect, saving the time usually spent by guessing methods used in so many shops.

Formed Cutters — The term formed cutter applies to cutters with teeth so relieved that they can be sharpened by grinding the face of the cutting edge without changing the form. The term may be applied, therefore, to any cutter which cuts a form, regardless of the manner in which the teeth may be relieved. Formed cutters are used in many shops where work of irregular shape is milled in large quantities as in gun and automobile shops. If many formed mills are to be relieved it is advisable to procure or make a machine especially designed for relieving, or as the term is applied, "backing-off" the teeth. The backing-off lathe attachment can be purchased with nearly all standard lathes, of which the Hendey is one of the best. I have had quite a bit of experience with this type of backing-off attachment and have produced very good results even on large worm hobs.

There are several ways in which an ordinary lathe can be used to back-off a small forming cutter. One is by placing a stud on a lathe face plate or driving plate. The stud is placed in such a position that the cutter will clear the outside edge. The cutter, which must be a fit on the stud, is clamped by means of a nut. A stationary block is so located on the driving plate as to bring the tooth to be backed-off into its proper location and to keep it from turning during the operation. The forming tool is fed in gradually until the tooth is formed. The finger in the stationary block is then disengaged from the flute in the cutter which is held in position by means of a set screw. The finger is formed to the exact shape of the space milled for clearance or flute. Each tooth is milled separately; therefore, the forming tool is fed in the required distance for each tooth when in position and the process repeated until each tooth has been backed-off. When backing-off cutters in this device it is necessary to cut the notches or spaces between the teeth somewhat wider than the ordinary milling cutter.

When backing-off the teeth for clearance by any of the means described, it is first necessary to form the blank, gash it or cut the notches, and then

back-off the teeth. After backing-off, it is necessary to mill the face of each tooth back $\frac{1}{32}$ inch or more to cut away the "jump," as it is termed, caused by the forming tool drawing in a trifle when it first strikes the edge of the tooth. Cutters of this description are sharpened by grinding the face of the teeth.

Fly Cutters — The simplest form of milling-machine cutter is known as a fly cutter. It has only one cutting edge but is particularly valuable when making one or two pieces of a kind in experimental work or for a part of a firearm which cannot be machined in any other manner. Since these cutters have but one cutting edge, they produce work very accurately as to shape, but they must be fed very slowly, and only small cuts can be taken. These cutters do not last as long as those having more teeth; however, they are used on all special work because of the small cost of making them. It is necessary to hold such cutters in a fly-cutter arbor, which can be made or procured from all the large tool-supply houses.

The cutter which is used in a fly-cutter arbor may be filed to a gauge or templet, giving the necessary amount of clearance so that the back edge or "heel" will not drag. If it is desirable to make the impression on the shaper or milling machine it is well to do so to remove a considerable amount of the rough form. The piece of steel from which the cutter is made can be held in the milling-machine tool maker's vise and the shape and clearance cut with a milling cutter. The desired amount of clearance may be set by tilting the vise at an angle of a few degrees.

Arbors — The ordinary taper arbor known as a mandrel is one of the common tools in all shops and is used to turn work pressed upon its cylindrical surface, shown in Figure 28. Mandrels are

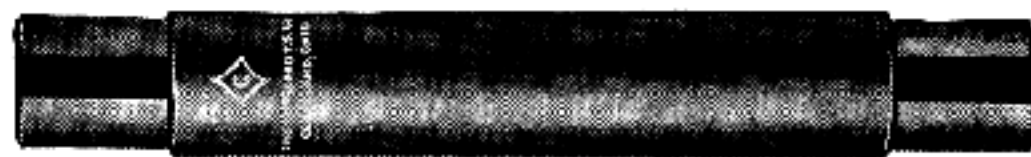


Fig. 28
Lathe mandrel

made of tool steel hardened all over and ground to size. Most arbors can be procured from any of the large tool-supply houses in the standard sizes, and it does not pay to make them except for a special size or form.

When making mandrels of tool steel that are to be hardened the entire length, it is not necessary to use the best quality of steel; a lower grade will do if it hardens well. Select stock somewhat

larger than the finished diameter. Take a cut off the outside sufficiently heavy to remove all scale, and leave $\frac{3}{64}$ inch or more for a finish cut on sizes up to $\frac{1}{2}$ inch and correspondingly more for larger sizes. The mandrel should be normalized perfectly in the annealing box. The ends should have a deeper center than in tools where the centers are not used after they are finished. So that the centers will not be mutilated when driven in or out of the work, they should be slightly counterbored or recessed and the edges of the angle rounded with a scraper. This operation is known as "cupping the centers."

Barrel plugs are a form of mandrel, and the instructions given in Chapter IX may be followed when making shoulder barrel plugs where a center is used to have the dead center run on. Before hardening an arbor, the centers should be re-countersunk to true them; for this operation, it is best to use a special combination center drill with an angle of 59 degrees instead of the standard 60-degree tool, as the former facilitates the lapping of the centers to a 60-degree angle after hardening. A round fine India oilstone is used for the purpose of lapping the angle. The manner in which the angle is turned on such a stone is in the lathe with a fine small sharp diamond. Other laps may also be employed, such as copper or cast-iron charged with diamond dust or emery. After the lapping operation the centers should be cleaned thoroughly with gasoline.

Examine very carefully the condition of the centers on the grinder, for the trueness of the arbor depends in a great measure on their condition. A mandrel may be ground in a lathe with a Dumore grinder or any universal grinder. Better results can be obtained, however, with some form of grinder having water connections, the liquid continually playing on the work to prevent heating, as heat is very likely to spring the piece, especially if it does not run true, and make the grinding heavier on one side than on the other. When a dry grinder is used, do not force the work fast enough to heat it. The mandrel should be ground to within about 0.003 inch of size with a coarse wheel free from glaze and then finished with a fine wheel.

The amount of taper varies on most arbors, and those procured from the manufacturers have a 0.001-inch taper per inch of length. I have found that the best results are obtained when they are made with a 0.0005 inch and less taper per inch for the reason that nearly all gun work consists of small parts except the tools made for their production.

Drill Jigs — A drill jig is a device for holding

work so that one or more holes can be accurately drilled; the location of the holes may be governed by hardened bushings through which the drill is run and centered. The design of a jig depends entirely on the shape of the piece and the nature of the work to be done, but it should be so that parts may be placed in them and taken out as quickly as possible. The fastening or holding-down device should allow rapid manipulation, yet be capable of holding the work without danger of changing the part in location. The construction of a drill jig calls for great accuracy, tho no undue effort should be indulged in. If the location of a hole in a piece of work is near enough when within a limit of plus or minus $\frac{1}{32}$ inch it is a waste of time to attempt to get it within a gauge limit of 0.0003 inch. Still, if the work is of such a character that it is necessary for holes to be within a limit of 0.0005 inch plus or minus or even closer, every effort should be made to locate the drill bushings as accurately as possible.

There is such a large amount of special work to be done on firearms that it is often advantageous to make a temporary jig to secure the accurate results desired. Such designs demand the ingenuity of the tool maker to construct them at a reasonable cost, for they may only serve one purpose and then be discarded.

Laying Out Work — The expression "laying out" as used in the gun shop refers to those geometrical operations in which the shapes and dimensions of parts are indicated by lines made with various laying-out or marking instruments already described in the first part of the chapter. In some complicated details requiring shaping, milling, boring, drilling, etc., a preliminary "layout" is necessary to determine whether the work will "true up" and also to make the machine operations more simple. After the principal base lines of the design have been established, the work is machined to these lines and then the centers for boring, drilling, etc., are constructed in their proper relations to the base surface.

Having planed, shaped, milled or turned a piece of work, completing what are usually termed the roughing operations, we coat the "layout" side with a mixture of coppering solution or with any other suitable preparation that will enable us to see the lines more distinctly. By using the instruments described, lines are established which may be indicated with the center punch. The center being ascertained, dividers are often used and successively set to various dimensions, and short arcs are inscribed, intersecting lines. With dividers set to the correct radii, circles equal in diameter to the

required holes should next be drawn from the indented center. The circles may also be indented with center-punch marks, various distances apart. In a great number of cases, center-punch marks are scarcely necessary when the coppering solution is used.

Circles of the same diameter as the drill will usually be obliterated by a drilling operation and it is a good plan to make additional larger circles by which the accuracy of the drilling may be tested when the operation is completed.

To insure accuracy the prick-punch marks in the centers should be very light, and after the laying out is finished they should be slightly enlarged with the center punch and then drilled with a small combination center drill in order to guide the drill point properly. The first drill is ground to the angle of the center drill in order to follow the true center. After a depth of about $\frac{1}{8}$ inch is reached a standard ground drill can finish the operation.

A surface plate or laying-out plate, as it is often called, would be necessary in connection with the described examples, and it would be proper to describe briefly the construction of such plates. For small and ordinary work a surface plate is a

very simple affair. Any cast-iron or machinery-steel plate of rigid construction will answer. It is well, also, to have the edges of the plate planed at right angles and the top accurately finished.

So much laying-out work is done in connection with the making of firearms that I would like to see some tool manufacturer introduce some such circular form of surface plate as Figure 29 illustrates, made to revolve upon ball bearings and with four sides squared. The principal object of such a plate and its construction is to admit of turning any side of the work toward the light. A plate so designed would be a great improvement over the standard form of square or oblong surface plate commonly seen in tool rooms.

Surface plates of this construction for very large work should be proportioned by a competent designer and supported upon a foundation of masonry. Small plates could also be designed to fit the work bench, but a small bench or stand so placed at the tool maker's side so that he may conveniently get around it is better.

The slightest mark raised upon the surface plate with a hammer will interfere with the accurate use of a height gauge or any other tool; therefore, straightening strips of metal on the plate and other such abuses should be strongly condemned; in fact, no tool maker of refinement will allow such a practise.

The Precision Bench Lathe — I can not resist giving a brief description of the merits of bench-lathe practise in gun work and the tools constructed for their production. It is a pleasure to walk into a well organized tool room and see these lathes. The modern bench lathe finds wide application in the construction of small parts requiring a considerable degree of accuracy as well as in fine tool work where its facility of operation and its accuracy make it one of the most ideal tools. Bench lathes have been developed in these last few years to the same high standard of efficiency as the larger types of lathes, and the design of various attachments has broadened the field of these machines so that it is possible for them to handle a wide range of work.

In addition to their adaptation to precision turning and boring operations, bench lathes are equipped for milling, external and internal grinding, thread cutting, filing, turret work, etc. Many of the attachments can be made to take care of any special parts made or manufactured in the tool or production departments. All the parts and attachments should be interchangeable as far as possible; therefore, when several lathes are in a department, a given attachment can be used on

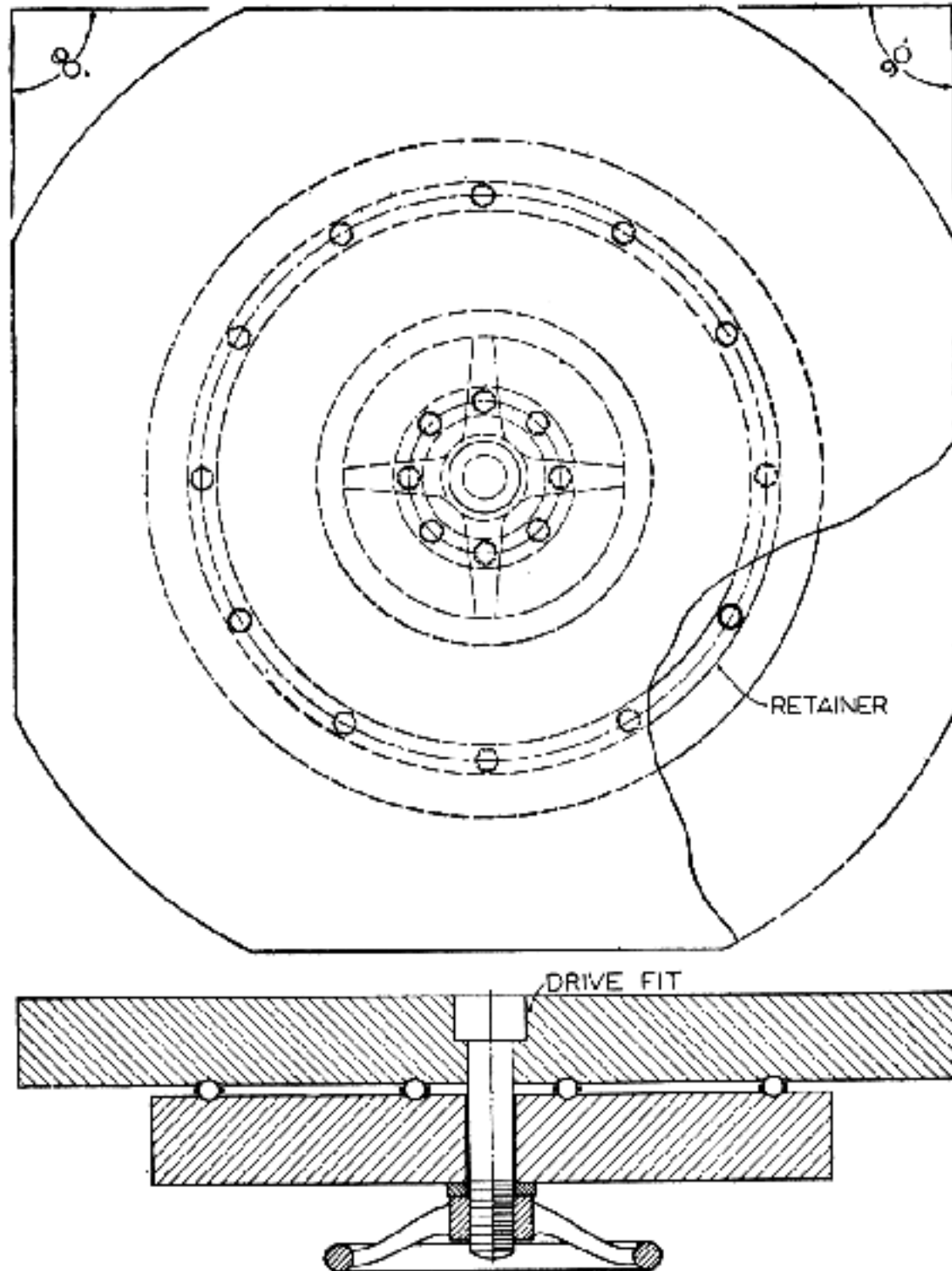


Fig. 29
Suggested design for surface plate

any machine that may require it. For this reason machines of one manufacture should be adhered to.

Past experience in the use of a bench lathe has shown that the proper countershaft equipment adds greatly to its efficiency. It is well to fasten the countershaft to a pipe frame attached solidly to the bench, wall, or ceiling. The frame may be made of ordinary pipe threaded at the ends with collars that are bolted to the bench or other supports. The countershaft should have adjustable brackets which will fit the pipe frame so that it can be adjusted to any desired point, making it possible to use an endless belt. Countershafts should be ordered with grinding attachment pulley, even tho it may not be used at the present time. These lathes are often changed over for other work and serve many purposes. In the production of fine gun work and for the finer work in the tool room, the bench lathe is invaluable. The ordinary lathe is too large and unwieldly, not excepting those lathes constructed on the same principle as an engine lathe made for the bench.

Gauges — While any tool or instrument used for taking measurements may properly be called a gauge, this term, as used by the tool maker, is usually understood to mean that class of tool conforming to fixed dimensions and used for testing sizes but not provided with graduated adjustable members for measuring various lengths or angles. Gauges are used in shops to make one part of a machine or implement, or a tool corresponding to some other part, so that when the whole is assembled, every part will go into its respective place with little or no fitting. The measuring instruments discussed in the first part of the chapter are indispensable, but in shops where work is made on the interchangeable plan—where a piece of work made today will exactly duplicate a similar piece at some future time—a very thorough system of inspection is necessary. In order that the inspection may accomplish the desired result, gauges are made that will show any variation from a given standard. There are various forms of gauges designed for various classes of work. With the modern system of interchangeable manufacture, gun parts are made to a definite size within certain limits, varied according to the accuracy required, which in turn depends upon the nature of the work. To insure having all parts of a given size or class within the prescribed limit so they can readily be assembled without extra and unnecessary fitting, what are known as "limit gauges" are used.

Gauges are usually made from machinery steel, as hardened steel has a tendency to change its shape and size for a considerable time after the harden-

ing has taken place. This change is small, so small indeed that it may never be considered except in the case of gauges where great accuracy is required; yet it has led some of the most prominent gauge manufacturers to use pack-hardened machinery steel.

When making gauges the tool maker should observe the points emphasized with regard to fine precise measurements in the first part of the chapter and also in other chapters dealing with fine measurements upon similar work. When tool steel is used in the construction of gauges, the tendency to change shape may be overcome by referring to Chapter IX, which describes the seasoning of gauges.

It is always necessary to stamp the name of the part to be gauged and the size of the different parts of the gauge. The tool maker should bear in mind that the effects of driving stamps, letters, or figures into a piece of steel will be to stretch it; therefore, it is advisable to stamp the gauge before finishing any of the gauging portion to size, even if there is an allowance for grinding.

To make any plug gauge, which is one of the simple forms of gauges, stock should be selected large enough to turn off the decarbonized surface after roughing out the blank. The handles are turned to size and knurled and the under-cut turned out between the gauging portion and the handle. The blank is reversed on centers and the gauging diameter is turned, allowing from 0.012 to 0.015 inch larger for grinding. A flat is usually milled on the knurled handle and the size of the gauge or any other distinguishing marks which may be stamped thereon. It is also a custom to stamp the under-cut or recess between the cylindrical portion of the gauge and handle, but the stamping on the milled surface of the handle shows greater refinement.

Plug gauges should be heated very carefully for hardening; the lower the heat, the more compact will be the grain, and a piece of steel having grain that is fine and compact will wear much better than one having a coarse grain. If the gauge is one requiring extreme accuracy, it may be left from 0.002 to 0.003 inch above size and seasoned. If not, the gauge may be ground to a size 0.0003 inch larger than the finished size, after which it must be lapped to size. When grinding a gauge of this description it is advisable to use a grinding machine having a supply of water running on the work to keep it cool in the same manner as the grinding of arbors. If this form of grinder is not available, the gauge should not be heated any more than necessary. It should be measured while cool, as steel always expands from the heat, and if

ground to size when heated it will be too small after cooling.

If possible, a form of grinder having two dead centers should be employed. A lathe is often used in the grinding operation, running the work between a dead and live center. Lathes that have been in use for some time are very likely to have become worn so that accurate work is impossible; this is especially true of the spindle which will duplicate its own inaccuracy on the gauge. When necessary to grind a gauge on a machine of this description it is advisable to leave a trifle more stock for the lapping operation.

Lapping—Lapping is a form of grinding applied to work requiring a higher degree of refinement than is possible by the ordinary process of a plain or universal grinder. Figures 42 and 43, Chapter IV, Volume I, illustrate lapping arbors and lap holders, and describe the methods used for such operations. The laps described are the best and cheapest for internal and external lapping. Cast-iron and copper make good laps; but copper has the preference for roughing, and cast-iron for finishing. The lap is split as shown, and the length should be somewhat greater than the length of the work to be operated on.

These lapping arbors are made to the taper-pin standards and ground to the same taper. A hardening swedging plug should be made for each arbor for the purpose of driving the laps on the arbor to keep them expanded to the work. If, in the operation of lapping, the hole becomes "bell mouthed"—that is, enlarged at the ends—it is usually caused by the introduction of emery from time to time as the hole is lapped. To obviate this the lap should be cleaned of all loose emery and the lap kept well expanded by driving it in farther. The hole is usually dry-lapped with a cast-iron lap by using the finest optical emery that will stick or be charged into the lap. This process must be repeated occasionally until the proper size is ob-

tained. If the tool maker is careful to see that the proper emery is obtained and the lap kept expanded to fit the work at all times, the result will be a straight hole. There are quite a few variations in the practise of lapping, and the best methods often depend upon existing conditions. The material used for holding the abrasive is one of the most important factors when the work is soft, and it is very important that this material should be softer than the work; therefore, in the case of shotgun barrels, where every bore is finished by lapping, lead has been adopted as the best metal to use.

Bench-lathe Knurling Tool—A tool of this description is essential for knurling small pins, screw heads, adjusting screws, etc. Figure 30 illustrates the tool as it is constructed. The height of the bottom center and the height of the shank will be best suited to the particular bench lathe employed; therefore the height must come in the exact center; also for the knurl holder. No. 2 holder is pinned in position with a dowel pin solid against the square upright section of the shank. The second knurl holder is made with a free sliding fit so that it will be adjustable. No. 1 is the screw-adjusting holder. Two holes are provided in the shank, making two positions possible; one for small work and the outside hole for larger pieces. The pin which holds this piece in position is reamed out with a taper-pin reamer and a hardened taper pin is fitted.

The knurls are made in any form. The straight knurls are made fine, coarse, or medium. For best results they should be cut on a milling machine, using a 90-degree angle cutting one cut right-handed and the other left-handed. All parts should be hardened for longer life of the tool.

Boring-tool Holder—Figure 31 illustrates a lathe boring-tool holder with which every tool maker is familiar; it is one of the first tools made

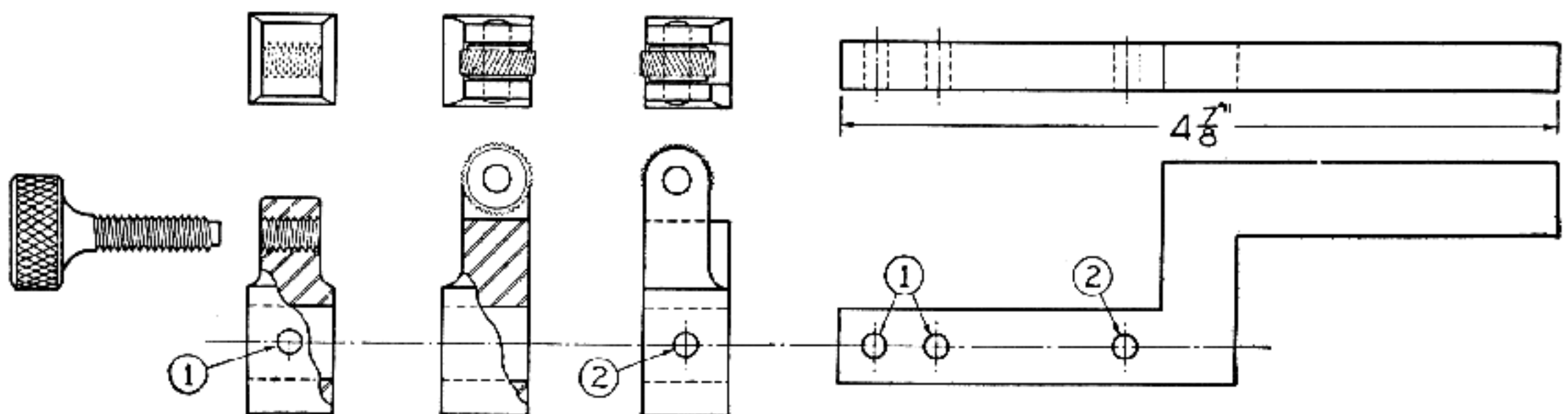


Fig. 30
Bench-lathe knurling tool. Very handy for knurling heads of screws, etc.

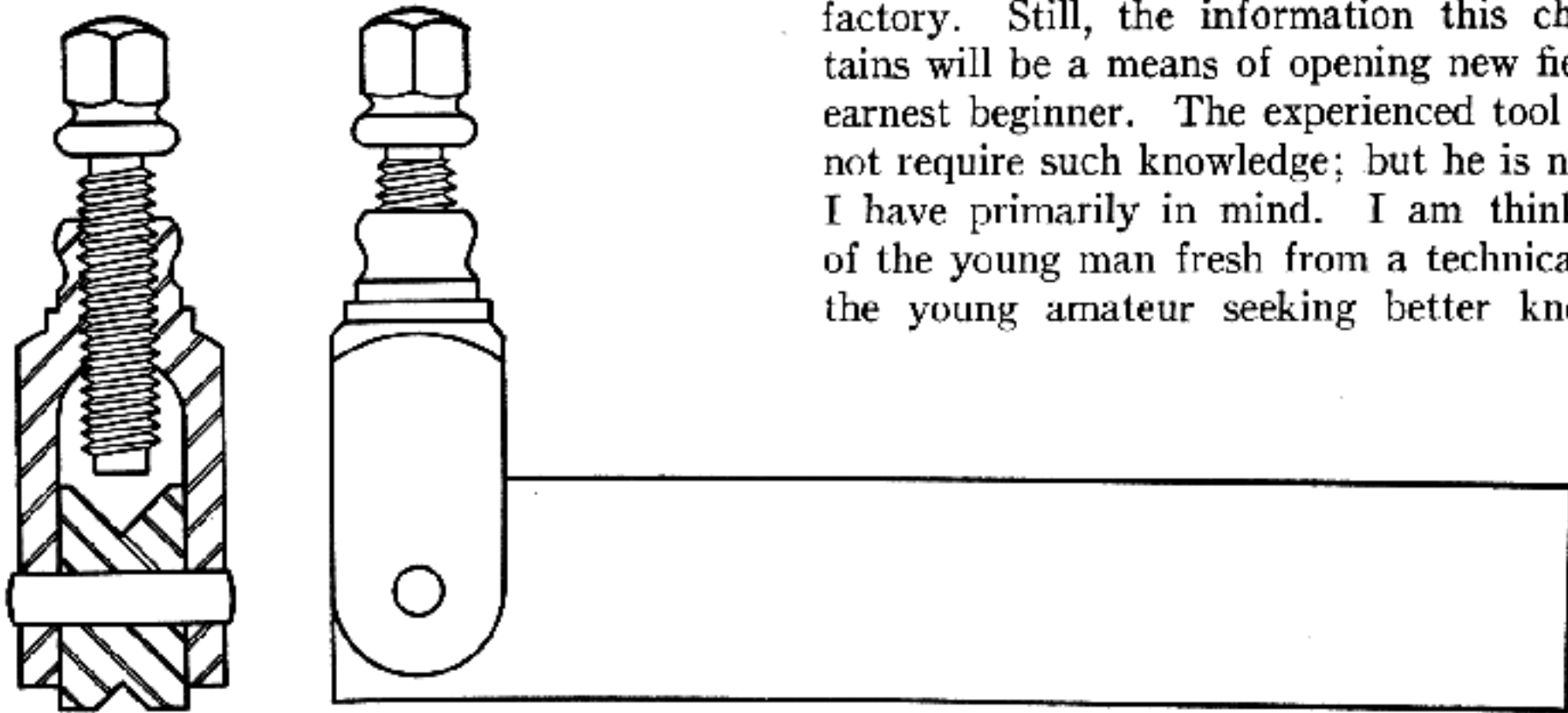


Fig. 31
Boring tool holder. Used on lathe to hold internal boring tools

factory. Still, the information this chapter contains will be a means of opening new fields for the earnest beginner. The experienced tool maker will not require such knowledge; but he is not the man I have primarily in mind. I am thinking rather of the young man fresh from a technical school or the young amateur seeking better knowledge of

by the apprentice. The best kind is essential for the gunshop.

Sine Bar — Figure 32 illustrates a sine bar. These tools must be very accurately made; they are instruments of close precision, and as all accurate angles are laid and checked from them, great care must be used in the making. The distance of 5 inches must be within plus or minus 0.0001 of an inch. To secure this close measurement the body of the bar must be well seasoned, and the holes ground and lapped. The two plugs are made in even figures; thus the diameters are .6000, .8000, or 1.000 inch, or any figure that two can be divided into and result in an even figure. Such a tool is used frequently in the gun shop.

After beginning this chapter I realized that a book was necessary to describe some of the actual work accomplished in the modern gun shop, particularly in the arsenal or any other large arms

tools and their construction; for there is no greater field for knowledge of the tool maker's art than in the construction of firearms and ammunition. Very few manufacturing plants offer that knowledge today, for modern methods demand a profit from all labor, and the result is that time limits are placed on all tools produced. The average workman today has become a fixed machine, and in time all our fine workmen will be driven away to seek other occupations.

I do not wish to seem discouraging, but since I have gone through the mill, so to speak, I would not advise any young man to seek long experience in an industrial plant. Let him prepare himself in one of the finer technical schools, and, upon receiving his degree, remove the white collar and step out into these plants for a short period. Let him not stay at one, but make it his business to work in many, and at the end of that time he can judge for himself the path he wishes to follow.

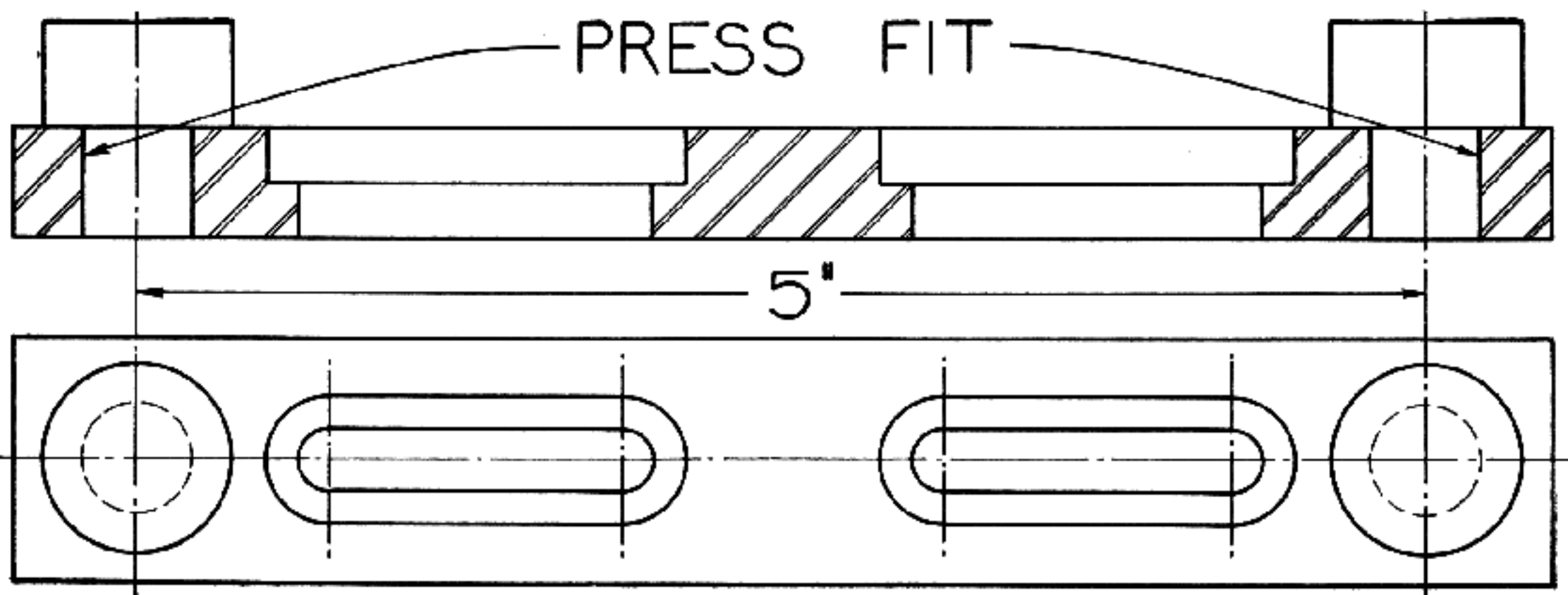
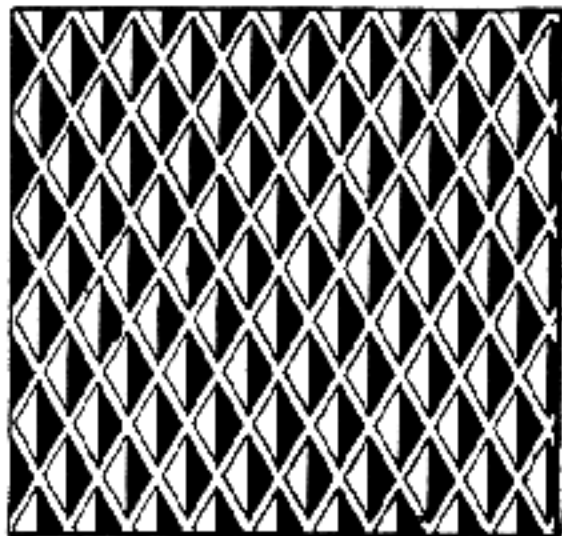


Fig. 32
Sine bar: Used to determine angles and to lay out angles on work for machine operation

CHAPTER IV
Die Making



CHAPTER IV

Die Making

DIES are now used extensively and have made possible wonderful results in rapid production of parts, as well as in the production of sheet-metal work. Take for an example our modern cartridge case and bullet; 90 per cent of the operations performed on these are produced with dies. Consider our modern motor car; it would be safe to estimate that over 50 per cent of the production methods employed are by dies. The rifle and shotgun involve the development of dies for butt plates, pistol-grip caps, sights, sight covers, swivel bows, etc. Air rifles for boys are mostly made from dies, which shows what can be done to cheapen machine operations on certain types of metal merchandise. It is rather difficult to classify and give the proper definition of the many designs and types of dies used on power presses for the production of sheet-metal work, to which this chapter will be mostly devoted. Cartridge and bullet dies will follow later, for such a subject must be treated from a different angle.

Die making is in the same general class as tool making, and it is well for any one to gain experience in it, since it comes in very handy on various phases of rifle and shotgun work. One of the advantages gained in die making is that it teaches one the use of a file; it requires a considerable amount of patience and perseverance, particularly when two weeks are spent filing out a complicated form in a blanking die. Die making is fascinating work, even tho it usually taxes the ingenuity of the mechanic when it comes to forming metal in dies. The modern diemaker does not figure out any of his dies as he did a few years ago; today, complete drawings come from the engineering department. Some jobs may require as many as eight or more operations; consequently a mechanic may only get one of these dies to make, the rest being divided among others in the tool room.

A die used for punching a blank from sheet metal is termed a blanking die and is usually considered as belonging to one of four classes: plain, progressive, gang, or compound. As will be seen, however, the main classes of dies are based on the use of the die, and while there are, of course, some general classes into which all dies may be divided, the various types overlap in so many cases that one

is often in doubt as to the proper classification.

All dies may, in the first place, be divided into two general classes: cutting dies and forming dies. Cutting dies are often termed blanking dies, including all designs which simply cut or punch flat blanks or pieces of the required outlines from the sheet metal fed into a punch press. On the other hand, forming dies include all those which change the shape of the material from its original flat condition. This second division, however, often includes features which are common to the first; that is, some dies are a combination of blanking and forming dies, the blank to be shaped or formed being first cut out or blanked to the required outline from the material and then formed to the desired shape. Study the fenders or body on your car as an example of such work, tho it is, of course, accomplished a little differently from the manner just described.

The cutting or blanking dies first mentioned may be further subdivided according to the construction of the various types of dies in that class; thus we distinguish between the aforementioned four distinct dies. The second main division—that of forming dies—cannot be subdivided in that manner. Owing to the great variety of work performed in forming dies, the designs vary greatly for a proper classification on the basis of constructional features. They may, however, be divided into subclasses arranged according to their general use; thus, there are dies for bending, embossing, forming, drawing, and curling.

Blanking Dies — Plain blanking dies are the simplest of all types and are used to cut out plain flat pieces of metal not having punched holes. (The term usually applied to punched holes is "perforation.") This type of die consists of a die block or female die which has an opening that conforms to the shape of the part to be cut or blanked out. A male die or "punch," which accurately fits the die block, by a shearing action does the cutting as it descends into the die-block opening, a stripper plate being provided which strips the material from the punch as it is withdrawn on the up-stroke of the press. The opening in the stripper plate conforms to the shape of the punch and is in most

cases slightly larger to provide a little clearance. Between the stripper plate and die block there is a guide (the back of the stripper taking that function in most cases) which serves to keep the stock in alinement with the die opening as it is fed along. In the case of strip stock, a channel is cut in the center of the stripper and the stock is fed through this channel. The space between the die and stripper will be somewhat greater than the thickness of the material used; in fact, this space should be sufficient to allow the stock to move along easily even tho the surface or edges are cut irregularly by the shears or by the punch on each operation or hit of the press. In a simple die of this kind, the spacing of the punched hole is commonly controlled by some form of stop pin which engages each successive opening; for instance, after a blank is cut out, the operator feeds the stock along until the opening made comes against the stop, thus locating the material for cutting out the following blank.

Progressive Dies — This form of die is known by the name of follow die, and is used for work which must be cut from stock to the required shape and at the same time be provided with holes or perforations. The principle of the progressive die is that while one part of the die punches holes in the stock, another part, following behind, blanks out the work at a place where, at a former stroke, a previous hole or opening has been punched. Two separate operations have been performed at the same time, the operation being a progressive one in which the holes are first pierced after which the material moves along until the pierced section is in line with the blanking punch.

Forming Dies — Forming dies are those in which a blank is shaped by simply being pushed into a cavity of the desired form in the die. Forming dies are made first to the desired shape, then placed in the press and templets are cut out until the correct form is obtained. Many trials may be found necessary, but as one is cut and filed, it is laid upon the stock and after the correct form is made it is held as the master templet to make the blanking die. Drawing dies are also used for the formation of cup-shaped parts or articles, but the drawing process differs from forming in that the stock is usually confined between two surfaces so that when drawing radially inward from between them, no wrinkles can form. To define the difference between the two types of dies in another manner: forming dies shape the metal by compressing and bending; whereas drawing dies so act upon a flat blank or a previously drawn cup that the shape

is changed by drawing the metal as the punch moves relative to the die.

Making of Dies — When making a die there are several points to take into consideration. The first is the die height; that is, the press clearance and stroke which will accommodate the height of a finished die when assembled. This measurement is taken when the pitman is screwed up to its highest point and the press turned over until the throw of the crank is at its lowest point. The measurement between the bolster plate and ram is the die height or the maximum distance between the bottom of the die shoe and top of the punch holder when the punch is just entering the opening in the die. Second is the type of die holder; it may be necessary to use a die set, made with guide pins, since the pins keep the punch and die in perfect alinement, thus imparting longer life to them. Otherwise, you must rely upon the tightness of the ram riding in the ways and the perfect clamping of the die shoe to the bolster plate. The least shifting of any member means a sheared die and punch.

After selecting the proper die holder, the die block is shaped to equal width and thickness. A good method is to shape the sides; both top and bottom surfaces of the blank length are usually left as the cut-off saw leaves them, except when fitted into a depression in the shoe. The upper surface is smoothed in a shaper or it may be placed in a surface grinder and ground. It is necessary to have this surface smooth in order to lay out the correct shape of the hole, either from a templet or with instruments as described in Chapter III. A roughly machined surface would allow neither distinct nor correct lines. The die must be laid out so that the stock may be readily fed to it. If the grain of the stock is a matter of importance, as in making a tempered spring similar to those seen on some automatic shotguns, the diemaker must take care to see that the grain runs in the proper direction.

The face, or the upper surface of the die, is covered with the coppering solution or placed upon a hot plate and the color of the steel allowed to run to a very dark blue. The outlines of the piece to be punched are then laid out, and after the die has been carefully laid out from the templet or drawing, all round corners should be drilled with a drill of the proper size and then reamed from the back side of the die with a taper reamer to give the desired clearance. A tapered pin reamer is usually employed and the balance of the material removed by drilling.

The method of removing the center or core depends on the custom practised by the individual die maker; some may drill the holes so that they

break into each other; if so, the best drill to use is a "straight-fluted" drill. Some drill small holes and use a counterbore to enlarge to size so that the holes will break into each other, while others use a small standard twist drill and allow a small web between each hole and the next, the intervening stock being cut out with a flat-ended hand broach usually made from a power hack-saw blade with the temper drawn to a blue. The last-mentioned method is the safest and most reliable.

After the center has been removed the die may be placed in a shaper or a die-slotting machine, and by the use of specially-ground tools the desired angle of clearance can be given. The amount of clearance or draft varies with the nature of the work to be done. When a die is shaped out on a shaper, two parallels are made with a one-degree offset, and when placed between the jaws of the vise with the die in the center, the proper clearance is shaped out of the back side of the die. One degree is too great a clearance for some classes of dies; therefore, the parallels should be made with different angles according to the nature of the work to be made and the life of the die.

After working the impression as near to shape as possible in the machines by shaping or slotting, it is finished by filing. In order to give the die the proper clearance the inside surface should be gauged with a diemaker's square set to the proper angle. The clearance differs in various die shops and also on different classes of work, so no stated amount can be given. For the general class of work it varies from one-fourth to two degrees; the latter is excessive and is seldom given unless it is necessary that the piece punched shall drop from the die each time. From one-half to one degree is usually the standard clearance on all classes of work; therefore, for rifle parts, one degree is a standard which may be used on butt plates, pistol-grip caps, sights, etc.

Die Filing — In shops where much die work is done a die filing machine is employed for many of the operations of working the form in the die to shape; also for gauges, templets, lapping dies, and various other parts. One of the small filing attachments comes as standard equipment with a bench lathe. Since the tables of all modern filing machines can be set at any angle, dies can be filed or lapped at the proper angle to give the desired clearance. A saw may be used in place of the file when an overhanging arm is used as a guiding medium, and the core of the die sawed out. This is one of the most satisfactory methods of cutting the core from any small die having an irregularly shaped opening whose outlines are such that the ordinary

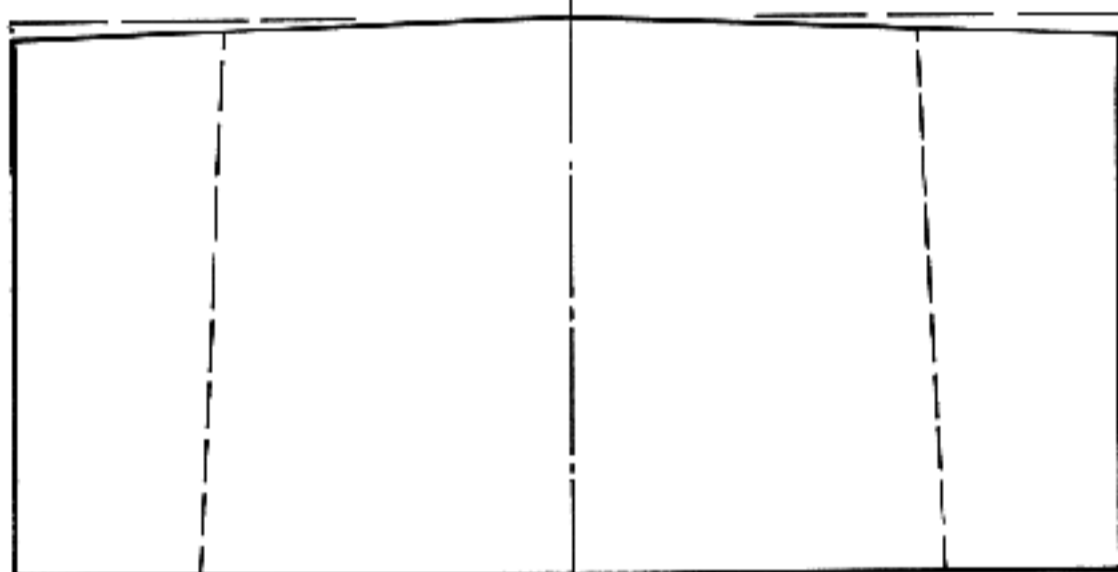
method either does not prove satisfactory or is extremely costly. For large work an ordinary hack-saw blade may be used, holes being drilled at the corners of the openings. For small work and where irregular shapes are to be produced a narrow blade whose teeth have considerable set is advisable.

For roughing out a die opening, a coarse file should be used, the file being clamped at either end and the work held against it by hand pressure while one or two hold-down fingers are held over the top, allowing enough freedom of the die to be moved at will. When taking finishing cuts with small fine files, the file is usually held in the lower clamp, and as the file clears on the return stroke undue wear is avoided. The surfaces produced by filing machines are flat and especially adapted to dies having but a small clearance angle where any rounding of the surfaces would not be allowable.

Shear — Die blocks have their cutting edges beveled as in perforating punches, so that the blank or slugs may be cut from the stock by a shearing



PUNCHES



DIE

Fig. 33

Illustrating shear on die and punches. Required when heavy stock is used

cut. Shear is given the face of the die to reduce the power necessary to cut the blank from stock. (See Figure 33.) The amount of shear given any die is gauged by the stock used; therefore, when a die is to blank out 16-gauge stock, the height of the center is the thickness of stock to each end of the die. There are exceptions to this rule when cutting this bevel.

The face of a die is sheared when the blank or piece forced through is the product to be saved, but whenever the piece surrounding the blank is to be saved and the outside material is of no use, the face of the punch is given shear and the face of the die is left perfectly flat. The cutting face of the die is usually given shear when very much is to be removed by a shaping operation; when only a small amount is required, it is usually done in the surface grinder by first grinding one side and then the other with a piece of metal used under one end to raise it the required amount to secure the proper shear.

Sectional Dies — So that dies may be more easily worked to shape, they are often made in two or more sections which are fastened together by dowels and screws and held in such a manner that they can not spread. A recess milled in the die shoe at a depth sufficient to hold them is employed as well as the dowel pins.

Dies of this form should have the surfaces that go together finished true; the pieces should then be clamped together and the dowel-pin holes and screw holes drilled and reamed. If the die blank is to be held by fillister-head screws, the die shoe is drilled and tapped or vice versa. The screw is inserted and the top is laid out to the outlines and punched. After the die is hardened and screwed in position, the dowel-pin holes are drilled and reamed in the die shoe; otherwise, the little change in the hardening of the section may cause them to be thrown out of line.

After the proper lines are scribed on the surface of the die, it is taken apart and the opening cut out on the shaper or milling machine. The section of the die is held at the proper angle to give the correct amount of clearance. After the two or more pieces have been put together, the opening to the templet may be finished with a file.

When the die is finished to the templet and the correct clearance given, make sure that the walls of the opening are straight—"not crowning." It is not always considered advisable to carry the clearance to the edge, as the size of the opening would increase every time the die were ground. In such cases the clearance extends from the bottom to within about $\frac{1}{8}$ inch of the cutting surface. The walls of the upper part of the opening are at right angles to the base of the die, but they must be straight, because, if the opening is wide enough to allow the punch to pass through the crowned part, the material, if thin, is likely to leave the blank with ragged edges, which would extend up on the sides of the punch and have a tendency to crack the die.

Punches — The punch is made to force the metal through the die, producing pieces of the desired shape. It is customary to make and harden the die using a templet or a drawing to secure the desired shape, after which the punch is fitted to it. The templet may be used in laying out the punch for a plain die if the shape of the opening in the die is the same on each side and the die does not change shape in the hardening. Either side of the templet may be next to the face of the punch, but if the outline is of an odd form it will be necessary to exercise care to see that the proper side is used because the side of the templet placed against the face of the punch when laying it out will be opposite to the one placed against the face of the die; therefore, it is always best to mark the templet "up on die" on one side and "up on punch" on the opposite side, then no confusion takes place when laying out either one.

To obviate this trouble many die makers lay out the face of the punch from the opening in the die before the shear or beveling takes place. In order to hold the punch and die together, so there will be no danger of the punch slipping while the shape is transferred, the die and punch are clamped together.

The machining of a punch blank varies according to the size of the punch. Some have shanks turned on the end, while others are fitted with fillister-head screws and dowels to the face of the punch holder. The method may depend upon the size and shape of the punch, and on whether it is to be used singly or in combination with other punches. If so, a separate cold-drawn piece of steel is used to set these in. The service for which the punch is intended is another point that should be considered; that is, whether the die is for producing comparatively few parts or is intended for continuous service. When punching heavy material the punch must be firmly secured against a vertical thrust in either an upward or downward direction, because when the punch ascends and is stripped from the stock, it is subject to a heavy downward pull. If the die is intended for a small amount of work, as in a gun shop, a cheap and quick method of making both the punch and die would be advisable. After deciding the method of clamping the punch to the punch holder the machining operation follows. The end which is to fit in the opening in the die should be finished with a smooth flat surface and colored with the coppering solution. After coloring it may be clamped to the face of the die with a clamp, and the outlines of the die marked on the face by scribing through the die opening. This outline should be accurately marked with a sharp-pointed scribe and prick-punched very

lightly, as the scribed lines are likely to become obliterated by the various operations of machining the punch to shape.

After the outlines have been carefully prick-punched, the punch is ready to be milled or machined in a shaper to the correct outline, leaving enough stock at all points to shear into the die. When the punch is milled to shape, the irregular surfaces may be produced by fly cutters, of which a description is given in Chapter III. If it is shaped to form, it is usually held between the vise jaws or between a pair of centers, and before the final finishing cuts on the lines it is filed on a bevel exactly to the lay-out lines, so that the shaper tool will not obliterate the lines or break off the metal in ragged edges, and will at the same time allow enough for the shearing operation.

At this stage of the operation the term "shearing in" is used. The punch should be machined very close to the lines and then placed over the hardened die and forced into it about $\frac{1}{32}$ inch, which gives a true impression of die openings. After the punch has been sheared in for a short distance it may be removed and worked to size by means of a file to the obviation marks, as that portion sheared in is termed. The operation of shearing in may be repeated until the punch enters the entire length.

The amount of clearance between a punch and die for blanking and perforating, or the difference between the size of the punch and the die opening, is governed largely by the thickness of material to be used. If the stock to be punched is thin and soft it is necessary to make the punch a closer fit in the die than if the material is heavy or very hard. For thin stock such as tin and soft brass, the punch should be a close sliding fit to the die in order to avoid ragged edges on the punched blank, but for heavier stock there should be some clearance, the amount depending upon the thickness of the material. The clearance between the punch and die when working heavy material lessens the danger of breaking the punch and reduces the pressure required for the punching operation. To obtain the clearance between the punch and die it would be well to look up the tables in various technical hand-books.

A loosely fitted punch will cut absolutely free from burrs up to a certain point, but if it is a little too loose or a little too tight, ragged edges will be left on the material as a result. A good general rule which I often use to determine the clearance is to allow a clearance between the punch and die equal to 5 per cent of the thickness of the stock to be cut. For example, suppose a punch and die are required for cutting out a blank for a butt plate 0.0625 inch thick. The 5 per cent of the thickness

of the stock equals $0.0625 \times 0.05 = 0.0031$ inch, which would be the difference between the punch and die. After the punch has been fitted to the die, the cutting edge should be faced off to insure a good working surface and a sharp edge. It is then ready for hardening.

Hardening Dies and Punches — When handling work of such a character as the hardening of punches and dies it is impossible to adopt any set method not to be deviated from. No class of work calls for greater exercise of skill and common sense than the correct hardening of dies and punches to secure the proper efficiency from them. The secret of success in hardening dies by the ordinary methods consists in getting as nearly as possible a uniform heat. To accomplish this, the die or punch should not be heated too rapidly, as the edges and lighter portions will heat faster than the balance of the piece. Unequal contraction, when quenching in the bath, follows uneven heating; and unequal contraction causes the die or punch to crack. High heats cause cracks in steel; then again, high heats render it weak, and the result is that it cannot stand the strain incident to contraction of one portion of the steel when another portion is hard and consequently rigid and unyielding. Steel is strong when hardened at the proper temperature, known as the "refining heat." See Chapter VII for further information on hardening.

Before hardening a die the stripper and other screw holes should be drilled and tapped, and also the holes for the gauge pins or stop. If any stamping of the die is to be done it should take place at this stage. If there is no stamping to be done on the die regarding the number or operation, the name of the steel should be stamped so that if any alterations are made in the future, the method of hardening will be known. This applies to the punch also. After all screw holes, top-pin holes, etc., which are blind, are filled with fire clay or asbestos mixed with water to the consistency of dough, the die and punch are ready for hardening. Extreme care should be exercised in the heating; the heat must be no greater than absolutely necessary, and it should be uniform throughout—the corners of the die or punch must be no hotter than the middle of the pieces, and the outside surface must be of the same temperature as the interior of the steel.

Most punches and dies are made from oil-hardening steel, very little of the high-carbon tool steel being used today for this purpose; if a high-carbon water-hardening tool steel is to be employed for draw-dies and punches, or even for blanking and forming dies used in double-acting presses, they

require an extreme hardness. For most work the tool steel used in making punches and dies should be of a good quality. A die or punch that has cost from fifty to one hundred dollars for labor is as likely to crack when hardened as tho the same steel had been made into any other form of tool; because of its shape and irregular thickness of stock at various points, and because of the numerous sharp corners that are likely to be present, it is a tool that requires extreme care in handling when hardened. A good grade of tool steel, either oil-hardening or a high-carbon tool steel free from harmful impurities, is less liable to fracture than an inferior grade, and the slight difference in cost is offset many times by the cost of labor in the die or punch construction. This does not mean that a high-priced steel must be used for this class of work; simply a good quality of steel, low in the percentage of any of those impurities which cause trouble when the steel is hardened. When we speak of good reliable steel, we do not necessarily mean a high-priced steel.

In the construction of some dies a saving may be effected by making the body of cold-drawn steel or even cast-iron and inserting bushings of tool steel; then if at any time the dies become worn they can be replaced simply by making new bushings, and if ordinary care is taken, the holes will be concentric and consequently the correct distance apart so that there will be no necessity of altering the location of the punches, as might be the case if a die made of a solid piece of steel were hardened.

As for irregular-shaped punches that are to cut thin stock, make them of machine steel and case-harden them. Soft steel, case-hardened, does not change its shape or form as much as some tool steel not given proper normalizing and heat treatment, and even if the punch does change slightly the interior is soft and can be readily forced back into position. Since the outside is hard, the punch will wear nearly as long as one made from tool steel, for practically the only wear that occurs on a punch occurs when it is passing through the stock. For thin brass the punch works well when made of tool steel and left soft; when worn badly the punch can be peened on the face enough to upset it and then be sheared into the die.

Many die makers overlook the importance of first roughing the die and punch nearly to size before normalizing them. Internal strains occur in the bar of steel during its manufacture which are sure to cause distortions of the die or punch unless these strains are removed before the work is brought to its finished size. Some steels may be free from strains, but there is no way of determining beforehand whether the steel has settled or not; therefore,

to guard against distortion, the careful die maker will not take any chances, but will anneal the piece after it has been roughed out, to relieve these possible internal strains.

Tempering — A very common method of drawing the temper of dies and punches and similar pieces is to heat a piece of iron or an old die block to a red heat and place the hardened piece on it, leaving the face of the piece uppermost. Experience has shown, however, that this method of treatment is too harsh for hardened steel, especially when the work is in the hands of one not thoroughly experienced, for it subjects one side of the work to an intense heat while the opposite side is exposed to the cooling effects of the air. When an open fire is used, a plate may be set on the fire and the die or punch placed on the plate before it is hot. The temperature of the plate may be raised gradually, the die being turned occasionally. In such a manner, the temper is drawn to the desired degree with safety. If such a fire is not available, two plates may be employed, one heating while the other is in use. The first one should not be very hot, the next somewhat hotter, and so on until the die or punch is drawn to the desired color.

When a die to be hardened is of such a shape that it is likely to give trouble, much more satisfactory results will follow if the pack-hardening process is used as described in Chapter VII. Run the dies in the fire from one to three hours, and after the specified time, dip them in raw linseed oil, back and forth, to force the oil through the openings. Dies with openings having perfect circles may be left a trifle small. After hardening, they are ground to size either on a lathe or an internal grinder.

Forming Dies — Notwithstanding the fact that forming dies are extensively used, there has been a lack of definite information pertaining to the fundamental principles and rules governing the drawing and forming of sheet metal. This is doubtless due to the fact that the exact method of designing and constructing a forming die depends to such a large extent upon the nature of the drawing operations. It is doubtful if any branch of die making requires more experience than that which has to do with the drawing and forming of sheet metal. The following outline of information on this subject is very incomplete; still, the practical problems that are frequently encountered in actual practise are covered; and in any case the reader, when taking up such work, should consult men who have had actual experience, for it will be difficult to find the necessary information in books.

When a forming or drawing die is to be made for producing a cup, skill must be exercised by the operator to determine what form or type of die will give the best results, what diameter of blank would be required to produce a part of the required form and depth, and whether one or more operations are necessary.

Clip Hand Guard—The subjects given here are parts that nearly all riflemen are more or less familiar with, and you can understand what an important part die construction is to even the fire-arm industry, even tho we do not see some of the parts or are not aware that dies were used to construct these pieces. The form of the finished part and the developed blank are described, but to show the design of dies used would be folly, for no one would be able to produce such parts for a profit. They could only be used for an experimental subject in a technical school teaching die construction.

Figure 34 illustrates a hand-guard clip as used on a Springfield service arm together with the developed blank. This part only requires two dies,

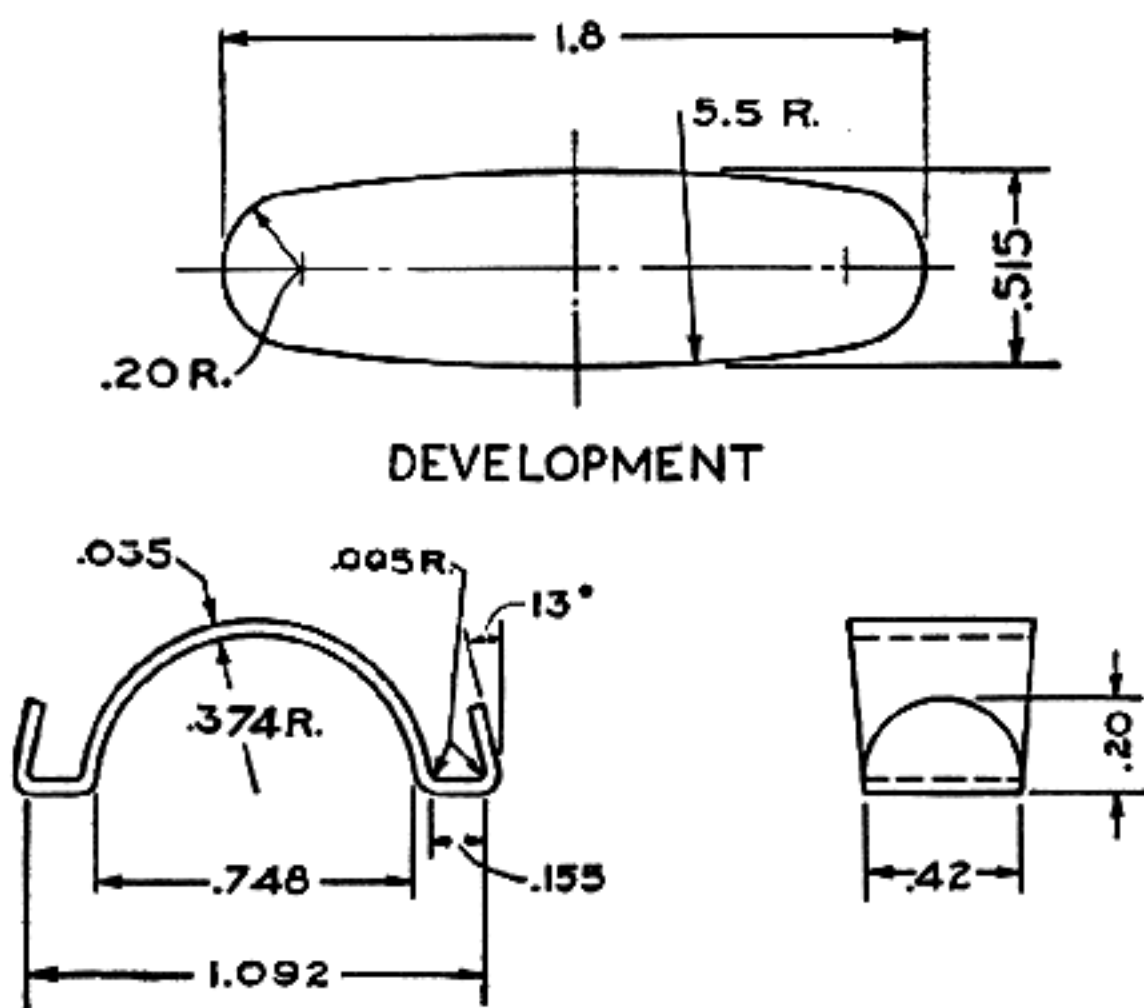


Fig. 34

Springfield hand-guard clip. Two of these clips are used to hold the hand guard in place

the blanking die and the forming die. The design of the forming die for this part is of a type in which the blanks are placed over a form at the bottom and the punch takes the opposite form. Dies for this class of work are designed for forming such parts in different ways. Since there are 12 degrees on the ears of the clip, these must be formed over a greater angle on the punch in order to take care of the spring of the metal. The inside punch must be floating and controlled by the action of springs, while the outside punch forms in the ears to the

correct angle. When the stock to be formed is elastic, such as spring steel, the part is bent slightly beyond the required angle to compensate for the backward spring when the pressure is released. To determine this allowance is, of course, a matter of experience; at times it is controlled by the pressure exerted by the adjustment of the press. The center of the blank has a $\frac{1}{16}$ -inch hole punched in the center; it is placed in this position for locating while forming. A small pilot punch must be placed in the center of the upper punch to hold the clip in position while it is being formed.

While it is possible to make this piece in one operation, two would be advisable to simplify the construction of the die. In this case it is possible to make the clip in the same die block, changing the piece from one operation to the other, which action also simplifies the stripping of the piece from the punch. The ears would be formed first in the right-hand side of the die, and the radius would be formed in the left-hand side; therefore it would be more simple in form and less expensive to make. It is also necessary to provide guides and stops to locate the clip properly. If the stock used in making the pieces is a high-grade spring steel it must be hardened and tempered. It will be found necessary to relieve parts with a radius where the bends occur, to prevent crushing or disarranging the grain

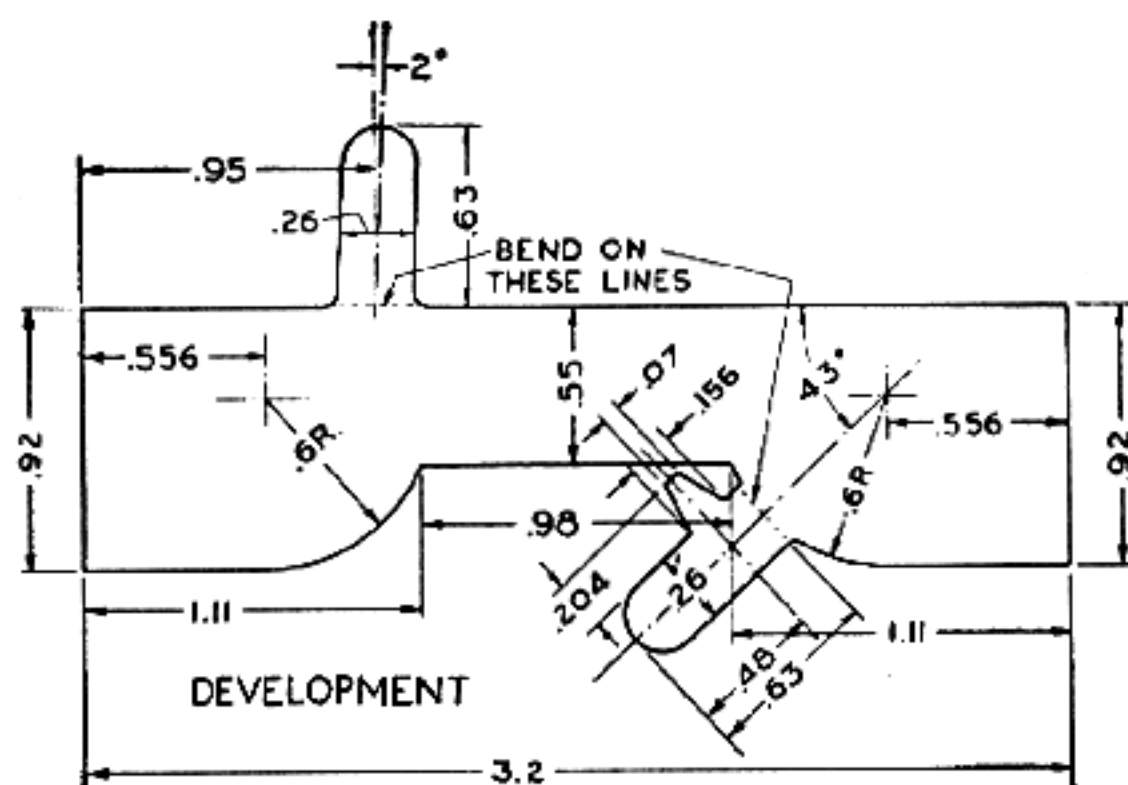


Fig. 35

Springfield front-sight guard or cover

cut from the stock to be formed. If setting a die for a piece in which the bends are not parallel but off at an angle, the practical method is to locate it approximately with the blank and slightly tighten the screws in the press bed; then, with tin strips of metal the same size as the blank, gauge the exact distance, after which the die can be secured to the bolster. Do not assume that a die is certain to be satisfactory when the samples have been produced by bringing down the press by hand very slowly. There is sometimes variation in what the tools will do when operated by power and when operated by hand.

Pressure Pads — Three separate means of controlling the pressure on the die pads are air, rubber, and springs. The first is the most satisfactory for securing the correct pressure on forming dies. The rubber pads used on various types of forming dies for supplying the necessary pressure to the die pad or blank holder should be of a circular form measuring between 5 and 6 inches in diameter. A hole should go through the rubber so that a long bolt may be fastened to the bottom of the die. A large steel washer should go next to the die, and then the cylindrical rubber pad; another washer and then a nut to tighten it against the die. Various pressures may be applied according to the amount the nut is tightened against the steel plates. Pins are located in given circles, which are usually made of drill rod and rest on top of the plate over the rubber pad. The length of the pins should be just so the top of the die pad comes flush with the top of the die, so that the punch will have action as soon as it comes in contact with it. Small sections of rubber are also built up under the die pad or blank holder. One advantage of the small sectional forms is that they will not settle and lose their resiliency like the larger piece of solid rubber, because the small sections are of better quality. The rise of section also makes it convenient to build up the pressure pad until the required size is obtained. The section can be utilized on different dies, but it is always best to have a piece of 1 inch thickness of flat rubber for all new dies. Rubber is also used for the top knockout pad where it is not possible to use the standard knock-out in the center of the ram.

Cartridge Clips — Every one is familiar with the cartridge clip which is made to clip the Model 1906 cartridges used in service for the Model 1903 Springfield and Model 1917 rifles. A multiple plunger press is designed to perform the six operations on the clip by means of a series of simultaneous operations. A complete body is produced at

every revolution of the press. These presses are constructed in various styles and sizes, the number of plungers ranging anywhere from three to eight.

The spring which is put into the clip to lock and hold the cartridges in place is made from thin spring brass, which is shown in Figure 37. The forming of the spring and piercing of the locking ears are done in one operation, and when the clips and springs are finished they are assembled in a

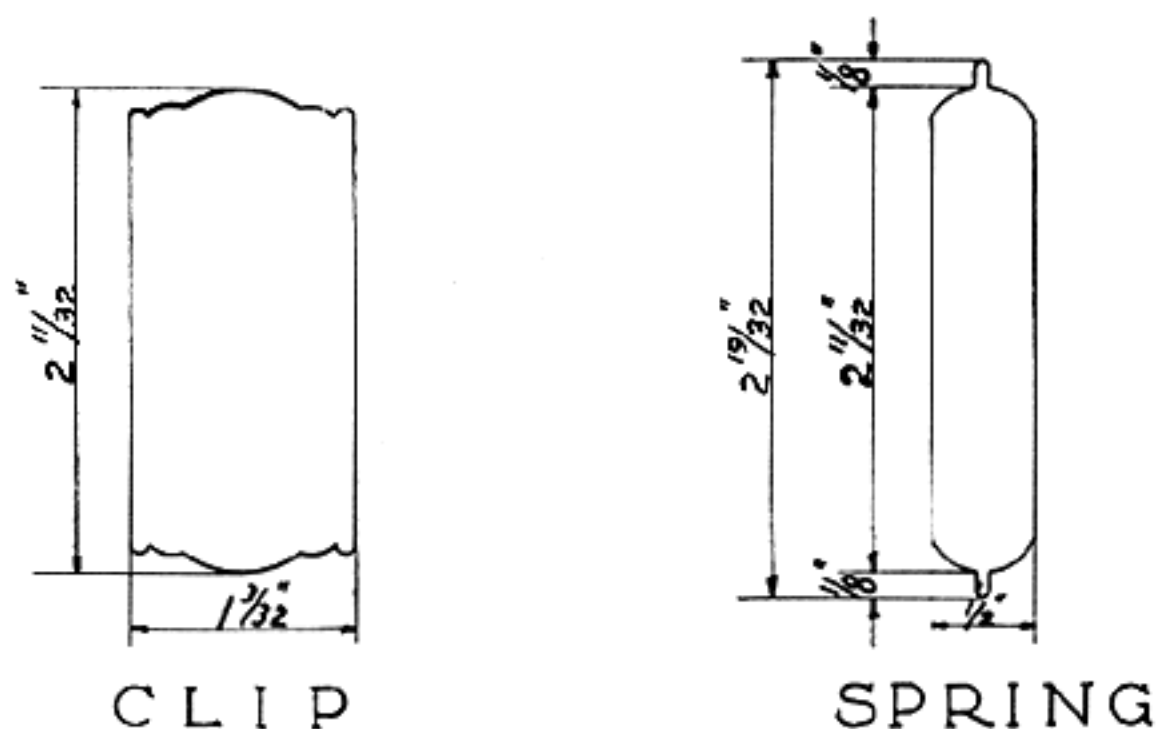


Fig. 37
Cartridge-clip blank development for the caliber .30 Model 1906 cartridge, showing clip and spring

special machine for this purpose. After they are assembled they go to a cartridge-clipping machine where five cartridges are clipped and the small ears at the end of the spring are turned over to hold the cartridges in place.

Figure 37 illustrates the blank for the clip as the first operation makes it on the multiple press. The blanking plunger is set one-half revolution in advance of the other plungers, so that the blank, after it is cut, is carried by the transfer slide over the first forming die before the plunger descends. This is accomplished by changing the position of the cam controlling the operation of the blanking plunger on the upper cam shaft in relation to the other cams. The plungers are operated by horizontal lifters, one lifter being provided for each plunger. These lifters are connected to rods, and knee pieces which connect the rods to the plungers effect their operation. The usual form of wedge adjustment is provided for increasing the pressure of the plungers, the adjustments being effected by means of wedges which lower or raise the bumpers as desired.

The clip is brought under each forming die until the six operations are completed; then the clip falls out into the truck. To give complete details of all the dies used to produce the clip and spring would require too much space; such an operation should go into a separate book on die work. This die-forming operation, however, will convey to the

reader what is accomplished in the manufacture of parts to make up the needs in the use of a firearm. The drawing of cartridge cases from sheet brass requires some very interesting tools and methods, as well as the bullets used with a cartridge case which will be described in future chapters.

Presses and Feeds — Power presses for producing articles or parts made from sheet metal have become a highly specialized business. In addition to the economy of more rapid production, the application of automatic feeds to power presses assists in protecting the hands of the operators. More men are made cripples in this work than in any other where machinery is used; therefore, whenever possible, power presses are equipped with devices for automatically feeding the strip flat stock or blanks to the dies. Cartridge cases involve highly specialized work, and automatic feeds are provided on all machines so that an operator never touches the case to feed it into the machine. The types generally employed for such machines are the single and double roll, grip, gravity, push dial, and reciprocating feeds. The operator only has to keep the machine constantly supplied with the metal from which the punchings are made.

Butt Plates — The power press selected for the small shop where a number of operations are to be performed should be large enough to take care of any of the work shown here. Most of the parts used in the manufacture of rifles or shotguns are small; therefore a large press is not needed, but one with good die clearance should be chosen. As an instance, the butt plates shown in Figure 82, Volume I, are the largest stamping produced and the largest pieces made in the manufacture of firearm parts. The blanking die is made reverse, the punch being secured to the bottom shoe, while the die is fastened to the top pad. Two punches are placed in the proper location for the screw holes and a knock-out is used to eject the blank from the die by a mechanical means as the press ascends. Since the punch is of the correct outline of the blank, two holes are drilled and taper-reamed from the bottom of the punch to pass out the punched slugs. There is usually a 4- or 6-inch round hole in the center of the bolster plate for the passing of stamped parts or various other purposes. If this is not provided, parallels should be fastened on the bottom of the die shoe between the slug holes—large enough for the slugs to be removed at will. A scrap stripper encircles the punch to remove the scrap stock of the punch by means of rubber or springs.

After the blanks are stamped out a forming die

is made to give the butt plate the exact contour both in width and length and at the same time to turn up the small pointed ear at the heel of the plate. This forming die is one of the most simple to construct, as the die is made to the exact outlines of the plate and provided with a pressure pad. The punch is made for the inside form of the plate; consequently when pressure is provided with air or rubber, the plate is in position and when it strikes the bottom of the die shoe the exact form is produced. The pressure compresses the air cylinder or rubber, and the pressure pad returns to its flush position to remove the formed plate; then another one is inserted.

Pistol-grip Caps — Because of the similarity in operations, a pistol-grip cap is made the same, except that a grip cap will have ragged edges caused by the deep draw and form; therefore, a trimming operation must occur after the forming operation. There are two methods which may be used; one is to make a blanking die near to the required size; the second, which is practised extensively, is to shear square blanks from the desired thickness of material and form them, allowing only enough material on the sides to trim after the form is made.

A trimming die is made similar to a blanking die, except that a pressure pad is made and the caps are trimmed upside down. The form in the pad is similar to the pressure-pad form used in the forming die. An outside stripper encircles the punch to remove the outside scrap, and since a rubber is used to control the pressure pad, the trimmed cap is returned to the surface to be removed by mechanical means or with a knock-out in the operator's hands.

Correcting Mistakes in Dies — Should the die maker, through misunderstanding or carelessness, make the opening in a die too large at any point, he should not attempt to peen the steel cold. I have often seen this done, and while it is possible to do so and then finish the surface in such a manner that it will scarcely be noticeable, the tool steel directly below where the peening took place will almost surely crack at some time during the life of the die. Should the mistake referred to occur, heat the die to a red heat, when the steel may be set in without any injury whatever. When setting in, a regular peening punch is used. If there is any objection to disfiguring the top surface of the die, this method cannot be used. It is never good practise to bend, set in, or otherwise alter the form of the steel when cold if it is to be hardened, as such attempts nearly always end unsatisfactorily.

When a die becomes so worn that the openings are too large or the top surface near the edge of the walls of the opening are worn so that the die is "bell-mouthed," it may be heated to a red heat, set in with a large-sized peening punch or a punch of the desired shape; after this it should be annealed, which necessitates reheating. After annealing it is reworked to size. This reworking, when care and judgment are used, gives excellent results; it also effects a considerable saving, as otherwise it would be necessary to make a new die, while the die may be reworked at a fraction of the expense of a new one.

Punch Troubles — Small piercing punches which have annular marks left on them from turning or polishing are much more liable to fracture than those having marks which run parallel with the punch, especially when perforating heavy stock. This is due to the fact that the metal presses into the minute lines left by the turning tools on the lathe, thus increasing considerably the force required for stripping. As is generally known, most punches when used on heavy metal are broken while in the act of stripping the stock and not when piercing it; consequently, the stripping should be made as easy as possible. The stripping may be facilitated by turning the punch slightly tapered toward the top, but this is not practised on small punches because the strength of the punch would be reduced too greatly. If a stripper plate is not parallel with a die, it will also cause broken punches. Even tho the error in alinement is small, the constant bending action that the punches must undergo every time the stock is stripped tends to shorten their life.

The making of small piercing punches requires attention to the most minute details in order to secure satisfactory results. It sometimes happens that the blanking punch or certain piercing punches are of such a shape that they tend to incline to one side and cause shearing when passing through the metal, thus injuring the edge of both punch and die. This is caused by the shearing thrust not being equal on all sides. For example, the shearing strain from two long sides sometimes crowds the punch over toward the shorter side. To prevent this the face of the punch should be ground to a slight angle so that it enters the shorter side first; then this side will be backed up by the die to take the thrust when cutting the remaining part of the blank.

When a die has a number of punches or even three or four, some very small punches and even some large, it is often advisable to make the large ones $\frac{1}{32}$ inch longer, or long enough to pierce the

material and just enter the die before the small ones touch the metal, especially when the stock is heavy. It is also advisable to drop the punches below the die surface or the thickness of the material so that the blank will be well supported before the punches take effect. It is also necessary to place a slight shear on small punches, facing the long part of the blank. The small angle ground should be both ways, allowing the punch to be high in the center. On large punches the shear should be four ways. Figure 33 illustrates the two methods, together with a shear on a die.

Stop Pins — The stop pin on a die is a device for controlling the position of the stock as it is fed through for each successive stroke of the press, so that the spacing of the openings cut in the material will be uniform and a certain distance apart. The design and adjustment of stop pins for blanking dies is an important point to be considered, for it affects both the quality and quantity of the output of a press. There are many different types of stop-pins, such as the plain fixed stop-pin, the bridge stop-pin, the simple latch, the spring-toe latch, the swing latch, the positive heel-and-toe latch, etc. These devices, with the exception of the first, may be used with either hand feed or automatic roll feed. The ideal output of one blank for every stroke the press can make in a day is never realized with single dies; delays arise from many sources, and they have to be eliminated so far as they contribute to unnecessary expense. In addition to improper design and poor adjustment of stop-pins, other causes of poor output are: lack of skill, inconvenient arrangement of the new material, the blanks and the scrap, inefficient methods of oiling the stock, and poorly made or poorly designed dies. A skilful operator will usually arrange the material distribution very well, but the design and the adjustment of the dies together with the stop-pins generally fall upon the die maker.

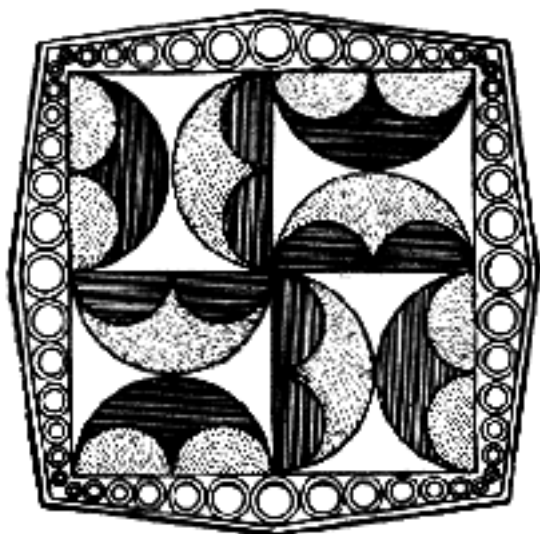
The use of dies in the manufacture of rifle accessories can often be turned into profit by the owner of a small shop. It gives a profit not only to him, but also to those who are seeking knowledge in the construction of tools to work sheet metal to the best advantage. Study most of the articles sold by a hardware store and count the number made by die work; also disassemble some of our cheaper arms, and you will be surprized to find how many parts are made by dies, making it possible for the manufacturer to place the product on the market at a price to suit the man or boy with only a limited sum to spend.

Throughout this chapter suggestions have been offered to illustrate the possibilities in die

and to convey to the reader their part in the making of firearms. It may seem useless to many to study die construction and its details, but probably such information will create new ideas in the mind of the young mechanically inclined person. A gen-

eral knowledge of die construction, broad enough to make one familiar with those features which have proved successful in firearm construction, may be acquired by studying as many different designs as possible.

CHAPTER V
Whims and Fancies
in Firearms



Whims and Fancies in Firearms

PSYCHOLOGISTS tell us that the best way to get something we want is to concentrate on it. This doesn't mean assuming the pose of The Thinker or waiting for a genie to drop the ideal gun into our lap; nor does it mean to isolate ourselves from friends and family, and pore over books and catalogs. And above all, do not say, "I cannot afford this gun because I or we are going to need this money next year"; instead, think and act positively. Spend for your hobbies now, and determine to make more money next year, for hobbies are just as important to our success in life as anything else. To hit a target you must see it; to arrive at any point, you must keep your eye on it, and make a course toward it in as straight a line as your eye follows to the black of a bull's-eye.

A gun is made to be used and for the purpose intended. Exclusive reasons prevent me from giving unfavorable or even favorable opinions concerning arms of various makes; moreover, arms are selected from personal choice, and not from the standpoint of deserving merit. Any one choosing a firearm must select it from the related equitable precedent.

The difficulty of determining merits of the modern rifle or shotgun which is offered to the buying public may be judged only after an analysis of the descriptive catalogs issued by the various arms companies. The inexperienced person who contemplates providing himself with a rifle or shotgun may well be excused if he find himself lacking sound knowledge in attempting a decision. If in his confusion he seeks the advice of others whom

he believes familiar with the subject, it is altogether probable that they may add to his confusion; very few men have opportunity for making comparative tests of a variety of arms. He will in such case naturally decide upon a gun whose particular adoption is most strenuously urged.

To begin with, the prospective buyer today will find a large choice of excellent arms, and keen competition is a guaranty that for the present a high standard will be achieved. Materials and workmanship may be depended on to maintain the public's confidence. Cheap arms only satisfy a certain demand, and the true gun lover will soon or late understand that "he only gets what he pays for." Perfection in all details can be obtained only in the best-quality arms, and it is for the individual to find it in a specially made-to-order weapon. It cannot be expected in a factory product.

In attempting, however, to give some practical suggestions which may be a service, it may be best to confine myself to the explanation of various principles whose application may be the chief desiderata.

If a gun is for target shooting with the greatest possible precision, nothing is so desirable as the .22 rifle for the beginner. There are so many good arms of both foreign and American make that it is best to study the various ones from observation at some of the large meets such as those held at Sea Girt, New Jersey, and Camp Perry, Ohio. All kinds of rifles and special barrels can be found in the hands of some of our experienced target shots.



Fig. 38

Model 52 Winchester caliber .22 rifle: original stock remodeled; barrel cut to 24 inches; muzzle reduced to 0.56 inches. An ideal arm for the woods

When a rifle is to be constructed, the first consideration is weight and striking energy of ammunition, and this is a question as old as the development of high-velocity arms. A gun's principal function is to strike a blow on an object, and, as a general rule, the heavier the striking energy of a bullet the more efficient will be the weapon. The sportsman in selecting an arm must choose between the labor of carrying it and the efficiency of the arm itself when fired. He must consider the importance of relation between rifle, weight, and striking energy of the most popular bullet.

A double rifle can be fired with two quick shots, either both barrels together, or one shot following the other with lightning speed so as to make the second shot almost as good as the first. The design of such a rifle supersedes the magazine type, and in proportion to striking energy and weight has the energy of two bullets. The design principle of a double rifle has given way to the over-and-under development seen in our best shotguns. This was a fancy based on sound judgment.

Before a description is attempted of the methods of calculating the pressure and velocity of a given combination of rifle and cartridges, let us carry ourselves afield and understand the relation between location and other factors. Choice of an arm must always depend first on the type of animal you expect to shoot, second the country you are going to hunt in, and lastly, on principles of experimental methods.

Big game animals can be placed in two general classes: dangerous and non-dangerous. The dangerous game can be subdivided into two classes: thick-skinned and thin-skinned animals. All non-dangerous game is thin-skinned. As far as the big game shot is concerned, we have these classifications of animals: dangerous thick-skinned, dangerous thin-skinned and non-dangerous thin-skinned. I am inclined, however, to place elephants in a class by themselves.

The usual range of long shots—that is, long shots from the sporting point of view—will be, as a rule, anything from 50 to 300 yards; in rare cases it may be more. However, I always place 300 yards as the normal limit at which sporting rifles should be sighted. The game usually found on a long-range shot is of the non-dangerous thin-skinned sort, and consequently great weight of metal is not of primary importance. In this form of shooting the chief difficulty is that of judging distances, and for this reason a flat trajectory is a desideratum in any suitable rifle. On this account your choice should fall either on the .30-03 or a magnum small bore, where the flatter the trajec-

tory the better. A flat trajectory naturally demands a very high muzzle velocity, and for this reason a rifle developing a muzzle velocity of over 2900 feet per second should always be chosen. It is a mistake to sacrifice bullet weight wholly to velocity, as a very light bullet breaks up all too easily when it strikes a bone; 150 grains is the absolute minimum limit of safety. In saying this I am not forgetful of some of the latest cartridges, in which an 87-grain bullet is discharged with a tremendous velocity. A price must always be paid for velocity, however, and it is safer to decide in favor of a bullet of 150 grains or over, and a velocity from 2750 to 3200 feet per second. Such a combination will provide trajectory to bring the line of sight so close that the bullet is nowhere above or below it for more than 2½ to 3 inches up to a range of 200 yards, and even at 300 yards the drop will only be 7 inches. This trajectory is as flat as one would want, and it is provided by a weapon which is handy to use and very efficient against game.

Contrary to general opinion, I am not a great believer in an extremely light rifle in the magnum class; but naturally this aspect of the matter must depend largely on individual physique. In countries where one has to carry one's rifle oneself this point must be considered well, for an 8½ to 9 pound rifle is found a detriment at the end of a day's hunt. One should choose weight of arm as well as other factors, so the first essential in the rifle is that it should be well within one's strength to carry all day and every day. Men vary in physique, and on this account it is impossible to lay down any rigid rule. It must, however, be remembered that a gun which seems light and easy to carry and handles well in the gun shop, may seem heavy and leaden when tried out after many hours of tramping in an open range country where the sun may be as hot as in a tropical climate. For this reason it is always better to "under-gun" than to "over-gun" oneself, because the majority of men shoot better with a rifle well within their strength at the time when they want to use it.

After weight the next question to be considered is stopping power. Game may be both heavy and dangerous, and on this account plenty of weight in the bullet is essential. Here I regard 220, or better still, 250 grains, as the lightest weight to be used, and the more the increase over 300 grains the better, from the point of killing power.

Since shots are very seldom taken at over 200 yards, a very high velocity is not necessary. In fact, it is so far from being unnecessary that it can be regarded as a mistake, because high velocities are only obtained at the expense of bullet

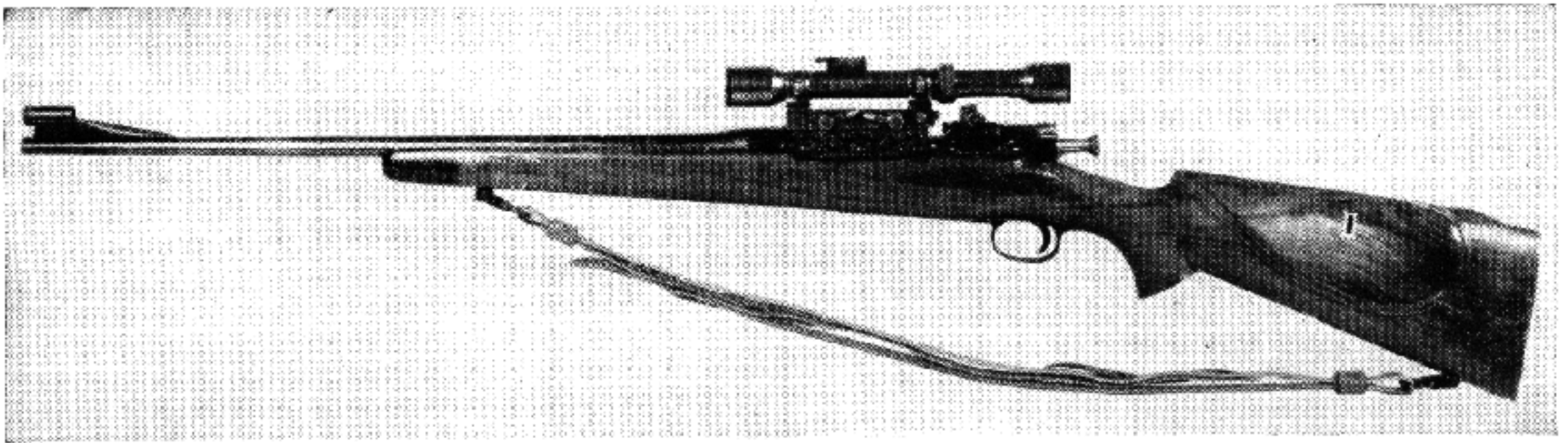


Fig. 39

Caliber .30 Model 1903 Springfield, remodeled. An ideal arm for the North American Continent, designed for Mr. William Palmer, Jr.

weight. There has existed in my mind for years the belief that the whole tendency in recent development of sporting arms is too strongly in the direction of velocity at the expense of bullet weight. In the United States, or even Africa, a velocity of 2100 feet per second to 2400 feet per second is high enough.

Many men are using the wrong rifle or even the wrong ammunition, and have chosen thus from unreliable recommendation and alluring advertisements. The sportsman who would do real hunting should accustom himself to one good gun. Study it thoroughly until you know just what can be done with it under different conditions. Since the government's admirable development of the Model 1906 ammunition and the cartridge companies' development of suitable game bullets, we have some highly commendable cartridges. Some day some one is going to make a flanged cartridge case in the .30-06 class adaptable to the over-and-under principle of design, and light in weight, and then a perfect combination of cartridge and rifle will be born, adequate for any game roaming the North American continent.

The question of weight and balance will arise in some minds. The weight of any rifle consists mainly of the metal used in its construction. The composition of the metal used in barrels is made for the purpose of resisting the high pressure of the explosion. The powder in the cartridge is expanded in every direction except one—directly forward. The crushing expansion is divided between the action and barrels. The mechanical design of any well-made receiver keeps the breech securely locked; that in the barrels not only confines the gases from the powder, but decreases in proportion to length of barrels until all energy is absorbed by the bullet. Such a force directs the course of the bullet. A very important consideration then is barrel construction in the direction of

strengthening to such a degree that it will not cause undue inaccuracy under pressure.

It is very surprising to know how little metal is required in a barrel, except at a given distance from the chamber, to prevent undue expansion. A wall thickness of $\frac{1}{16}$ inch can be made at the muzzle and still hold its form. This is only in the nature of an experiment and not recommended in good barrel design. Fifty thousand pounds' pressure per square inch or more may develop at the breech, but at the muzzle it reduces itself to less than 10,000 pounds per square inch. Since this is an established fact, we must turn to recoil. One object of weight in a large-caliber rifle is to take up a portion of recoil, and as added weight absorbs this, it prevents undue body shocks under fire. In barrels of ordinary design in firearms the highly developed steel far surpasses the necessity to withhold the bursting effect of the developed charge, but because of the design adopted they are all made alike; those who purchase one must accept a standard product.

The modern sportsman who chooses wisely and who goes on a hunting trip each year in Canada, the United States, or Mexico, will be interested in the following arms:

A caliber .30 rifle using the Model 1906 cartridge for bear, elk, moose, mountain sheep, mountain goat, and caribou. Weight about $7\frac{1}{2}$ pounds, barrel length between 22 and 24 inches; 22 preferred.

A 6.5 or 7 mm. rifle made on the Springfield or Mauser action, for deer. Barrel length between 21 and 23 inches. Can also be used for bear, mountain lion, etc.

A Model 1903 Springfield sporting type of rifle equipped with aperture and telescope sights for target shooting.

An M-1 .22-caliber Springfield or Model-52 Winchester for the same purpose.

A repeating .22-caliber rifle using the .22-caliber long rifle cartridge for squirrel and other small game.

A single-shot rifle of high velocity, such as the .22 W. C. F., known as the "Hornet," or the .25-20 W. C. F. cartridge for groundhog, crow, turkey, prairie dog, etc.

A 20-gauge shotgun for birds and small mammals; also a 12-gauge shotgun for duck and geese.

For revolvers, a .22 and .38 caliber special for target work, both guns made on the same frame, preferably by the same maker.

All these guns may be considered absolutely essential to the full enjoyment of the sportsman. Altho some may be made to do the work of others

with more or less unsatisfactory results, the rifleman can carry but one at a time; still he will often wish he had one of the other guns. Excellent shooting is usually the result of selecting one gun, utilizing it to its true efficiency, and not collecting a multitude of arms which prove worthless in the end.

This can be true only to a limited degree and

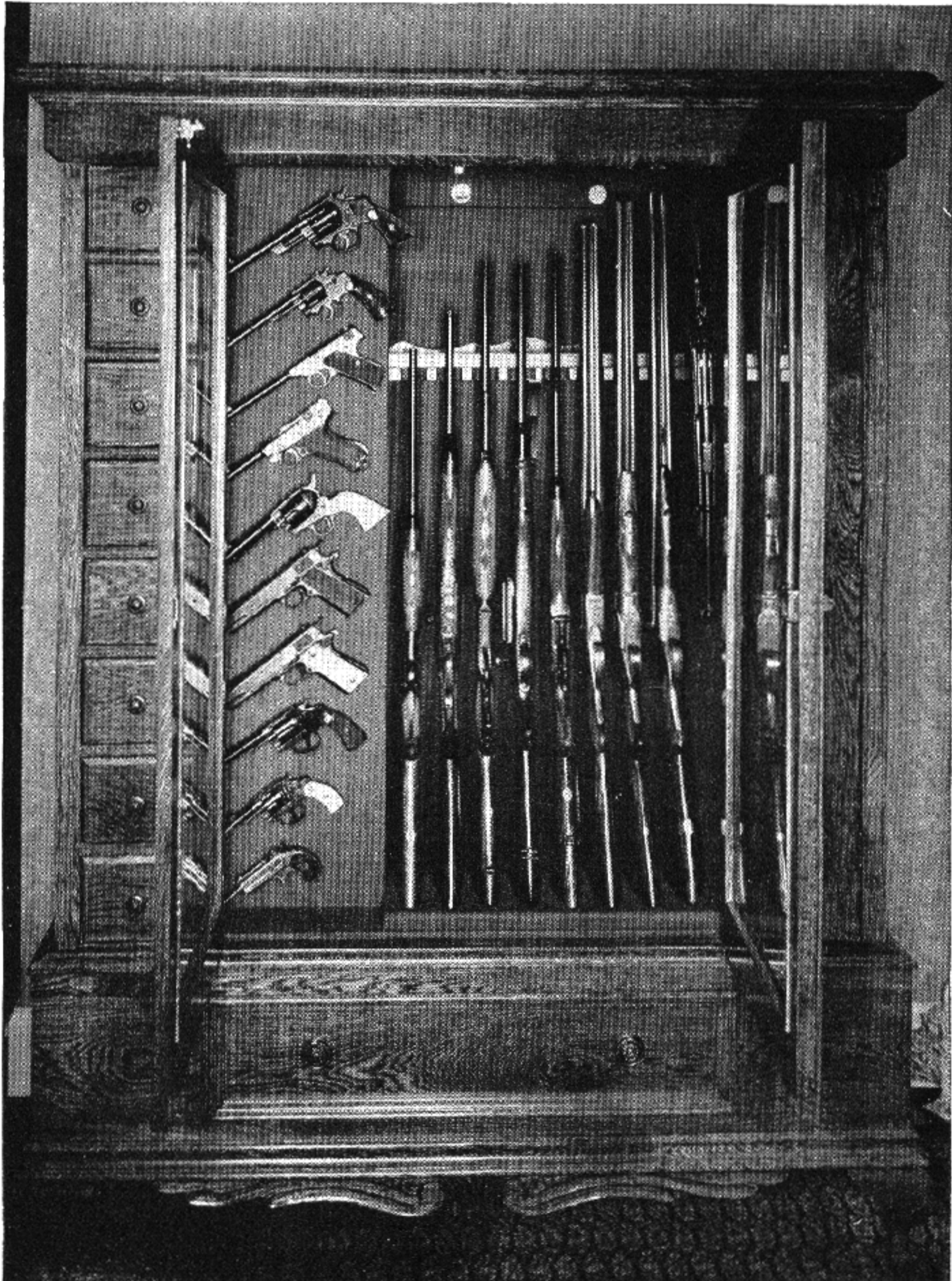


Fig. 40

Gun cabinet designed by Mr. Lee D. Elliott. Entirely constructed of oak. Note the two electric lights above the rifles and shotguns

requires an explanation. Should an experienced rifle shot or marksman take an arm to which he is unaccustomed, that is, before he learns the true relation of its line of sight at a given range, he can not expect to do any remarkable shooting. However, it is easy to aline sight settings by a little practise, and having done so, he may very soon decide the accuracy of the arm. Any experienced rifle shot, by firing a few rounds from an elbow and muzzle rest, can satisfy himself and others as to whether an arm shoots true and uniform groups. If the shots strike all over a hundred-yard target, it is evident that the rifle is inaccurate. I have often tested beautifully finished

ume I, the reader has learned that it is a matter of securing a direct understanding of the correct "stance" in a testing trial of a gun and its stock.

It is much better to have a stock too long than too short, or a comb too high rather than with too much drop. In either case alterations can be made which are not difficult. If the stock is entirely too long it can easily be reduced with the use of a hack-saw, and the old butt plate refitted. If the comb should be too high, any one can take a fine wood rasp and a mill file and reduce the height of the stock until the line of sight is directly parallel with and at the proper height above the sighting plane. But if the reverse condition should exist, a



Fig. 41
A Parker Brothers shotgun

arms whose attractive appearance would persuade the inexperienced person to add them to his collection. After testing such weapons it was impossible to keep all the shots in a 12-inch circle at 100 yards, and it is needless to add that such arms are only for collections. I have learned to be wary of very ornate arms having no maker's name.

Stocks — The question, "How do I know when my gun fits?" is as old as gun history. There are many men today who do not know the answer, and it is for their benefit that books like these are written. From having studied Chapter VIII, Vol-

rubber recoil pad can be fitted to lengthen the stock. To secure a higher comb, it must be built up, and this is not so easy.

If in your aiming test you have noticed that the line of sight passes to the left of the rear sight or favors the left side of the sighting plain, the stock needs more cast-off; or if the comb is full and well rounded it can be made much narrower with a file. This will be a necessity in most instances where the angle of one's jaw is full and the cheek rather fleshy.

I am of the opinion that a person whose face is of the average proportions, and full, needs no cheek piece; but one who is building stocks cannot al-



Fig. 42
Special 12-gauge Greener trap gun made on a heavy Martini action

ways dictate to a customer who admires a perfectly symmetrical shape and the ease of holding it. With a stock having too thin a comb or too much cast-off the rifleman loses that feeling of security and confidence that a full well-rounded comb gives. Contact at the comb gives a positive guide to uniform elevation and eliminates one of the faults of gun pointing, frequently the cause of wild shots in an otherwise good target.

Fancies originate not so much from the standpoint of factory production as from the ideas of men who study the subject from guns in their collections. These collections are quite costly, and especially so is the experience before one learns proper selection. To get acquainted with various makes of arms, be a frequent visitor to a well-stocked gun store; not so frequent that you become a pest, but be a keen observer. Catalogs from the various makers will also help you decide about your particular fancies.

Ammunition — Every hunter worthy of the name has probably had the high-velocity or speeding-up-the-bullet idea. Wisdom born of proper training in the game field, however, leads in a contrary direction. Many men who have a fancy for high-velocity ammunition will soon or late come to the conclusion that, with present bullet construction, velocities cannot be greatly increased; for then it is impossible to make the most reliable kills. Trajectories, of course, are straightened to a certain extent, but our kills are only at short range — no greater in most instances than 200 yards. If we are fully to utilize the tremendous velocities now possible with modern military powders, new forms of bullets must be designed which will stand up under greater pressure and equal the killing power of our present design in round-nose bullet form. When velocity is increased, the jacket must also be increased in proportion, so that it will not fly apart upon impact with animal tissue or heavy bone.

Tests of bullets on $\frac{7}{8}$ -inch pine boards or other material such as brick, rock, etc., explain very little. Make a survey of the development of sporting-rifle ammunition in the United States since 1920. We find that, with very few exceptions, the manufacturers have wisely refrained from flooding the market with too many new types of bullets. Greater development has been seen in powders, non-corrosive primers, gilding or copper-alloy bullets; this sooner or later will lead to better-designed projectiles.

Some men prefer to spend their money on almost anything rather than a good rifle for themselves, with which they could not only enjoy the sport

with good kills, but at the same time arm themselves with a reliable instrument of defense in a time of need. On the North American continent things are very different from what they are elsewhere, where one must choose the perfect combination, making the proper selection of ammunition first and then the proper rifle to use it in. We can travel from one end of the world to the other and find a vast number of obsolete arms in use, none of them made for their present uses.

Sights: Telescope and Metallic — To choose a sight is like deciding on stock measurements. In this instance, however, it is the eye that must be fitted instead of the physique. A good telescope sight has certain advantages over open or metallic sights, according to the purpose of design. One of the main advantages of a telescope sight is clearness of vision and accuracy of aim, provided one is a good holder. The first of these are clearly and easily demonstrated. A hunting telescope should be of low power. A low-power glass of the most finely ground lenses will give a clearer vision in all lights than ever possible with the naked eye, and naturally a brighter vision in poor lights. A telescope sight is a fine aid to good shooting and better yet when applied to a sporting rifle used in an open country and at long ranges. To select a telescope without reliable mounts is defeating the purpose of the telescope; or if suitable protection is not provided for transport of the telescope it is just a useless expenditure of money. Never rely on a telescope alone on any rifle; suitable metallic sights should also be provided. Apparently some men wish all their sights on their rifles at once, such as the telescope, open, and aperture.

Sights for a target rifle include telescopes and aperture for both front and rear. The person who purchases a telescope is very anxious to procure

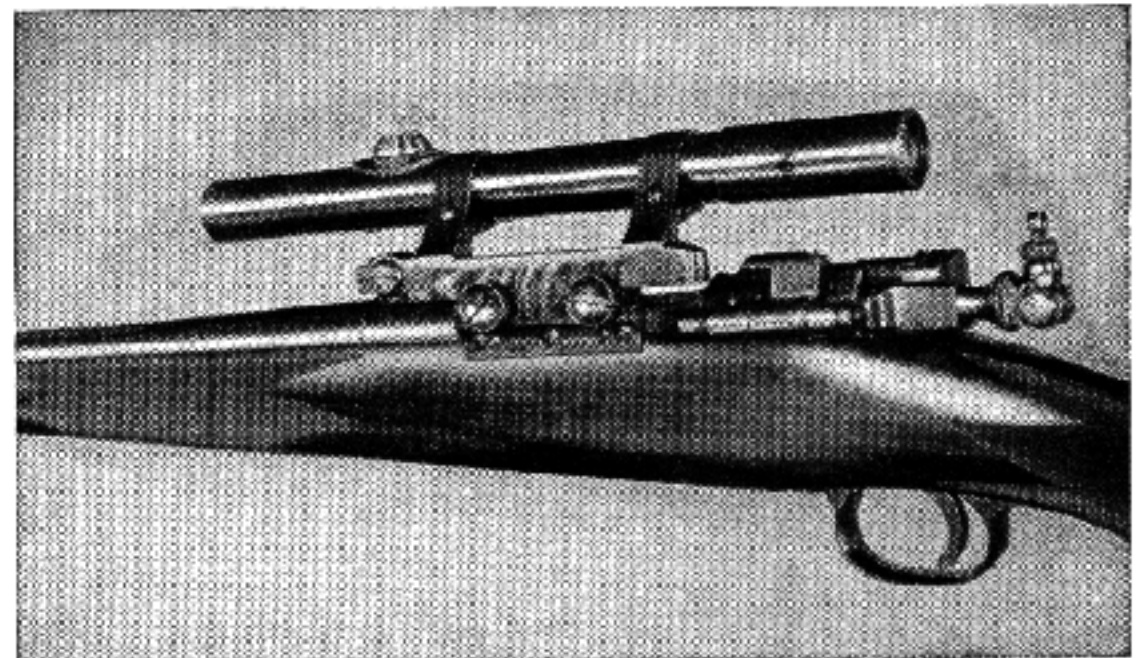


Fig. 43
Zeiss telescope and Niedner mount. Lyman aperture sight mounted on cocking piece, an ideal combination when two sights are desired

the best, not only in price of instrument but in power as well. Many figure that if a telescope of $2\frac{3}{4}$ power makes an object appear distinct, one of 4 power makes the object twice as clear and brings it so much nearer. Other elements enter into this, however. Altho a 4-power telescope magnifies an object one and one-quarter times more than the $2\frac{3}{4}$ power, it cannot be made the same weight and size as the other without reducing the field. You must also understand that a higher power multiplies the error of aim; you realize you are not the steady holder you thought you were when you used a telescope of $2\frac{3}{4}$ power. Therefore, to avoid the embarrassing and unpleasant dancing of objects, the sportsman is compelled to use a lower-power instrument. The "field" is the width of the surrounding landscape taken in by any telescope, and the field grows less as the power increases; in choosing the ideal instrument you must select both field and light-absorbing power. The field will allow you to pick out quickly any game that may be standing more or less concealed; and you can use it in the failing lights of evening or early morning.

With the matter of power, field, and light intake settled, the prospective fancier of a telescope should see that the instrument selected has the correct field for its power. The importance of the greater field is appreciated only by those who have used these sights on game.

The "cross-hairs" or what is commonly called the reticule should be a picket-pointed post running up and terminating at the center or just over the horizontal posts. The point is alined on the spot to be hit while the horizontal hairs are not shadowing the object. The old reticules having fine cross-hairs similar to the target telescope have been superseded by the more substantial designs of heavy pickets to withstand the heaviest recoil.

Aperture sights have become the accepted standard in metallic sights because better results are obtained on target work; but for a hunting rifle we must or should vary our standards to suit a particular location where open or telescope sights would be the most advantageous. The design of notch in a leaf sight preferred by different men varies so greatly that it is really difficult to know or even to recommend the correct form for all conditions and all kinds of eyesight.

After noting the various sights listed in any catalog or even given in this book, you will understand that fancies vary because we do not all have the same eyesight. We must continually strive for betterment in sight design to suit different men's vision and to make shooting a pleasure for all of them. Even tho some may have lost the sight of one eye, different aids may be brought forward for those so handicapped.

Experienced mechanics are often asked to carry out impossible ideas. A gun embodying the designs of all guns in one has been made and sold—the three- or four-barreled gun, for instance. Men who have the capital to invest in such a gun do so for no other reason than to have something different. These guns are only for those who need to carry a gun for all purposes, to be ready for all kinds of game and any emergency which may arise. In other words, they are made only for the novice and not for the practical and experienced hunter. Sellers of such arms will explain to amateur sportsmen: "Here is a gun for big game and a shotgun for feathered game, as well as a small rifle for small animals. Three guns in one with four barrels!"

A two-barreled gun known as the Cape rifle was designed for a country such as Africa, and when placed in the hands of the experienced hunter it will provide ample protection when needed. Beginners should remember that to be successful as

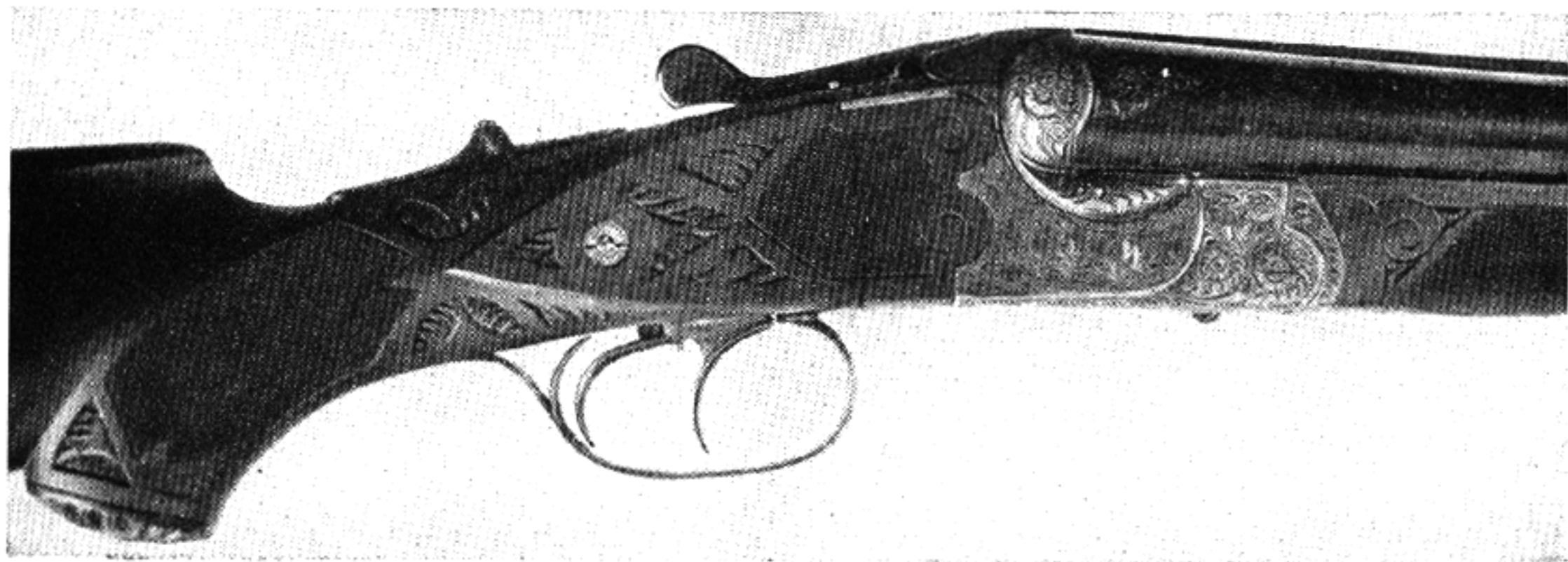


Fig. 44
Three-barrel gun of German make

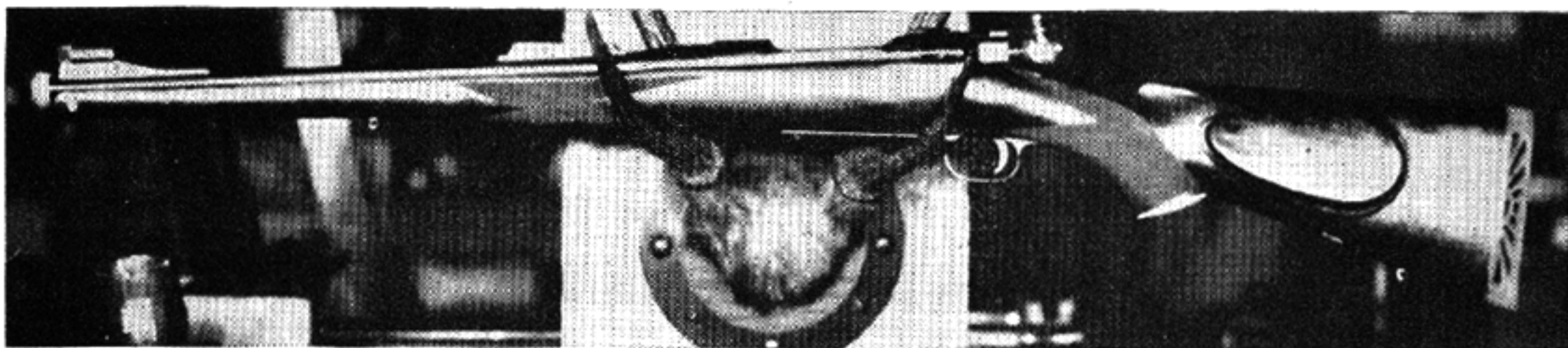


Fig. 45

Springfield Model 1903 rifle designed for Mrs. Charles G. King. Eighteen-inch barrel, "Mannlicher type." An arm well adapted to the saddle scabbard

a hunter, one must go out for one thing and not vary the bag; as a rule, if one follows up one kind of game for the day, the bag will be greatly increased. What the amateur sportsman wants to know is where to shoot and what to shoot with.

The average individual is like a boy with his first gun. To him it is an amazing mechanism and the most real and cherished possession he can own. All is as it seems on the surface—and all arises from the surface. He dreams, "What I can do with it!" The average unthinking person lives in a maze of mysteries which he calls his life; the unexpected is always happening to him. The expected and longed for happens but seldom, and when it does, he doesn't know how or why. He no more attempts to understand the laws back of his life dreams nor tries to figure out how a gun was made, than the small boy. He just takes it for granted and enjoys it after a fashion. We like the small boy who lives absorbed in the delusion that things are what they seem to be and who uses them without figuring the results. Science has shown us, however, that everything in the universe has some cause, and that the same cause always brings the same result. There are no accidents, nor are there any miracles performed.

I would not advise applying certain fancies I have named to a firearm except practically. So many ideas are advanced that are neither practical nor possible. While in charge of the experimental department at the Arsenal I spent many amusing hours reading the Patent-Office reports. A few ideas were good, but the majority showed that the inventors allowed convictions to get the better of common sense. They believed the thing was good, and spent good money on the idea in order to have such a fancy patented and satisfy a whim. A personal fancy is a capricious liking formed oftentimes without reason or exercise of judgment, particularly in gun work, and it is likely to fade as quickly as it was formed.

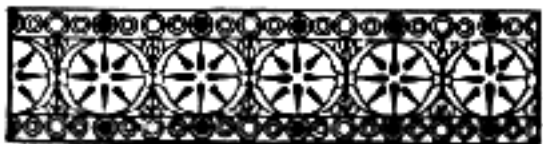


Fig. 46

Springfield floor plate. Moose and bear in gold. High relief engraving

CHAPTER VI

Principles of Iron and Steel



Principles of Iron and Steel

THIS subject, if treated in technical terms, would fill a volume alone, so I shall only give a brief description of the principles of iron, the basic foundation of all steels. Let me first give definitions of iron and steel which should be known to the beginner.

Alloy Cast-irons — Irons which owe their properties chiefly to the presence of an element other than carbon.

Alloy Steels — Steels which owe their properties chiefly to the presence of an alloy other than carbon, such as nickel, chromium, molybdenum, tungsten, manganese, vanadium.

Basic Pig-iron — Pig-iron contains so little silicon and sulfur that it is suited for easy conversion with steel by the basic open-hearth process. (Restricted to pig-iron containing not more than one per cent of silicon.)

Bessemer Pig-iron — Iron which contains so little phosphorus and sulfur that it can be used for conversion into steel by the original or acid Bessemer process. (Restricted to pig-iron containing not more than 0.10 per cent of phosphorus.)

Bessemer Steel — Steel made by the Bessemer process irrespective of carbon content.

Cast-iron — Iron containing so much carbon or its equivalent that it is not malleable at any temperature. It is recommended to draw the line between cast-iron and steel at 2.20 per cent.

Cast Steel — The same as crucible steel; obsolete and confusing.

Charcoal-hearth Cast-iron — Cast-iron which had its silicon and usually its phosphorus removed in the charcoal hearth, but still contains so much carbon as to be distinctly cast-iron.

Converted Steel — The same as blistered steel.

Crucible Steel — Steel made by the crucible process irrespective of carbon.

Gray Pig-iron and Gray Cast-iron — Pig-iron and cast-iron in the fracture of which the iron itself is nearly concealed by graphite, so that the

fracture has the peculiar gray color of graphite.

Malleable Castings — Castings made from iron which, when first made, is in the condition of cast-iron, and is made malleable by subsequent treatment without fusion.

Malleable Pig-iron — An American trade name for pig-iron suitable for converting with malleable castings through the process of melting. Treated when molten casting in a brittle state, and then made malleable without remelting.

Open-hearth Steel — Steel made by the open-hearth process irrespective of carbon contents.

Pig-iron — Cast-iron which has been cast into pigs direct from the blast furnace.

Puddled Iron — Wrought-iron made by the puddling process.

Puddled Steel — Steel made by the puddling process, and necessarily slag-bearing.

Refined Cast-iron — Cast-iron which has most of its silicon removed in the refining furnace, but still contains so much carbon as to be distinctly cast-iron.

Shear Steel — Steel usually in the form of bars made from blistered steel by shearing it into short lengths, and piling and welding these by rolling or hammering them at a welding heat. If this process of shearing, etc., is repeated, the product is called "double-shear steel."

Steel — Iron which is malleable at least in some one range of temperature and in addition is either (a) cast into an initially malleable mass, or (b) is capable of hardening greatly by sudden cooling, or (c) is both so cast and so capable of hardening.

Steel Castings — Unforged and unrolled castings made from Bessemer open-hearth crucible, or any other, steel.

Washed Metal — Cast-iron from which most of the silicon and phosphorus have been removed by the Bell-Krupp process without removing much of the carbon; steel contains enough carbon to be cast-iron.

Weld Iron — The same as wrought iron; obsolete and needless.

White Pig-iron and White Cast-iron — Pig-iron and cast-iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

Wrought Iron — Slag-bearing malleable iron which does not harden materially when suddenly cooled.

The above information will convey to the student a clearer understanding of how the different forms are classified, and he can gain the required knowledge to know what should be used. A further explanation of steels commonly used in gun work is necessary, as I have often mentioned tool steel, machinery steel, cold-drawn steel, etc., in these pages. Naturally, the beginner will not definitely understand such terms, and the only satisfactory method is to make them clear and to point out their proper application. In the automobile industry the requirements for different steels have reached a high degree of perfection, so we will select our steels from their specifications, which are known as the S. A. E. (Society of Automobile Engineers) standard and are given under various numbers, each suited to some particular part. I list these under their proper headings.

Carbon Steels

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus Maximum	Sulfur Maximum
1010	0.05-0.15	0.30-0.60	0.045	0.05
1015	0.10-0.20	0.30-0.60	0.045	0.05
1020	0.15-0.25	0.30-0.60	0.045	0.05
1025	0.20-0.30	0.50-0.80	0.045	0.05
1030	0.25-0.35	0.50-0.80	0.045	0.05
1035	0.30-0.40	0.50-0.80	0.045	0.05
1040	0.35-0.45	0.50-0.80	0.045	0.05
1045	0.40-0.50	0.50-0.80	0.045	0.05
1315	0.10-0.20	1.25-1.55	0.050	0.08-0.13
1050	0.45-0.55	0.50-0.80	0.045	0.05
1095	0.90-1.05	0.25-0.50	0.040	0.05
*1350	0.45-0.55	0.90-1.20	0.040	0.05
*1360	0.55-0.70	0.90-1.20	0.040	0.05

* The silicon content for 1350 and 1360 must not exceed 0.30 per cent.

The 0.10 per cent carbon steel (usually known as soft, basic, open-hearth steel) is commonly used

for seamless tubing, press-steel frames, sheet brake bands, etc. When annealed, it should be used where strength is required. The quality is improved by cold drawing or rolling. The 0.10 per cent carbon steel in its natural or annealed state cannot be machined easily; it will tear badly in turning, threading, and broaching operations. A heat treatment which will produce some stiffness is to quench it in oil or water at a temperature of 1500 degrees Fahrenheit. This steel will case-harden, but it is not as suitable for this purpose as 0.20 per cent carbon steel.

The 0.20 per cent carbon steel is known as machine steel or machinery steel. It forges and machines well, but is not suitable for screw machine work. Its particular use is for forged machine and case-hardened parts where strength is not of special importance. It can also be drawn into tubes and rolled into cold rolled forms. Heat treatment does not increase the strength of this steel, but causes a refinement of the grain after forging and increases the toughness; all that is necessary is to quench it in oil at 1500 degrees Fahrenheit.

The 0.30 per cent carbon steel is primarily a structural steel. It forges well, machines well, and responds to heat treatment in regard to strength, as well as toughness. It is used extensively in automobile construction and in rifle parts such as ramps, barrel bands, sight bases, etc.

The 0.40 per cent carbon steel is a structural steel of greater strength than that previously mentioned. Its uses are more limited and generally confined to parts requiring a high degree of strength and considerable toughness. It is commonly used for crank shafts, driving shafts, propeller shafts, etc. It has also been used for transmission gears, but is not quite hard enough without case-hardening. When properly annealed it machines well, but is not suitable for screw machine work.

The 0.50 per cent carbon differs but little from that just described, altho owing to its higher carbon content it is somewhat harder to machine and also somewhat stronger.

Nickel Steels

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus Maximum	Sulfur Maximum	Nickel Range
2015	0.10-0.20	0.30-0.60	0.04	0.045	0.40-0.60
2115	0.10-0.20	0.30-0.60	0.04	0.045	1.25-1.75
2315	0.10-0.20	0.30-0.60	0.04	0.045	3.25-3.75
2320	0.15-0.25	0.50-0.80	0.04	0.045	3.25-3.75
2330	0.25-0.35	0.50-0.80	0.04	0.045	3.25-3.75
2335	0.30-0.40	0.50-0.80	0.04	0.045	3.25-3.75
2340	0.35-0.45	0.50-0.80	0.04	0.045	3.25-3.75
2345	0.40-0.50	0.50-0.80	0.04	0.045	3.25-3.75
2350	0.45-0.55	0.50-0.80	0.04	0.045	3.25-3.75
2512	Max.-0.17	0.30-0.60	0.04	0.045	4.75-5.25

Alloy steels must be heat-treated; they should not be used in the annealed or natural condition. When annealed they are but slightly superior to plain carbon steels.

The 0.15 per cent. carbon nickel steel is suitable for carbonizing purposes. When properly carbonized and heat-treated, it has a strong and tough core and a hard exterior. This steel is especially adapted for case-hardened receivers and other case-hardened gun parts requiring both strength and hardness.

The 0.200 per cent carbon nickel steel may be used interchangeably with that just described. It is intended primarily for case-hardening purposes, but may, with suitable heat-treatment, also be used for structural parts.

The 0.25 per cent carbon nickel steel may also be used hardened and is satisfactory for barrels and transmission gears. The treatment for carbonizing must be slightly modified to allow the increase of carbon contents. It also can be used for many structural parts when subjected to heat-treatments.

The 0.30 per cent carbon nickel steel is primarily used for structural parts such as axles, crank shafts, driving shafts, transmission shafts, and barrels requiring strength and toughness. Wide variations as to elastic limits are possible by varying the quenching mediums—oil, water, or limes—and by variations in the drawing temperatures.

The 0.35 per cent carbon nickel steel is very similar to that just described. The 0.40, 0.450, and 0.550 per cent carbon nickel steels are not widely used, but are advisable for certain purposes. A greater hardness is obtainable than with steels having lower carbon contents, but as increased brittleness accompanies the greater hardness, the treatment must be modified to meet these conditions. For example, the final quenching must be

at a lower temperature in order to secure the desired toughness and other properties.

There are three kinds of nickel-chromium steels in common use: low, medium, and high nickel-chromium steels. In general, it may be said that the heat-treatment and properties of these steels are much the same as those of the plain nickel steels, except that the effects of the heat-treatment are somewhat augmented by the presence of chromium.

The low nickel-chromium with carbon contents up to 0.20 per cent are intended primarily for case-hardening, while those with carbon contents from 0.25 to 0.40 per cent are adapted to structural purposes. Those with carbon contents from 0.45 to 0.55 per cent may be used for gears and other structural parts where a high degree of strength and hardness is required and where toughness is not of first importance.

The medium nickel-chromium steels are of the same composition as the low nickel-chromium steels except that they contain more nickel and chromium. Their general usage is practically the same.

The high nickel-chromium steels require different heat-treatment from other types mentioned. Annealing before machining will be found necessary for these steels, owing to the high percentages of nickel and chromium. The steels with low carbon contents are case-hardened the same as low nickel-chromium steels, and those with higher carbon contents are used for structural parts. In general these steels are used where unusual strength is demanded. For example, the 0.45 per cent high nickel-chromium steel is used for gears where extreme strength and hardness is necessary. The carbon content is high enough to give the required degree of hardness by quenching and without case-hardening. This steel is difficult to forge. During

Nickel Chromium Steels

<i>S.A.E. Steel No.</i>	<i>Carbon Range</i>	<i>Manganese Range</i>	<i>Phosphorus Maximum</i>	<i>Sulfur Range</i>	<i>Nickel Range</i>	<i>Chromium Range</i>
3115	0.10-0.20	0.30-0.60	0.04	0.045	1.00-1.50	0.45-0.75
3120	0.15-0.25	0.30-0.60	0.04	0.045	1.00-1.50	0.45-0.75
3125	0.20-0.30	0.50-0.80	0.04	0.045	1.00-1.50	0.45-0.75
3130	0.25-0.35	0.50-0.80	0.04	0.045	1.00-1.50	0.45-0.75
3135	0.30-0.40	0.50-0.80	0.04	0.045	1.00-1.50	0.45-0.75
3140	0.35-0.45	0.50-0.80	0.04	0.045	1.00-1.50	0.45-0.75
3215	0.10-0.20	0.30-0.60	0.04	0.040	1.50-2.00	0.90-1.25
3220	0.15-0.25	0.30-0.60	0.04	0.040	1.50-2.00	0.90-1.25
3230	0.25-0.35	0.30-0.60	0.04	0.040	1.50-2.00	0.90-1.25
3240	0.35-0.45	0.30-0.60	0.04	0.040	1.50-2.00	0.90-1.25
3245	0.40-0.50	0.30-0.60	0.04	0.040	1.50-2.00	0.90-1.25
3250	0.45-0.55	0.30-0.60	0.04	0.040	1.50-2.00	0.90-1.25
3312	Max.-0.17	0.30-0.60	0.04	0.040	3.25-3.75	1.25-1.75
3325	0.20-0.30	0.30-0.60	0.04	0.040	3.25-3.75	1.25-1.75
3335	0.30-0.40	0.30-0.60	0.04	0.040	3.25-3.75	1.25-1.75
3340	0.35-0.45	0.30-0.60	0.04	0.040	3.25-3.75	1.25-1.75
3415	0.10-0.20	0.30-0.60	0.04	0.040	2.75-3.25	0.60-0.95
3435	0.30-0.40	0.30-0.60	0.04	0.040	2.75-3.25	0.60-0.95
3450	0.45-0.55	0.30-0.60	0.04	0.040	2.75-3.25	0.60-0.95

the forging operation, it should be kept at a high or plastic heat and should not be hammered or worked at ordinary forging temperatures, as cracking is liable to follow. On the other hand, too high a temperature is not advisable, as the steel then becomes re-short and breaks.

in such steels varies from 2.5 to about 5 per cent, and of carbon from 0.8 to 2 per cent.

The composition of ordinary screw stock should be in general about as follows: carbon, from 0.08 to 0.20 per cent; manganese, 0.30 to 0.80; phosphorus, not to exceed 0.12 per cent; sulfur, 0.06 to

Chromium-Vanadium Steels

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus Maximum	Sulfur Maximum	Chromium Range	Vanadium Min.	Vanadium Desired
6120	0.15-0.25	0.50-0.80	0.04	0.04	0.80-1.10	0.15	0.18
6125	0.20-0.30	0.50-0.80	0.04	0.04	0.80-1.10	0.15	0.18
6130	0.25-0.35	0.50-0.80	0.04	0.04	0.80-1.10	0.15	0.18
6135	0.30-0.40	0.50-0.80	0.04	0.04	0.80-1.10	0.15	0.18
6140	0.35-0.45	0.50-0.80	0.04	0.04	0.80-1.10	0.15	0.18
6145	0.40-0.50	0.50-0.80	0.04	0.04	0.80-1.10	0.15	0.18
6150	0.45-0.55	0.50-0.80	0.04	0.04	0.80-1.10	0.15	0.18
6195	0.90-1.05	0.20-0.45	0.03	0.03	0.80-1.10	0.15	0.18

Chromium-vanadium steels are used for many automobile parts, particularly springs, axles, driving shafts, and gears—and also in springs for guns, etc. Those grades which contain from 0.15 to 0.20 per cent of carbon are intended primarily for case-hardened parts, while those of from 0.25 to 0.50 per cent carbon steel may be used for gears and springs. When used for structural parts, if an exceedingly high strength is desirable, the 0.50 per cent carbon chromium-vanadium steel is suitable for springs and gears.

0.12 per cent. Screw stock is easily machined and cheap, but lacks strength and toughness, and is not safe for vital parts. Screws made from hot-rolled bars of this material should be heat-treated and not used in an annealed condition. Screws made from cold-rolled bars are much stronger, but the best results in either case are obtained by a heat-treatment. After machining, heat to 1500 degrees Fahrenheit, quench, reheat from 600 to 1300 degrees Fahrenheit, and cool slowly. This steel is used extensively on .22-caliber barrels by Amer-

Molybdenum Steels

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus Maximum	Sulfur Maximum	Chromium Range	Nickel Range	Molybdenum Range
4130	0.25-0.35	0.40-0.70	0.04	0.045	0.50-0.80		0.15-0.25
4140	0.35-0.45	0.40-0.70	0.04	0.045	0.80-1.10		0.15-0.25
4150	0.45-0.55	0.40-0.70	0.04	0.045	0.80-1.10		0.15-0.25
4615	0.10-0.20	0.30-0.60	0.04	0.045		1.50-2.00	0.20-0.30

Molybdenum steels have properties similar to tungsten steels, except that a smaller quantity of molybdenum than that of tungsten is required to secure corresponding results.

ican gun makers, and is known as cold-drawn steel.

General Properties of Alloy Steels— Alloy or "special" steels are combinations of iron and

Chromium Steels

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus Maximum	Sulfur Maximum	Chromium Range
5120	0.15-0.25	0.30-0.60	0.04	0.045	0.60-0.90
5140	0.35-0.45	0.50-0.80	0.04	0.045	0.80-1.10
5150	0.45-0.55	0.50-0.80	0.04	0.045	0.80-1.10
52100	0.95-1.10	0.20-0.50	0.03	0.030	1.20-1.50

Chromium steel is well adapted for armor-piercing projectiles, owing to its hardness, toughness, and stiffness, and is extensively used for this purpose. Chromium steel is also used in the construction of safes and for castings subject to unusually severe stress, such as those used in rock-crushing machinery, etc. The percentage of chromium used

carbon with some other element such as nickel, chromium, tungsten, vanadium, manganese, or molybdenum. All these metals give certain distinct properties to the steel, but in every case the principal quality is the increase in hardness and toughness.

Nickel steel usually contains from 3 to 3.5 per

Screw Stock

S.A.E. Steel No.	Carbon Range	Manganese Range	Phosphorus Maximum	Sulfur Maximum
1112	0.08-0.16	0.60-0.80	0.09-0.13	0.075-0.15
1120	0.15-0.25	0.60-0.90	Max.-0.06	0.075-0.15

cent nickel and from 0.20 to 0.40 per cent carbon. This steel is used for armor plate, ammunition, barrels, receivers, bridge construction, rails, etc. One of the reasons why nickel steel is adapted for armor plate is that it does not crack when perforated by a projectile. The Krupp steel used for armor plate contains approximately 3.5 per cent nickel, 1.5 per cent chromium, and 0.25 per cent carbon. The advantage claimed for nickel steel for railroad rails is its increased resistance to abrasion and high elastic limit. On sharp curves, it has been estimated that a nickel-steel rail will outlast four ordinary rails. High grade barrels are made from this steel.

Tungsten steel is largely employed for high-speed metal-cutting tools and magnet steels. It has also been used in the manufacture of armor plate. All cores used in the .30 and .50 caliber armor-piercing projectiles are 3.5 per cent tungsten. In the latter case, the metal is combined either with nickel or chromium, or with both of these metals. The property that tungsten imparts to steel is that of hardening in air after heating to the required temperature. This steel usually contains from 5 to 15 per cent tungsten (altho the percentage is sometimes as high as 24 per cent with from 0.4 to 2 per cent carbon).

Vanadium steel ordinarily contains from 0.16 to 0.25 per cent vanadium. The effect of vanadium is to increase the tensile strength and elastic limit, and it gives the steel the valuable property of resisting, to an unusual degree, repeated stresses. Vanadium steel is especially adapted for springs, car axles, gears subject to severe service, and for all parts which must withstand vibrations and varying stresses.

Manganese steel contains 12 per cent manganese and from 0.8 to 1.25 per cent carbon. If there is only 1.5 per cent manganese, the steel is very brittle, and additional manganese increases this brittleness until the quality has reached 4 to 4.15 per cent, when the steel can be pulverized under the hammer. With a further increase of manganese, the steel becomes ductile and very hard, these qualities being at their highest degree when the manganese content is 12 per cent. The ductility of the steel is brought out by sudden cooling, the process being the opposite of that employed for carbon steel.

Crucible or Tool Steel—Crucible or tool

steel, formerly called cast steel, is made by using high-grade low-phosphorus wrought iron and adding carbon to it. The oldest method of adding carbon was the "cementation process," in which iron bars were packed in airtight retorts with powdered charcoal between the bars. The filled retorts were put in a furnace where they were heated to a red heat for several days. The carbonized bars commonly called "blistered steel" were then cut in small pieces, remelted in a crucible, and poured into moulds, forming small billets. The newer method is to put small pieces of wrought iron into an airtight crucible containing the proper amount of powdered charcoal and melt them down. The other ingredients, such as chromium, tungsten, etc., are also added in the crucible.

The most common defects in finished bars of tool steel are:

1. *Seams.* These can generally be seen with the naked eye on the surface of the bar; they run lengthwise. Tools made from steel containing seams are liable to open in forging or to crack in hardening.

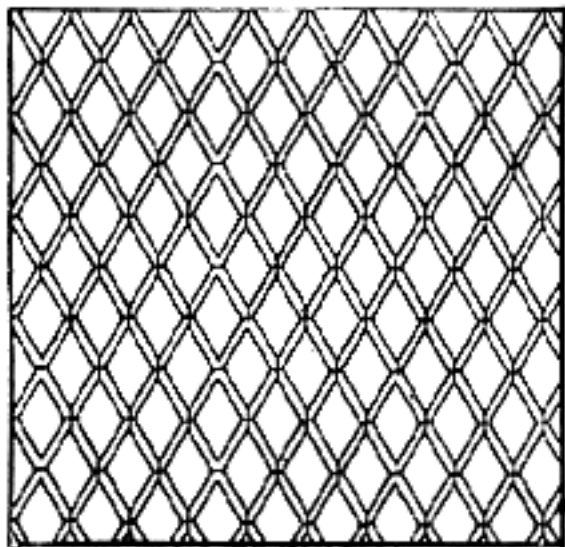
2. *Laps.* These are caused either in rolling or drawing down under the hammer. They present an appearance similar to a seam, but are usually longer, and in the case of rolled bars, frequently run the whole length of the bar.

3. *Pipes.* These defects are caused by the contraction when cooling and are in the top half of the ingot. The lower half is usually sound, as its contraction when cooling is fed by the molten metal in the top half. The larger the ingot, the more difficult this defect is to deal with. This defect causes tools to split from the center in hardening.

Tool steel which is purchased from the steel manufacturer is generally stamped-annealed to permit easy machining, but for forging purposes the unannealed bars are all that is required, for they must be annealed before any machining can be done.

If the student wishes to go into this subject extensively he should become familiar with all steels which are placed in the market by the large steel companies. Secure various catalogs, as some of these contain valuable information. As you know, steel-making today calls for men who have had scientific training, for it is a science in itself. The experience which I gained at the arsenal in handling all makes of steel, together with their heat-treatment for a vast number of tools and gauges, fitted me to treat the subject for the beginner. It would have been far easier to treat it technically, but if you need such knowledge you will acquire it from the proper source.

CHAPTER VII
Heat-treatment of
Steel



Heat-Treatment of Steel

THE problem of giving a satisfactory exposition of the subject of this chapter is very simple, but as a rule only one out of a hundred readers will have access to the hardening room in order to carry out the methods I am about to outline. These methods are vital in every detail, however, for complete gun work. At the arsenal we had a very elaborate hardening equipment; furnaces, quenching baths, recording instruments meant the success of the manufacturing division. The amateur in his struggle must devise ways and means to solve this problem. I shall outline the correct methods and then he can figure out his own equipment, even tho he constructs it from materials close at hand.

Heating Furnaces — The furnaces used for the hardening, annealing or tempering of steel are heated either by gas, oil, electricity or solid fuel. Furnaces using oil or gas are made in many different styles and sizes to suit various classes of work, but differ very little in general arrangement. Crude oil and kerosene are commonly used in oil-heated furnaces. To insure an unvarying temperature, the air and fuel pressure should be uniform. Gas furnaces use either natural, artificial or producer gas. Some gas furnaces are equipped with an automatic apparatus which operates in conjunction with a pyrometer for controlling the temperature to within a few degrees of a given point. The air supply is generally obtained from a positive blower, altho where a compressor is installed for operating other tools, the air is sometimes utilized for the furnace by interposing reducing valves to diminish the pressure.

Artificial gas is more expensive than oil, but is much cleaner, and the supply tanks required for oil are unnecessary. Producer gas obtained from a separate plant is not economical, unless there are a considerable number of furnaces. When oxidization or the formation of scale is particularly objectionable, furnaces of the muffle type are often used. These furnaces contain a refractory in which the steel is placed, thus excluding the products of combustion. These muffles must be replaced quite frequently and more fuel is required than for an oven type of furnace.

Electrically heated furnaces are generally the most satisfactory for the heat-treatment of high-grade work, altho the cost of electricity exceeds that of liquid or gaseous fuels. A type of electric furnace commonly used derives its heat from a heavy low-voltage current which passes through electrodes to resistance elements in the heated chamber. This type of furnace gives uniform heat and is adapted to accurate regulations. Electrically heated furnaces are also used in conjunction with heating baths, the current being transmitted through a bath of metallic salts, or by two electrodes on opposite sides of the crucible.

The conductivity of the salt is very small at normal temperatures. When in a molten condition, the salt offers a comparatively low resistance to the electric current, and therefore, when the bath is hot, it forms an electric conductor, and each part of the bath produces its own heat.

Solid fuels, such as coke, coal, charcoal, etc., are also used as described in Chapter XIX, Volume I. A common type of solid-fuel furnace is equipped with a grate upon which the fuel is burned and an arch above the grate which reflects the heat back to the plate that holds the steel to be heated. This plate should be so located that the flames will not come in direct contact with the steel and injure the finished surfaces. To prevent this, the steel is sometimes safeguarded by placing it inside of a clay or cast-iron retort which is encircled by the flames. The solid-fuel type of furnace is inferior to other types for most purposes because it is almost impossible to maintain a uniform temperature, and the gases of combustion are liable to injure the steel.

Pyrometers — Pyrometers are a necessary addition to furnace equipment and have great value in connection with the heat-treatment of steel, as they make it possible to determine high temperatures accurately; moreover, the temperature, when heating for hardening, can be regulated to conform with the temperature that has given the best results in practise. There are several different types of pyrometers commonly used in industrial service, and they may be classified according to the principle upon which they operate.

Thermo-Electric Pyrometer — On this type of pyrometer, temperature variations are determined by the measurements of an electric current generated by the action of heat on the junction of two dissimilar metals; that is, on junction of the thermo-cuppler which has a temperature different from the other, a current is developed, and a meter indicates the temperature, the relation between the strength of current and the temperature being constant. The thermo-cuppler and the meter form the essential parts. The two dissimilar metals composing the thermo-cuppler are connected at one end, which is called the "hot end" and is placed in the furnace at the temperature required. Except at the hot end, the two wires or elements do not touch. The free ends, called the "cold end," are kept away from the heat. When the hot end is heated, the intensity of the current generated depends upon the difference between the temperature of the hot and cold ends. The meter is connected to the cold end and shows the value of the current in degrees Fahrenheit or Centigrade. Some pyrometers of this type may be used intermittently for temperatures up to 3000 degrees Fahrenheit.

Heating Steels in Liquid Baths — The liquid baths commonly used for heating tool steel preparatory to hardening are molten lead, cyanid of potassium, barium chlorid, a mixture of barium and potassium chlorid, and other metallic salts. The molten substance is retained in a crucible, which is usually heated by gas or oil. The principal advantages of heating baths are as follows: no part of the work can be heated to a temperature above that of the bath; the temperature can easily be maintained at whatever degree has proved in practise to give the best results; the submerged steel can be heated uniformly; and the finished surfaces are protected against oxidization.

The Lead Bath — I have mentioned this bath often in chapters pertaining to steels, but it will do no harm to give another explanation. The lead bath is extensively used, but is not adapted to the high temperatures required for hardening high-speed steel, as it begins to vaporize at about 1190 degrees Fahrenheit, and if heated much above that point, rapidly volatilizes and gives off poisonous vapors; therefore lead furnaces should be equipped with hoods to carry away the fumes. Lead baths are especially adapted for springs, reamers, and small tools made for gun work. Gas is the most satisfactory fuel for heating the crucible. It is important to use pure lead that is free from sulfur. The work should be preheated before plunging into the lead.

Cyanid of Potassium Bath — This is another bath which is extensively used by gun manufacturers to harden parts and at the same time secure an ornamental color effect. Many steel hardeners prefer cyanid of potassium to lead for heating steel cutting tools, gauges, dies, etc. When cyanid is used, the parts should be suspended from the side of the crucible by means of wires or wire-cloth baskets, to prevent them from sinking to the bottom. Steel will not sink in a lead bath, as lead has a higher specific gravity than steel. Cyanid of potassium should be carefully used, as it is a violent poison. The fumes are very injurious and the crucible should be enclosed with a hood connecting with a chimney or ventilation shaft.

Barium Chlorid Bath — As a temperature of about 2400 degrees Fahrenheit can be obtained with this bath, it is used to harden high-speed steel parts such as barrel drills, barrel reamers of high-speed steel etc. The tools come from this bath free of scale. When barium chlorid is used for the lower temperatures required for carbon steel, it is mixed with chlorid of potassium. For temperatures between 1400 and 1650 degrees Fahrenheit, use three parts barium chlorid and two parts chlorid of potassium. For higher temperatures, the amount of potassium chlorid should be proportionately reduced, pure barium chlorid being used for temperatures above 2000 degrees Fahrenheit. All steel should be preheated to 600 or 800 degrees before being immersed in the bath. Temperatures below 1075 degrees Fahrenheit can be obtained by using equal parts of potassium nitrate and sodium nitrate. This mixture sets at 400 degrees Fahrenheit and can be used as a tempering bath.

Annealing Steel — The purpose of annealing or normalizing is not only to soften steel for machining, but to remove all strains incident to machining, rolling or hammering. A common method of annealing is to pack the steel in a cast-iron box or pipe containing some material such as powdered charcoal, slaked lime, or sand. The box and its contents are sealed with fire clay on the ends and then heated in a furnace to the proper temperature for a length of time depending upon the size of the steel. After heating, the box or pipe and its contents should be allowed to cool at a rate slow enough to prevent hardening. The best time to do such work is in the afternoon before going home. Heat the box or pipe in the furnace to the required temperature and shut the furnace off, allowing it to cool with the furnace, and remove the following morning. It is essential, when annealing, to exclude the air as completely as possible while the

steel is hot, to prevent the outside of the steel from becoming oxidized.

The temperature required for annealing should be slightly above the critical point, which varies for different steels. Low-carbon steel should be annealed about 1650 degrees, and high-carbon steel between 1300 and 1400 degrees, Fahrenheit. This temperature should be maintained just long enough to heat the entire piece evenly throughout.

Care should be taken not to heat the steel much above the decalescence or hardening point. When steel is heated above this temperature, the coarseness increases with an increase of temperature. Moreover, if steel that has been heated above the critical point is cooled slowly the coarseness of the grain corresponds to the coarseness at the maximum temperature; hence, the grain of annealed steel is coarser.

If only a small piece of steel or a single tool is to be annealed, this can be done by building up a fire-brick box in an ordinary blacksmith's forge, placing the tool in it, covering over the top, then heating the whole, covering it with coke, and leaving it to cool over night. Another quick method is to heat the steel to a red heat. Bury it in dry fine sand, lime, or hot ashes, and allow it to cool. I have read of quick annealing methods such as heating the piece to a dull black-red, and plunging it into hot soapy water, and also into hot water. Methods of this kind are not to be recommended; the advice in their favor flows from the pen of the inexperienced.

Annealing High-Speed Steel — The following method is used to anneal high-speed steel, and also to normalize barrel tools after they are centered and roughing cuts are taken. All such tools must be given these treatments or you will lose half of the reamers; for these will run out when placed between centers, and will not clean up to required sizes. Use an iron box or pipe of sufficient size to allow at least one-half inch of packing between the pieces of steel to be annealed and the sides of the box or pipe. It is not necessary that each piece of steel be kept separate from the one next to it, but only that the steel be prevented from touching the sides of the annealing pipe or box. Pack carefully with powdered charcoal or fine dry lime, and cover with an airtight cap with small holes, or lute with fire-clay; heat slowly to a dull red heat of about 1470 to 1500 degrees Fahrenheit, and allow to remain at this heat from two to eight hours, depending upon the size of the pieces to be annealed. All barrel tools require about two hours. Cool as slowly as possible, and do not expose to the air until absolutely cold. A good way to insure

this is to allow the box or pipe to remain in the furnace until cold.

We have conducted a series of experiments to determine the proper temperature to heat high-speed steel for annealing, with the following results: When the steel was heated to below 1250 degrees Fahrenheit and slowly cooled, as in annealing, it retained the original hardness and brittleness imparted in forging. When heated to between 1250 and 1450 degrees, the Brinnell test indicated that the steel was soft, but turning tests proved that the steel still retained its original brittleness. However, when heated to between 1475 and 1575 degrees, the steel became very soft; it had a fine-grained fracture and the initial brittleness had entirely disappeared. In carrying these tests further to 1625, 1725, and 1825 degrees Fahrenheit, it was found that steel became very soft, but that there was a gradual increase in brittleness and in the size of the grain, until at 1875 degrees the steel again became as brittle as annealed steel. Lime was used as a packing medium in making these tests.

Hardening, Critical Temperatures — The "critical points" of carbon tool steel are the temperatures at which certain changes in the chemical composition of the steel take place during both heating and cooling. Steel at normal temperatures has its carbon (which is the chief hardening element) in a certain form called "pearlite" carbon. If the steel is heated to a certain temperature, a change occurs, and the pearlite becomes "martinsite" or hardened carbon. If the steel is allowed to cool slowly, the hardened carbon changes back to pearlite. The points and the effect of these molecular changes are as follows: When a piece of steel is heated to a certain point, it continues to absorb heat without appreciably rising in temperature altho its immediate surroundings may be hotter than the steel. This is the "decalescence point." Similarly, steel cooling slowly from a high heat, will at a certain temperature actually increase in temperature, altho its surroundings may be colder. This takes place at the "recalescence point." The recalescence point is lower than the decalescence point by anywhere from 95 to 200 degrees Fahrenheit, and the lower of these two points does not manifest itself unless the higher one has first been fully passed. These critical points have a direct relation to the hardening of steel. Unless a temperature sufficient to reach the decalescence point is obtained, so that the pearlite carbon is changed into a hardening carbon, no hardening action takes place; and unless the steel is cooled suddenly before it reaches the recalescence point, thus preventing the change back again from hardening to pearlite carbon, no

hardening can take place. The critical points vary for different kinds of steel and must be determined by tests in each case. It is the variation in the critical points that makes it necessary to heat different steels to different temperatures when hardening.

Determining Hardening Temperatures — The temperatures at which decalescence occurs vary with the amount of carbon in the steel, and are also higher for high-speed steel than for ordinary crucible steel. The decalescence point of any steel marks the correct hardening temperature, and the steel should be removed from the source of heat as soon as it has been heated uniformly to this temperature. Heating the piece slightly above this point may be desirable, either to insure the completeness of the structural change throughout, or to allow for any slight loss of heat which may occur in transferring the work from the furnace to the quenching bath. When the steel is heated above the temperature of decalescence it is non-magnetic. If steel is heated to a bright red it will have no attraction for a magnet or magnetic needle, but at about a "cherry-red" it regains its magnetic property. This phenomenon is sometimes taken advantage of for determining the correct hardening temperature, and the use of a magnet is to be recommended if a pyrometer is not available. The only point requiring judgment is the length of time the steel should remain in the furnace after it has become non-magnetic, as the time varies with the size of the piece. When applying the magnetic needle test, be sure that the needle is not being attracted by the tongs.

The correct hardening temperature for any carbon steel can be determined accurately by the use of a pyrometer. This form of apparatus, often used for testing specimens of steel, consists of a small electric furnace in which to heat the specimens, and a special thermo-couple pyrometer for indicating the range of temperature through which the steel passes. The pyrometer consists of a thermo-couple, connecting leads, and an indicating meter. The thermo-couple is a small wire which responds readily to any slight temperature variations. When testing a piece of steel with this instrument the temperature indicated by the meter rises uniformly until the decalescence point is reached. At this temperature, the indicating pointer of the meter remains stationary. The added heat is consumed by internal changes. When these changes are completed, the temperature again rises; the length of the elapsed period depends upon the speed of heating. The temperature at which this pause in the motion occurs should be

carefully noted. To obtain the lower critical point, the temperature is first raised about 100 degrees Fahrenheit above the decalescence point; the steel is then removed from the furnace and allowed to cool. The decrease of temperature is immediately shown by the fall of the meter pointer, and at a temperature somewhat below the decalescence point there is again a noticeable lag in the movement of the pointers. The temperature at which the movement ceases entirely is the recalescence point. Immediately following, there may occur a slight rising movement of the pointer.

During these intervals of temperature lag, both during heating and cooling, there may occur a small fluctuation in temperature, hence a definite point in each of these intervals should be considered when a test is made, both critical temperatures being taken at the time the points first become stationary.

While it is possible to harden steel within a temperature range of about 200 degrees and obtain what might seem to be good results, the best results are obtained within a very narrow range of temperatures close to the decalescence point. The hardening temperature for both low tungsten and carbon steel can be located with accuracy, and the complete changes from soft to hard occur within about a range of 10 degrees Fahrenheit or less. After the temperature has been increased more than 35 to 55 degrees Fahrenheit above the hardening point, the hardness of the steel is lessened by a higher temperature, providing the heating is sufficiently prolonged for the steel to be thoroughly heated.

Hardening Baths — When the steel heated above the critical point is plunged into a cooling bath, the rapidity with which the heat is absorbed by the bath affects the degree of hardness; therefore baths of various kinds are used for different classes of work. Clear cold water is commonly employed, and brine is sometimes substituted to increase the degree of hardness. This is very necessary for draw punches used in cartridge manufacturing. Sperm and lard oil baths, with sulfur and resin added, are used for hardening springs. Raw linseed oil is excellent for cutters, reamers, and other small tools. The effect of a bath for steel depends upon its composition, temperature, and volume. The bath should be amply large to dissipate the heat rapidly, and the temperature should be kept constant, so that successive pieces will be cooled at the same rate. Greater hardness is obtained from quenching in salt brine and less in oil than is obtained in water. This is due to the difference in heat-dissipating qualities of these sub-

stances. When water is used, it should be "soft," as unsatisfactory results will be obtained with "hard" water. If thin pieces are plunged in brine there is always danger of cracking, owing to the suddenness of cooling.

The temperature of the hardening bath has a great deal to do with the hardness obtained. In certain experiments a bar quenched at 41 degrees Fahrenheit showed a scleroscopic hardness of 101. A piece from the same bar quenched at 75 degrees had a hardness of 96, while, when the temperature of the water was raised to 124 degrees, Fahrenheit, the bar was decidedly soft, having a hardness of only 83. We found at the arsenal that a temperature between 80 and 110 degrees Fahrenheit was about right for some steels. The higher the temperature of the quenching water, the more nearly does its effect approach that of oil; and if boiling water is used for quenching, it will have an effect even more gentle than that of oil; in fact, it will leave the steel nearly tempered. With oil baths, the temperature changes have little effect upon the degree of hardness. Parts of irregular shapes are sometimes quenched in a water bath that has been warmed somewhat to prevent sudden cooling and cracking. A water bath having one or two inches of oil on top is sometimes employed to advantage for tools made of high-carbon steel, as the oil through which the work first passes reduces the sudden action of the water.

Irregularly shaped parts should be immersed so that the heaviest or thickest section enters the bath first. After immersion, the part to be hardened should be agitated in the bath; the agitation reduces the tendency of the formation of a vapor coating on certain surfaces, and a more uniform rate of cooling is obtained. The work should never be dropped to the bottom of the bath until quite cool. High-speed steel is cooled for hardening either by means of an air blast or an oil bath. Both fresh and salt water are also used, altho as a general rule water should not be used for high-speed steel. Various oils, such as cottonseed, linseed, lard, sperm, kerosene, etc., are also employed. Many prefer cottonseed oil. Linseed oil has the objection of becoming gummy, and lard oil has a tendency to become rancid. Whale oil or fish oil gives satisfactory results, but both have offensive odors; this defect can be overcome by an addition of about 3 per cent heavy "tempering" oil. Steel should never be removed from the bath when once immersed, until perfectly cool.

A quenching solution of 3 per cent sulfuric acid and 97 per cent water will make hardened carbon steel tools come out of the quenching bath bright and clean. This bath is sometimes used for

drills and reamers which are not to be polished in the flutes after hardening. Another method of cleaning drills and similar tools after they are hardened is to pickle them in a solution of one part hydrochloric acid and nine parts water. Still another method is to use a heating bath consisting of two parts barium chlorid and three parts potassium chlorid. This method is satisfactory for reamers and tools which are not to be polished in the flutes after hardening.

Kinds of Quenching Baths

(1) Water (soft), preferably distilled; good carbon tool steels should require no mixture added to pure water.

(2) Salt added to water (brine). This quenching fluid will produce a harder scale than will pure water.

(3) Sea (salt) water—the keenest natural water for hardening.

(4) Pure soft water containing soap.

(5) Sweet milk.

(6) Mercury.

(7) Carbonate of lime.

(8) Wax.

(9) Tallow.

(10) Air—mostly used for high-speed steel. Mere exposure, however, is in many cases, and for many steels, not sufficient to produce hardness, and an air blast is necessary, as this furnishes cool air in rapid motion.

(11) Oils such as cottonseed, linseed, whale, fish, lard, lard and paraffin mixed, special quenching oils, etc. A small quantity of sal ammoniac added to the oil bath has a tendency to make the tools come out clean from the bath. Linseed and cottonseed oils are especially used for high-speed steel.

The order of intensity with which various cooling baths will harden steel of about 0.90 to 0.100 per cent carbon is: mercury, carbonate of lime, pure water, water containing soap, sweet milk, different kinds of oils, tallow, and wax. In all cases—except possibly the oils, tallow, and wax—it must be remembered that the tools become harder as the temperature of the bath becomes lower.

Tank Used for Quenching—The main point to be considered in a quenching bath is to keep it at a uniform temperature so that successive pieces quenched will be subjected to the same heat. The next consideration is to keep the bath agitated so that it will not be of different temperatures in different places. Experience has proved that if a piece is held still in a thoroughly agitated bath, it will come out much straighter than if it has been moved around in an unagitated bath. This is an important consideration, especially when hardening long pieces and reamers. It is, besides, no easy matter to keep heavy and long pieces in motion unless it is done by mechanical means. Nearly all tools which the gunmaker requires are of small size; he must construct quenching baths which will

suit his general purpose. Oil for springs requires a special oil mixture, water, etc. Even the tanks are small, provision must be made for suitable covers and convenient locations for them.

Hardening High-speed Steel—High-speed steel must be heated to a much higher temperature for hardening than carbon steel. A number of tools which the gunsmith uses today are made from this class of steel; in fact, all barrel tools are made from it. A temperature of from 1350 to 1550 degrees Fahrenheit is sufficient for carbon steel. High-speed steel requires from 1800 to 2200 degrees Fahrenheit. The usual method of hardening a high-speed steel tool, such as a lathe turning tool or forming tool, is to heat the cutting end slowly to a temperature of about 1800 degrees Fahrenheit, and then more rapidly to about 2200 degrees, or until the end is at a dazzling white heat and shows signs of melting. The tool point is then cooled, either by plunging it in a bath of oil (linseed or cottonseed) or by placing the end in a blast of dry air. When an oil quenching bath is used, its temperature is varied from the room temperature to 350 degrees Fahrenheit, according to the steel used. The exact treatment varies for different steels, and it is advisable to follow the directions given by the steel manufacturers. Formerly the air blast was recommended, but oil is now extensively used. It is very important to quench the heated steel rapidly after removing from the source of heat.

The barium-chlorid bath is used quite extensively by most arms manufacturers and gunmakers. I have found that this is the only bath to make the small high-speed barrel tools come out clean and hard. The barium chlorid forms a thin coating on the steel, which is thus protected from oxidization while being transferred from the heating bath to the cooling bath of oil. Tests have demonstrated, however, that barium-chlorid baths have certain disadvantages for heating high-speed steel preparatory to hardening, because if the steel is heated to the required temperature, the surface of the tool is softened to some extent. Nevertheless, whatever experiences have resulted in this respect, I have found it to be the only successful method to use on small high-speed tools.

The method which I use to secure these satisfactory results in hardening high-speed tools such as drills, reamers, cutters, counterbores, etc., have been obtained as follows: Coat the tools well with bone-black mixed in raw linseed oil and preheat in an oven type of gas furnace from 1550 to 1700 degrees Fahrenheit. Then transfer the steel to the barium-chlorid bath heated to about 1800 degrees.

Gradually bring the temperature up to 2200 degrees, and allow the tools to remain at that temperature for five minutes. Remove swiftly and immerse directly in the oil bath. Such tools, after becoming cold, are then heated in an oil bath between 350 and 400 degrees Fahrenheit, to relieve all strain, and are then dipped into a caustic-soda bath to remove any oil which may adhere to the tools, and then into hot water. This method should be applied to all tools after being tempered.

Local Hardening—One method of hardening locally is to cover the part that is to remain soft with a thin metal shield, so that it prevents the surface from being suddenly cooled by direct action of the cooling medium. (This method is often applied to shotgun parts.) The steam or vapor which forms beneath the cover prevents the cooling medium from entering until the work has cooled sufficiently to prevent hardening; therefore, a rather loose-fitting shield is desirable. The shield should be made of sheet-iron or steel of about No. 29 gauge (0.014) for ordinary work. It is composed of one or more pieces, depending upon the shape of the part, and when several pieces are required they can be bound together with wires. Of course, the surfaces to be hardened are left exposed. The heating should be done in a furnace or open-forge fire. A lead bath should not be used because the hot lead beneath the shield will cause an explosion when the part is cooled. The quenching bath may be the same as when the shield is not used.

Local hardening is also effected by the application of a compound called "enamelite" to the parts which are to remain soft—an application of Formula 27 in Chapter XVI. This compound for tool steel comes in the form of a powder which is mixed with hot water to form a paste. It has the property of clinging to the steel and liberating hydrogen (the greatest known non-conductor) when heated steel is plunged in water. This causes the steel to retain its heat long enough to escape the chill, and remains soft where the enamelite has been applied. A coating of the coppering solution applied to the piece will also cause a spot of local hardening.

Hardening Defects—Uneven heating is the cause of most of the defects in hardening. Cracks from the corners or edges of the tool indicate such uneven heating. Cracks of a vertical nature and dark-colored fissures indicate that the steel has been burned and should be scraped. Tools which have hard and soft places have been either unevenly heated, unevenly cooled, or "soaked"—a term

used to indicate prolonged heating. A tool not thoroughly moved about in the hardening fluid will show hard and soft places, and have a tendency to crack. Tools which are hardened by simply dropping them to the bottom of the tank sometimes have soft places, owing to contact with the floor or sides of the tank. They should be thoroughly quenched before dropping them completely. When a tool appears soft and will not harden, it probably has been decarbonized on the surface by too much heat or by soaking too long. The surface must be removed before the tool will harden properly. Tools are sometimes soft because the cooling bath is not large enough and becomes too warm after a few pieces have been hardened.

Overheated Steel—Overheated steel that is not actually burned can be partly restored by heating to the proper heat and allowing it to cool slowly in hot ashes or sand. When cold, the steel is hardened again at the proper heat throughout. If the overheating originally took place in forging, the risk of cracking in hardening will be lessened by adopting the process mentioned. Care should be taken that the tyer of the forge is well covered when heating tool steel; a tool coming in direct contact with the air blast will become surface-burned, show soft places in hardening, and wear badly in use.

Scale on Hardened Steel—To prevent scale, care must be taken to keep the heated steel from being exposed to the direct action of the air. When using an oven-heating furnace, the flames should be so regulated that they are not visible in the heated chamber. The heated steel should be exposed to the air as little as possible when transferring it from the furnace to the quenching bath. An old method which we used for preventing the scale and retaining a fine finish on tools in the manufacturing division at the arsenal was to paint the work with bone-black mixed in sperm oil. I have always used this and always obtain fine results on tools. Another method which is used by jewelry manufacturers for small dies, taps, etc., is to fill the die impression with powdered boracic acid, and place near the fire until the acid melts. A little more acid is added to insure covering all the surfaces. The die is then hardened in the usual way.

If the boracic acid is not removed in the quenching bath, immerse the work in boiling water. Dies hardened with this method are said to be as durable as those heated without the acid. The advantage of using bone-black is that as soon as

the steel is immersed in the bath, the bone-black disappears.

Tempering by the Color Method—Hardened steel can be tempered or made softer and less brittle by reheating it to certain temperatures (depending upon the nature of the steel and its intended use) and then cooling. When steel is tempered by the color method, the temper is gauged by the colors formed on the surface as the heat increases. First, the surface is brightened to read the color changes, and then the steel is heated either by placing it upon a piece of red-hot metal or gas-heated plate, or in any other available way. As the temper increases, various colors appear on the brightened surface. First there is a faint yellow which blends into a straw, then light brown, dark brown, purple, blue and dark blue, with various intermediate shades. The temperatures corresponding to the different shades are given in tables on temperatures and colors for tempering. (Figure 47.) Lathe and milling-machine tools, chisels, etc., are commonly tempered by first heating the cutting end to a cherry red, and then quenching the part to be hardened.

When the tool is removed from the bath, the heat remains in the unquenched end until the desired color (which will show on the brightened surface) is obtained, after which the entire tool is quenched. The foregoing methods are convenient, especially when only a few tools are to be treated; but the color method of gauging temperatures is not dependable, as the color varies with the composition of the metal.

The modern method of tempering, especially in quantity, is to heat the hardened parts to the required temperature in a bath of heated oil; the parts are then removed from the bath and quenched. The bath method makes it possible to heat the work uniformly, and to a given temperature within close limits.

Tempering in Oil—Oil baths are extensively used for tempering tools, the work being immersed in oil heated to the required temperature as indicated by a thermometer. It is important that the oil have a uniform temperature throughout and that the work be immersed long enough to acquire this temperature. Cold steel should not be plunged into a bath heated for tempering, owing to the danger of cracking it. The steel should either be preheated to about 300 degrees Fahrenheit before placing in the bath, or the latter should be heated to the required degree. A temperature of from 650 to 750 degrees Fahrenheit can be obtained with a potassium nitrate bath.

FAHRENHEIT-CENTIGRADE

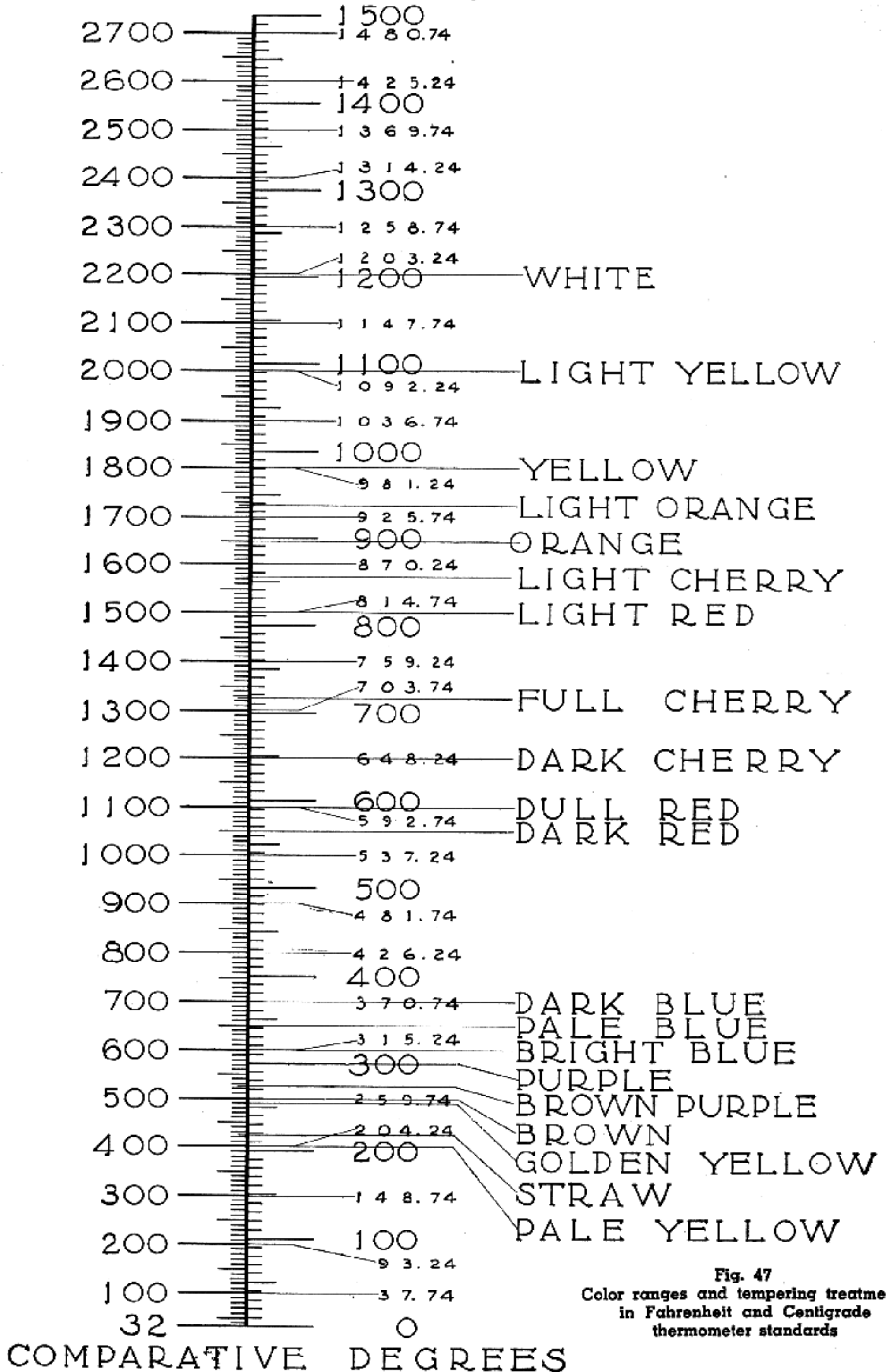


Fig. 47
Color ranges and tempering treatments
in Fahrenheit and Centigrade
thermometer standards

COMPARATIVE DEGREES

Tempering Furnaces — In tempering furnaces, the only really important consideration is to make sure that the furnace is so built as to heat the bath uniformly throughout. It is never safe, however, to let any tools being tempered rest against the bottom or sides of the tank, as no matter how scientifically the furnace may be built, these parts are in most cases hotter than the fluid itself. It is, of course, just as important to keep the thermometer from resting against any of these parts, in order to insure correct readings. After the pieces tempered are taken out of the oil bath, they should immediately be dipped in a tank of caustic soda (not registering over 8 or 9) and after that in a tank of hot water. This will remove all oil which might adhere to the tools.

Case-hardening — Case-hardening is the process of hardening the surface of low-carbon steel or iron by carbonizing the surface. When parts must be case-hardened in quantity, they should be packed in an iron box containing some carbonaceous material. The box and its contents are then heated for a certain length of time, depending upon the degree of hardened surface desired and the nature of the material. The heat for case-hardening varies from 1550 to 1700 degrees Fahrenheit, the temperature being governed to some extent by the requirements. The absorption of carbon begins when the steel reaches about 1300 degrees. At the end of the carbonizing period, the box is withdrawn from the furnace and is allowed to become quite cold. The box and the articles are then placed in a muffle furnace and reheated to about 1450 degrees Fahrenheit after which they are quenched in cold water, tepid water, or oil, the bath depending upon the purpose for which the parts are to be used. For ordinary purposes, clear cold water is satisfactory. To produce a very hard surface, use salt water. When a hard surface is not important, as in the case of a tough core, use an oil bath. The practise of allowing the box and its contents to cool and then reheating prior to quenching is based on the old rule of hardening on a rising heat. This method gives more satisfactory results than that of plunging the parts into a tank of cold water at the end of the carbonizing period.

Carbonizing Materials — The carbonizing materials in general are charred leather, powdered bone, cyanid of potassium, wood and "animal" charcoal, prussiate of potash, and other compositions consisting of mixtures of carbonaceous matter and certain cyanids of nitrates. For slight hardening, cyanids are often used. Charred leather gives good results, altho poorly charred leather or

that made from old boots, shoes, belting, etc., should not be used. A mixture preferred by some to charred leather consists of 60 parts wood charcoal and 40 parts barium carbonate. There are some excellent carbonizing materials made by the E. H. Houghton Company of Philadelphia, Pennsylvania.

Steel for Case-hardening — The percentage of carbon in steels ordinarily used for parts to be case-hardened varies, as a general rule, from 0.15 to 0.20 per cent. If the carbon exceeds 0.20 per cent, it tends to give a hard instead of a soft core. If the carbon content is too low, the steel may be difficult to machine; therefore, steels containing as much as 0.20 to 0.25 per cent carbon are often used for case-hardening. For general work, steel of the following composition will be found satisfactory: carbon, 0.16 to 0.20 per cent; manganese, less than 0.35 per cent; silicon, not over 0.30 per cent. The sulfur and phosphorus should be as low as possible, not exceeding 0.10 per cent.

Degree and Depth of Hardened Surface — The percentage of carbon contained in the case-hardened surface should vary according to requirements. A high-carbon case contains 1.10 per cent carbon, giving a very hard wearing surface suitable for work that must withstand a fairly constant pressure such as shafts running in bearings; but for parts which must withstand repeated shocks, such as actions, this amount of carbon would render them too brittle; in such cases it is advisable not to exceed 0.90 to 1 per cent carbon. For most purposes, 0.90 per cent carbon is preferable. Various experiments indicate that the percentage of carbon in the hardened crust varies with the depth of the latter; the deeper the penetration, the higher the contents. Crusts about 0.050 inch deep usually have from 0.85 to 0.90 per cent carbon on the surface. In many instances a penetration of 0.040 inch is sufficient, but if the work is to be ground after case-hardening, it is advisable to carbonize to a depth of about $\frac{1}{16}$ inch. Too deep a carbonized case makes the work more brittle, partly because of the prolonged exposure to a high temperature and partly on account of the increase in the hardened section and the decrease in the softer and more ductile core; hence, parts to withstand bending stresses, like gear teeth, should not be carbonized too deeply. Further, penetration of the carbon increases with the temperature and with the time of exposure, but not in direct proportion to these two factors. Carbonization takes place rapidly until the crust is saturated with carbon, when there is a sudden diminution in the rate of carbon-

ization, which varies according to the temperature.

Case-hardening for Colors — For hardening and at the same time coloring such parts as single-shot actions, shotgun actions, guards, butt plates, etc., the following mixture may be used: 10 parts of charred bone, 6 parts of wood charcoal, 4 parts of charred leather, and 1 part of powdered cyanid. The leather should be black, crisp, and well pulverized, and the four ingredients well mixed. The object in charring the bone and leather is to remove all grease. The parts to be colored must be well polished and should not be handled with greasy hands. If the colors obtained are too gaudy, the cyanid may be omitted; and if there is still too much color, leave out the charcoal. The parts to be colored and hardened should be packed in a piece of common gas pipe having a closed end. Pipe is preferable because the pieces can be dumped into the cooling water with little or no exposure to the air. The opened end of the pipe can be placed close to the surface of the water before the parts are removed, but with a box there would be more or less exposure. This class of work should be heated to a dark cherry-red and kept at that temperature for three hours or longer. If the temperature is too high, no colors will appear. The tank should be arranged with a compressed air pipe connected with the water pipe at the bottom in such a way that a jet of air is forced upward, thus filling the tank with bubbles. There should also be a sieve or basket in the tank for receiving the work. After quenching, place the parts in boiling water for five minutes, and then bury them in dry sawdust for half an hour. Another mixture recommended for coloring consists of 10 parts granulated bone, 2 parts bone-black, and 1 part granulated charred leather.

To Clean Work After Case-hardening — To clean work, especially if knurled, where dirt is likely to cling in the crevices after case-hardening, wash it in caustic soda (1 part soda to 10 parts water). In making this solution, the soda should be put into the hot water gradually, and the mixture stirred until the soda is thoroughly dissolved. A still more effective method of cleaning is to dip the work in a mixture of 1 part sulfuric acid and 2 parts water. Leave the pieces in this mixture about three minutes; then wash them off immediately in a soda solution.

Pack-hardening — Pack-hardening, as the term is generally understood, consists in treating steel (generally tool steel) with some carbonaceous material and quenching it in oil. The terms "pack-

hardening" and "case-hardening" are often used interchangeably, the two processes being similar. The surface of the steel is supplied with additional carbon by the use of some carbonaceous material that will not be injurious. To do this, the steel is packed in sealed in iron boxes with the carbonizing material. Bone should never be used for pack-hardening tool steel, as it contains a high percentage of phosphorus which tends to make the steel weak and brittle. For steel that is to contain not more than 1.25 per cent carbon, charred leather is recommended. For obtaining a higher carbon content, use charred hoofs or horns, or a mixture of the two. The leather, hoofs or horns can be used repeatedly by adding a quantity of new material each time. A mixture of charred leather and charcoal is used for pack-hardening. The work should be so packed that it does not come in contact with the box. First, place a layer of carbonizing material in the bottom and then a layer of the work, no two pieces touching each other. When treating gauges or parts that are likely to spring, they should be so packed that there will be little liability of springing when they are drawn up through the packing material. The parts should not be plunged into the quenching bath, as it is better to handle the pieces separately. It is a good plan to attach a piece of iron wire to each part to facilitate the removal from the box. If there are several layers of work, the wires should be so arranged that the various layers can be taken out in the proper order, beginning with the top row. The temperature for pack-hardening should be as low as is consistent with the desired results, and should be uniform throughout the box. To gauge the heat, holes may be drilled through the cover at the center so that test wires (say $\frac{3}{16}$ inch diameter) can extend to the bottom of the box. When the latter has been in the fire long enough to heat the contents to about a dull red (as near as can be judged) a wire is withdrawn; if it is red hot, begin timing the heat; if not, wait and draw another later, the test being continued until one is withdrawn that has the desired heat. The length of time necessary for heating depends upon the depth of hardening surface desired. For ordinary gauges, from one and one-half to two hours after the steel is red-hot is sufficient. Ordinary work requires a temperature of about 1425 degrees Fahrenheit. Pack-hardening minimizes the danger of cracking and warping.

Case-hardening Alloy Steels — When nickel steels are heat-treated by case-hardening, nickel seems to retard the process somewhat and reduce the hardness of the "case" in ordinary carbon

steels; on the other hand, nickel tends to oppose the crystallization of the steel at high temperatures and to eliminate the consequent brittleness. The steel should first be quenched from a temperature of 1750 degrees Fahrenheit. It is then given a second heating to 1375 degrees and is again quenched. After cooling to about 1275 degrees, a single quenching from 1275 degrees gives the greatest hardness in the case, but not the greatest tenacity in the core. Quenching from 1375 degrees Fahrenheit gives a somewhat higher tenacity, but a slightly lower hardness in the case. A 6 per cent nickel steel should be quenched first from 1550 degrees, and after reheating, from 1450 degrees. Since this high nickel percentage almost completely prevents the brittleness of the core, one quenching from about 1300 degrees Fahrenheit is in most cases sufficient. Steels with from 1 to 1.2 per cent chromium are sometimes used when an especially hard case is required. This element aids the crystallization of the core and the double quenching is necessary. Chrome nickel steels with a low chromium content require about the same heat-treatment as pure nickel steels. A mixture of 60 parts wood charcoal and 40 parts barium carbonate is recommended for carbonizing.

Different Methods of Hardness Testing—

There are four typical methods for testing the hardness of metals. These are the sclerometer method introduced by Turner; the scleroscope method invented by Shore; the indentation test adopted by Brinnell, and the drill test introduced by Krupp.

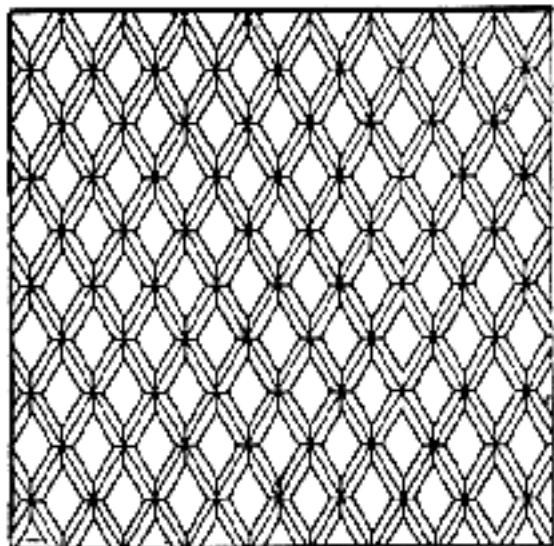
The Shore scleroscope: in this instrument a small cylinder of steel with a hardened point is allowed to fall upon the smooth surface of the metal to be tested, and the height of the rebound of the hammer is taken as the measurement of hardness. The hammer weighs about 40 grains, the height of the rebound of hardened steel is at the point of 100 on the scale, or about $6\frac{1}{4}$ inches, while the total fall is about 10 inches, or 254 millimeters. This instrument is one of the most simple to use, and very accurate results are obtained. We

had both the Shore and Brinnell instruments at the arsenal, but the Shore scleroscope was the one mostly used. Of course, where strength of materials is to be considered, the Brinnell instrument is used constantly.

This chapter is submitted as a help to students, but they should inform themselves more fully in regard to the underlying principles as well as the methods employed in the heat-treatment of steels. Every chemical reaction has a time factor. In the slow cooling or heating of steels the reaction takes place at the critical temperatures, and the products of the reactions are in a state of stable equilibrium. If this time factor be disturbed, the state of equilibrium is also disturbed. If the rate of cooling is rapid enough, the reactions which ordinarily take place on slow cooling are suppressed and the metal is maintained in the condition in which it existed at the temperatures from which the cooling began. I could continue to fill page after page of such valuable information, but you would only be burdened with information that would still be incomplete, for steels are a scientific study; a careful reading of the following books is recommended: *Iron, Steel, and Other Alloys*, by Howe; *Metallography*, by Desch; *Microscopic Analysis of Metals*, by Osmon and Stead; *Metallography of Iron and Steel*, by Sauveur.

In conclusion it may be stated that there is a tendency to overrate the heat-treatment of steels. These pages contain valuable information for actual practise, and most of these results were taken from our heat-treating department in the Small Arms Division at the Frankford Arsenal. It will be well to secure microscopic photographs of steel which will enable you to judge steel and its composition and defects. Also one must understand what a large amount of special equipment it requires to undertake the heat-treatment of actions such as the Springfield model 1903, Enfield model 1917, Krag model 1898, or Mauser action; but before attempting any such work, train yourself and secure the necessary experience; for without this special training and equipment you are only courting a considerable amount of disaster.

CHAPTER VIII
Rifle Barrel Design
and Fitting



Rifle Barrel Design and Fitting

PROPER tools and a fair understanding of mechanics are the first essentials in the construction of a rifle barrel. Altho it is possible for any skilled and ingenious person to follow these instructions and make a barrel, there are a certain number of machine tools required to make a rifle barrel for our modern high-velocity cartridges. Some will say that it is impossible to make any kind of a barrel without complete, if not elaborate, equipment. Nothing is impossible if determination dominates. This has been demonstrated time and time again throughout the history of mankind, but the following instance applies best to our subject.

Some years ago I corresponded with a man who had spent eighteen years of his life wandering in the isolated districts of Alaska. During the course of our correspondence he told me of an interesting discovery. Deep in the interior of the country, over two hundred miles from civilization, he met one of the most ingenious men with whom he had ever come in contact. This man had set up a workshop to carry out his own ideas, using wood for almost everything except the steel tools that were required, such as reamers, etc.; his turning lathe, reaming machine, and rifling machine were made from hard wood obtained from the surrounding forests. In this workshop he made two single-shot rifles, constructing the barrels and the action from his home-made and extremely crude equipment. The steel blanks for the barrels and steel for the actions were procured from the States. The action was filed out mostly by hand, and the making of a rifling head and chambering reamers alone required a genius, for these tools are difficult for even specialized tool makers. When asked why he did not secure a Springfield rifle, which was easily available to him, he explained that he was under the impression that Springfield rifles were unsafe; thus he made these up himself, knowing them to be safe and to his liking. Then he tried them out, and found that at a distance of one hundred yards they shot as well as any Springfield.

If a man with only the most primitive means can accomplish so difficult a feat as building a firearm, certainly we who have the most modern and efficient supplies at our very finger-tips, so to speak, should become expert in using our hands to carry out orig-

inal ideas where it is impossible to have these performed as one desires. We all dream sometimes of realizing some definite ambition, but are without means or perhaps inclination to secure the knowledge necessary. This knowledge is sometimes acquired through books, and again through watching an expert. All things can be accomplished if you have the patience to develop the skill that is a prerequisite in this work. Always remember that it requires hours of hard work to become experienced. The mistakes we make should only be of further value to us.

In the design of modern barrels, the purpose for which they are to be used governs their construction. For game, a barrel must be made as light as possible, considering, of course, the limits of its safety. In a hunting rifle, therefore, the barrel should be light, for this is where most of the weight is confined. We have two types of actions to consider when giving a finished arm the correct balance. On bolt-action rifles, the barrels can be made much shorter for balance, but in a single-shot arm we must apply length in order to match the difference in action length. A serious factor is presented in barrel design, particularly to those who have never applied any forethought to the subject. As an illustration, look at the number of shooters who are procuring .22-caliber M-1 barrels and fitting these to single-shot actions; the balance is out of all proportion for the action. For single-shot actions, the length of barrel should be between 26 and 30 inches; in a bolt action, 24 inches is sufficient.

Target-rifle barrels have been the theme of endless discussions, and no one knows to this day what the correct weight should be. A number of limitations are arbitrarily imposed just because Bill Jones can handle a 28-inch $1\frac{1}{4}$ straight barrel (he is six feet and weighs better than 220 pounds) and produce fine scores at long ranges; for this reason Tom Green orders the same barrel (tho he only weighs 140 pounds and is five feet seven inches tall). Long-range rifle shooting is the most difficult; it requires finer training, wider knowledge, and better physique; therefore, heavy barrels must be constructed according to the build of the individual; if one person is successful in using the heaviest barrel, other men may be defeated because of its weight.

True, weight is needed for steady holding; and it will minimize movements which flinch or jerk the trigger and prevent small muscular tremors which disturb aim so greatly. A target barrel should be designed rather muzzle-heavy, so that, in the act of holding and aiming, it has a tendency to swing slower in various directions from the target.

To reduce weight and give the desired balance to the modern sporting-rifle barrel, it is made as light as possible at muzzle with length between 18 and 26 inches; the breech or chamber end varies slightly, as Figure 50 illustrates. The straight portion is carried forward to a point corresponding to the forward shoulder at the chamber. There is usually a short sharp taper or a radius at a point approximately $1\frac{1}{4}$ inches ahead of the chamber, therefore insuring much heavier metal over the portion of the barrel containing the chamber; at this point is where the peak of the pressure comes. From the forward end of this short taper or radius there should be a continuous straight taper within four inches of the muzzle. This straight portion is made for the intended use of a ramp.

Barrel Steels — A service Springfield rifle fired from the shoulder recoils about $\frac{1}{8}$ inch before the bullet leaves the muzzle, the point of resistance to its movement being below the center of gravity, which has then already begun to rise. The barrel is not, as often supposed, a rigid body incapable of bending; just the reverse—it is very sensitive to stress. The pressure of a finger will bend it considerably. Like any other metallic rod or tube, a rifle barrel vibrates when struck, and owing to its proportions it more closely resembles a rod than a tube in the manner in which vibrations take place. However, it is with its vibrations as a rod rigidly fixed at one end that we must be more immediately concerned. In such a state there are two types of transverse vibrations which can take place; first, fundamental vibrations in which the whole length of the barrel vibrates as a single unit, there being only one point at which the barrel is still—the location at which it is fixed or screwed into the action—"the breech"; second, a series of overtones in which the barrel is divided longitudinally into a number of vibrating sections, each terminating in a position at the nearest end—the chamber. These two types of vibrations can, and usually do, coexist. The frequency of the fundamental vibrations depends on the proportions of the barrel, and that of each particular overtone is always in a fixed ratio to that of the fundamental. The shock of the explosion naturally sets up these vibrations in a forcible manner, and they are affected more or less by the irregularities in the shape of the contour of the

barrel; also by any external attachments not designed for the purpose intended, or placed in the wrong position, and also by the manner in which it is stocked. The compounded effects of the fundamental vibrations and the overtones at the time when the bullet leaves the muzzle on the inclination of the last few inches of the barrel, in relation to the axis of the bore before firing, constitute the main contributory factor in the "jump" of the rifle.

Variations in the vibrations may also arise from various other causes. As the bullet passes up the barrel, the gases behind it are exerting pressure in all directions upon the chamber and upon the bore; the entire bore is, indeed, expanded in a minute degree in the rear of the bullet. The bullet fits the bore tightly, therefore sealing it, and creating heavy friction during its passage. Any variation from one shot to another in the amount of this friction will affect not only the velocity, but the amount of movement imparted to the rifle before the bullet has reached the muzzle. Therefore, to have all bullets one size, diamond resizing dies should be employed so that bullets will come in one given diameter. The actual and relative effect of these influences will, of course, vary largely under different conditions. A heavy barrel is less affected than a light one by equal stresses. A heavy charge will set up more vibrations and general motion than a light one in the same barrel. On the other hand, when the velocity is low, the motion will have more time to develop before the bullet emerges, and consequently the whole disturbance may be equally great, tho less violent and rapid.

Steel is a variety of iron containing carbon to the extent of from 0.1 to 2.0 per cent. Other alloys are present in varying proportions, but the carbon is the most important substance, and it is to the presence of carbon that steel owes its most valuable property—that, by certain heat-treatments and methods of cooling, it can be brought to any desired state of hardness or softness within very wide limits. Steel is placed under various classifications, as the property of "hardening" increases up to certain points with the percentage of carbon contained; therefore a higher-carbon steel is employed in the barrel than would be found in a sling swivel or butt plate. In the case of the barrel steel employed, a very rigid tensile-strength test is applied; the yielding point must not occur at under 50 tons to the square inch, and the test piece must not show an extension of less than 20 per cent before fracture.

Since the high development of steels these past few years, two classes of barrel steel should be used altogether for rifle barrels, regardless of caliber: $3\frac{1}{2}$ per cent nickel steel and stainless or rust-proof steel. In the past, in general practise among rifle

manufacturers, barrel steels were divided into four classes:

- (a) Cold-drawn steel, known as black-powder barrel steel.
- (b) High-carbon steel, sometimes known as "ordnance steel."

In later years the following have been added:

- (a) Alloy steel, known as 3½ per cent nickel steel.
- (b) Stainless or rust-proof steel.

Under these general classifications, gun manufacturers have their own specifications as to the composition of the alloys, together with their physical properties, under which they buy their steels from the mills in the form of bars. Chapter VI is devoted to all classes of steels, and it would be well to refer to this before making a rifle barrel.

Cold-drawn or Black-powder Steel — This is the steel usually used in the manufacture of .22-caliber rifle barrels, for the reason that any lead bullet only requires a steel of a low carbon content, and the ammunition having lead bullets never develops any greater breech pressure than 20,000 or 30,000 pounds per square inch. The tensile strength of this steel runs between 45,000 and 65,000 pounds per square inch; therefore it once answered all general purposes of such ammunition. Because of the introduction of high-velocity cartridges with jacketed bullets, a change was necessary for higher carbon contents, greater tensile strength, and elasticity.

When cold-drawn steel is used for .22 or .25 rim-fire cartridges having lead bullets exclusively, this steel is very satisfactory from the manufacturing point of reasonable-priced rifles; but for finer accuracy in target barrels the higher carbon or alloy steels should be used.

High-carbon Steel — Ordnance steel is a medium-carbon steel with a high manganese and added silicon content; therefore it is being used by a number of manufacturers for high-power rifles. This steel is known as No. 1350 under the S. A. E. (Society of Automobile Engineers), and to this is added 0.25 per cent silicon. A heat treatment greatly increases its yielding point and ultimate strength. The modern practise of the heat-treatment of steels has become so complex, involving, as it does, a very definite knowledge of the thermal changes occurring in the metal as it is heated and cooled, that it is well to read as much as possible on the subject before attempting this work or going to the expense of equipment. I believe that it will be far better to rely on nickel steel and use it as a standard for nearly all rifle barrels.

Nickel Steel — This steel is best adapted to rifle barrels because of its nickel content, regardless of whether it is to be used for a high or low velocity arm. To secure the finest results from this steel it should be given a heat treatment, for when annealed it is slightly better than ordnance steel, and is still superior to it in wearing qualities. It is a little more difficult to drill and rifle than the ordnance steel; accordingly, high-speed drills, reamers, and cutters are required—with the exception of chambering tools.

Altho the heat treatment of this steel is in principle essentially like that of the plain carbon steel, the introduction of the alloying element, nickel, necessitates that the treatment be modified profoundly to raise the high tensile strength and give it greater elasticity. If this is done, it will never change even tho it becomes heated after a number of shots are fired, a common defect in high-carbon or nickel steel that has not been heat-treated.

In general, with the addition of the special element, nickel, the treatment may be modified in the following way: by the lowering of the critical ranges or transformation temperatures, which are, in plain carbon steels, stable only at high temperatures. Nickel is one illustration of this behavior.

The structural condition in which the special element exists determines largely the proportion of the steel and to a large extent the heat treatment necessary to develop the required proportion; that is, whether the added element enters into the ferrite constituent, nickel, or into a combination with the carbon, as with chromium in the latter. The special element increases the mineral hardness of the steel without increasing the brittleness to such a degree as an addition of two or more special elements will. The advantages of each may be retained and the disadvantages largely neutralized, as in chrome-nickel steels, which as a type probably represent the best all-around alloy steel in commercial use for barrel making.

I conducted exclusive tests with these two steels in rifle barrels and found that the nickel steel with a percentage of chromium and vanadium gives the steel sufficient tensile strength and elasticity limits so that it can be turned on a lathe from the 1½₁₆-inch bar down to 0.56 inch on a taper to the muzzle, at high speed, the length of the barrel being 34 inches. By using a high speed and a coarse feed, the entire tube was turned upon this taper and only showed about 0.003 inch out on the inside after it was completed and allowed to cool. Such steel is known as "AAA" and is made by the Ford Motor Company.

In these tests it was necessary for the steel to be

"normalized," which may be considered under the head of annealing. It consists of heating the steel above the critical range after the drill has been passed through and a roughing cut taken over the entire length of the bar in order to have the outside and bore concentric with each other before the barrel is placed in the furnace. The usual rule for normalizing any steel is to heat it above the critical range and cool it in air, which serves to put the steel in an undressed condition of fine crystal size and arrangement; in these tests, however, the furnace was turned out and the steel and furnace were allowed to cool, which gave it a better physical proportion and did not allow the friction or the heat generated by the turning tool to spring it out as on ordinary barrel steel.

After this roughing operation, another normalizing took place which could be called double annealing; this was done for maximum grain refining. The steel was heated to a temperature somewhat above the critical range, air-cooled for three minutes out in the open, and then quenched in oil, followed by reheating to a temperature just below the critical range. The completion of the reaming and finish-turning took place, and also the rifling, chambering, and final fitting.

The toughening or hardening must be just above the critical range, and the barrel should be heated long enough to insure complete grain refining; too high a temperature must be avoided. Since the normalizing temperature is above the critical point, it places the steel in a fine crystal form, so this must be watched; otherwise, when placed in the tempering bath, too great a change takes effect and allows the barrel to warp the slightest amount, which cannot be straightened by pressure or any other means. If it is held just a little above the critical range the barrel comes out very straight. The oil bath imparts to the steel a very tough surface and greatly lengthens the life of the barrel.

The making of a rifle barrel by such methods requires rather large furnaces and other elaborate equipment, but the day is not far distant when perfect rifle barrels will be made, particularly to satisfy the target shooter. Such barrels will be expensive; but when all rules of precision are used and a perfect barrel is made, the conditions of sports will change so that to predict future results will be almost impossible, except, of course, that ammunition will have to be competent for the barrels. The shorter the range, the greater would be the possibilities allowed to overcome the difficulties presented, and such barrel design together with the proper steels would overcome all discussion. Range and position governs the design of any target barrel; at the same time the sporting rifle barrel could

be reduced greatly in weight and such arms would be made better in balance.

Stainless or Rust-proof Steel — This steel has been adopted by one of our leading firearm manufacturers for rifle barrels with an additional cost over the nickel-steel barrels. We have not had the opportunity to make any extensive tests with this steel of American manufacture, and so whether it will be the barrel steel of the future cannot be foretold. Some of the earlier forms of rustless steel were imported from Germany and Austria, such as Poldi "Anticora" steel and Boehler "Antinit," which were used for rifle barrels. Both steels are very hard to drill, ream, and rifle, and require the importation of special tool steel. The American so-called "stainless" steel has a high percentage of chromium content; therefore we must place it under the head of a special alloy steel with a copper content also. None of these steels are really rust-proof; all will rust if given enough exposure to the elements, but they are much more resistant to rust than other barrel steels. All these rustless steels are so resistant to rust that it takes as many as twenty applications of the bluing solution to bring out a satisfactory blue appearance. Before the solution can be applied, a special coppering process must be first applied and then subjected to the bluing solution, which really turns the copper to a black-gray color, except Formula No. 1, Chapter XVI, which takes on stainless steels. As stated before, all these steels are very difficult to operate upon. This, in addition to the high original cost of the steel, makes these barrels much more expensive than the ordinary nickel-steel barrels, with the added difficulties taken into account.

If the bore were given a treatment of chromium plating, the nickel steel would be far more satisfactory than any form of rustless steel made. A perfect heat-treated nickel-steel barrel, given a plating of chromium in the bore—or a higher-grade alloy than chromium—would solve the problems of rust and produce a far better barrel, incidentally eliminating friction to a greater extent. Such alloys would completely fill the small invisible grooves left by the barrel tools and give the interior a highly polished surface which would be difficult to secure without using a diamond cutter in the rifling head.

Standard Barrel Design — A rifle barrel must have a certain wall thickness in order to be safe against bulging in the chamber when using a high-velocity cartridge; bore pressure is also a vital factor; therefore steel of a hard texture is required. Figure 48 illustrates the standard barrel for sport-

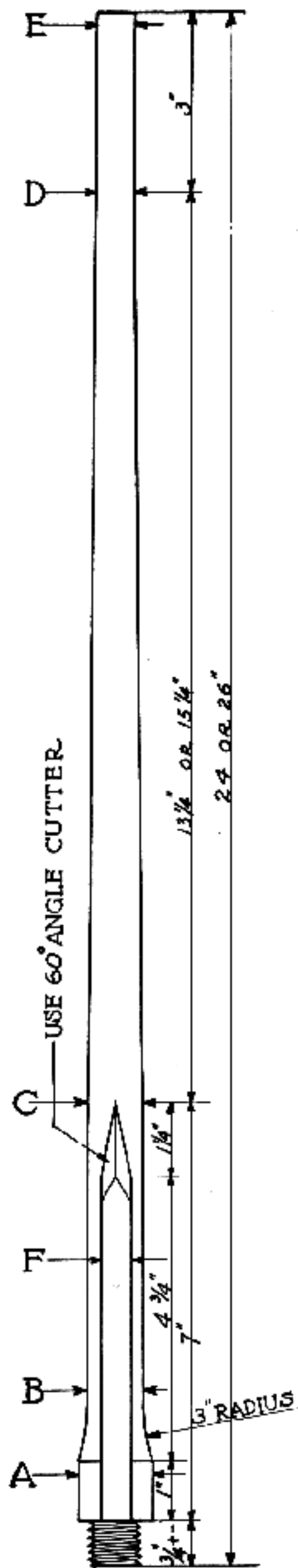
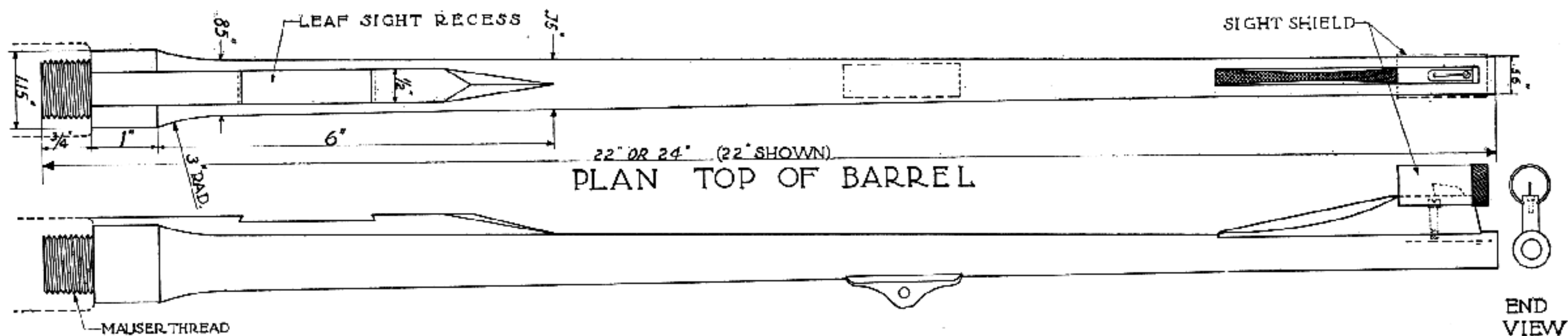


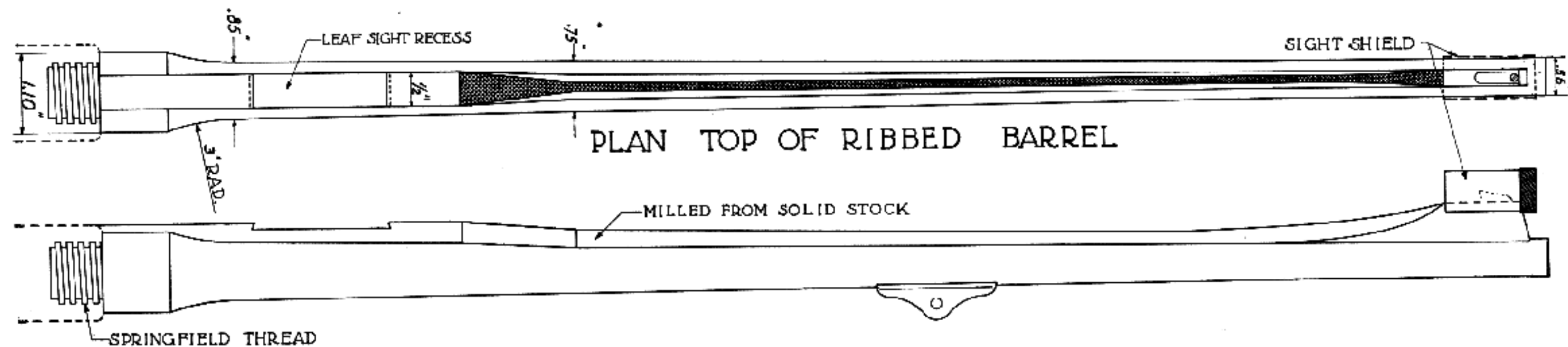
Fig. 48
Standard rifle-barrel design

STANDARD BARREL DIMENSIONS						
CALIBER	A	B	C	D	E	F
250/3000	1.125	.750 ^{to} .775	.700 ^{to} .725	.566	.566	1/2
6.5 M/M	1.20 ^{to} 1.21	" "	" "	"	"	"
7. M/M	1.200 ^{to} 1.225	.775 ^{to} .800	.725 ^{to} .750	"	"	"
275 MAG	1.225 ^{to} 1.250	.850 ^{to} .875	.750 ^{to} .775	"	"	"
280 ROSS	" "	" "	" "	"	"	"
3066 GOVT	" "	" "	" "	"	"	"
300 MAG	" "	.875 ^{to} .900	.775 ^{to} .800	"	"	"
375 MAG	" "	" "	.825 ^{to} .850	.630	.630	"
404 MAG	" "	.900 ^{to} .925	.850 ^{to} .875	.690	.690	9/16
10.75 M/M	" "	" "	" "	"	"	"
416 MAG	1.25	.925 ^{to} .950	.875 ^{to} .900	"	"	"
505 MAG	1.275	1.025 ^{to} 1.050	.950 ^{to} .975	.815	.815	.60
VERY LIGHT 3066 GOVT	1.20 ^{to} 1.21	.825	.725	.566	.566	.50
LIGHT 250/3000	1.125	.700		"	"	

SELECTION OF STANDARD CALIBERS FOR BOLT ACTIONS						
CALIBER	NO OF GROVES	TWIST	WIDTH OF GROOVE	WIDTH OF LAND	GROVE DIA	LAND DIA
.505 MAG	8	1 IN 16"	.115	.0795	.5055 .5045	.4955 .4945
.404 MAG	6	1 IN 14"	.140	.075	.4240 .4230	.4145 .4135
400 WHELEN	6	1 IN 14"	.140	.075	.4035 .4025	.4115 .4105
10.75 M/M	6	1 IN 13 1/4"	.140	.075	.4240 .4230	.4145 .4135
.375 MAG	6	1 IN 14"	.112	.080	.3760 .3750	.3680 .3670
.35 WHELEN	6	1 IN 16"	.106	.078	.3575 .3570	.3505 .3500
.300 MAG	6	1 IN 14"	.095	.062	.3085 .3080	.3005 .3000
.3063	4	1 IN 10 ^{or} 12	.170	.058	.3085 .3080	.3005 .3000
7 M/M	6	1 IN 10"	.090	.055	.2855 .2850	.2767 .2760
.270 WINCH	4	1 IN 10"	.154	.058	.2785 .2780	.2705 .2700
.25 NIEDNER	6	1 IN 12"	.076	.055	.2575 .2570	.2505 .2500
.22 NIEDNER	4	1 IN 16"	.073	.04	.2235 .2230	.2175 .2170
.22 LONGRIFLE	4 or 6	1 IN 16"			.2235 .2230	.2175 .2170



SIDE ELEVATION OF BARREL



SIDE ELEVATION OF RIBBED BARREL

Fig. 49
 Rifle-barrel designs—Ribbed and three-quarter ribbed

ing arms, as roughed out, and Figure 49 shows the finished barrel together with a rib barrel integral with the tube; also the fastening for the sling connection, whether quick-detachable or swivel-bow. This may also be integral with the barrel the same as the front-sight ramp, but the one at the top in Figure 49 is sweated in place and held with a screw; every part which is essential should be integral so that all will be solid. Of course, when any parts such as the ramp swivel base or rear sight base can be satisfactorily sweated, suitable screws should be used as well. The rear leaf-sight base should be a part of the barrel if open sights are to be used, and the sight rib and top of receiver should be flush, allowing the use of very low leaves. A light barrel on which the rib extends up a certain distance could be milled out with a shotgun rib effect with a small-end mill or slitting saw, not only to produce a pleasing appearance of the rib but at the same time to reduce weight considerably.

In the design of a modern barrel, weight and balance of the finished arm must be well considered, particularly on a sporting arm. A hunting rifle should be made as light in weight as is consistent

artificial aid he stumbles upon—foremost the long heavy barrel. It is doubtful whether all things can be equal or if this barrel of precision cannot be looked upon as a miniature piece of artillery rather than a small arm; but to the gunmaker it is as interesting as some of the suggestions he is often confronted with.

Barrels intended for target shooting, regardless of caliber, should be governed by the build of the individual. The very heavy "free rifle" barrel used in the International Matches—No. 8 barrel (Figure 50)—would be the top barrel, which has no taper in its entire length. This barrel when made between 28 and 30 inches in length is usually advisable for a rather large person, but a smaller person should first test it thoroughly and then cut it off until he can hold it steady and at the same time minimize muscular trembling. Target barrels should be near the same diameter as the receiver in order to place the greatest weight as near the receiver as possible, and this straight portion should continue about eight inches ahead, and then have the gradual taper of the muzzle. Such a straight section is better for the mounting of telescope bases where two blocks are mounted low. The ideal weight for a target

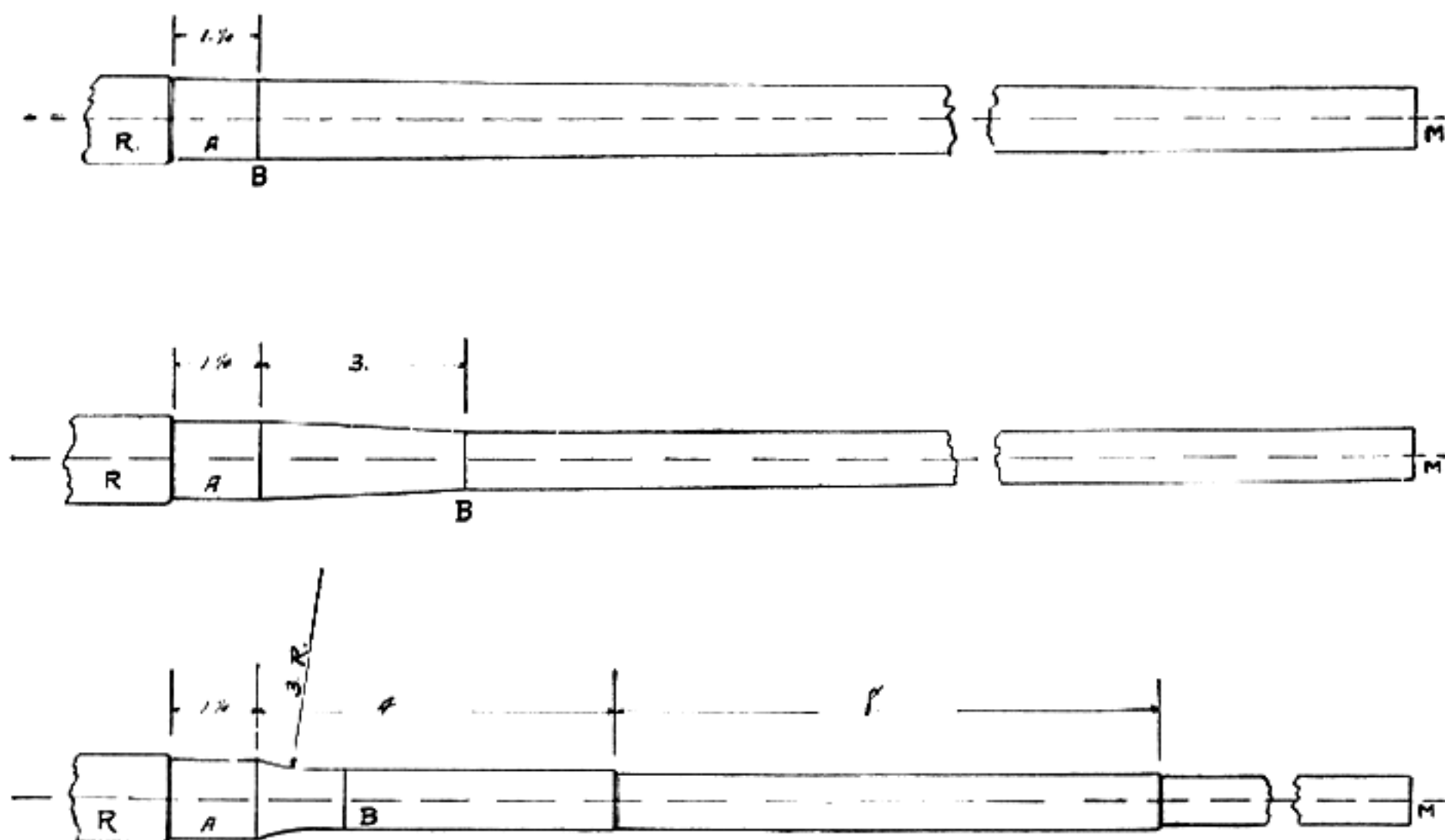


Fig. 50
Barrel design. Size to govern weight

with fine accuracy and moderate recoil, and should balance particularly well a short distance in front of the trigger, so that it will handle and move quickly for quick snap shots and shooting at running game. In a target-rifle barrel there should be weight enough to hold it steady. Yet some regard it as a scientific toy with which the target shooter attempts absolute accuracy and allows himself every

Number	Diameter at "A"	Diameter at "B"	Diameter at "M"
1	1.00	.75	.50
2	1.05	.85	.56
3	1.15	.95	.647
4	1.15	1.00	.700
5	1.20	1.05	.750
6	1.20		.875
7	1.25		1.00
8	1.25		1.25

barrel is difficult to define, for every one has his own idea on the subject.

It will be noted in Figure 48—Standard Barrel Design—that a number of the barrels have, at *E*, a diameter of 0.566 inch. This size is better for a more perfect balance and at the same time has a better appearance with the inclined ramp sweated in place at the top without an encircling band.

Many riflemen prefer the encircling band on the ramp to have more material for strength. Encircling bands on ramps have been a standard for the past ten years or more, but styles change in firearms as well as in clothes and the wise person usually adopts something with a better appearance. In the tables shown in Figure 48, one has a choice of barrel dimensions; but for the average person a suitable weight is a varying question in a sporting arm; therefore we must treat the question from an angle that all gunmakers have adopted. Accuracy is the first consideration and balance follows. To reduce weight in any barrel from a given standard for accuracy requires due consideration for the balance and at the same time recoil. Here is where stock design must be freely consulted to have both made in proportion, as weight in a barrel can often defeat the real purpose of balance in a standard designed stock; consequently, a stock must be made in proportion to the barrel weight.

Because barrel length has been considered but slightly, let me say that 24 inches in length is generally the standard from which nearly all hunting ballistics are obtained. We must regard this as a standard except for those in the magnum class, which should be 26 inches. The longer the barrel, the higher the muzzle velocity a given cartridge will develop. In the Springfield Model 1903 rifle and Model 1906 cartridge, a reduction of one inch in barrel length is equivalent to approximately 25 f. s. lost in muzzle velocity. On the Krag using the old W. A. powder, which burns more completely in a short barrel length, the difference between a 30-inch barrel and one cut off to 22 inches is only 60 f. s. lost in muzzle velocity. As the barrel is shortened, muzzle blast, flash, and report become greater, and because of these objectionable features many men disparage the advantages of short barrels, particularly when discovered by themselves. In high-velocity arms 20 inches should be the minimum length for rifles in the caliber .30 class, 18 inches the minimum length for .25 caliber, and 22 inches for the .505 Gibbs, .416 Rigby, .404 Jeffries, and .375 Holland & Holland magnum cartridges.

It is fallacious to suppose that the longer the barrel the better will be the accuracy. The most accurate length for caliber .30 barrels is between 24 and 28 inches, but it is impossible to say that

a 28-inch barrel is more accurate than one measuring 24 inches. In fact, the longer the barrel, the greater the friction, and as the pressure in a caliber .30 Model 1903 at 22 inches is only about 8000 pounds at the muzzle, and as it requires between 110 and 2200 pounds to expel a bullet from a barrel, nothing is gained with the longer barrel except sight radius. Of course, when iron sights are used, the longer sighting radius reduces errors to a minimum; also, some men can hold and swing a gun more steadily when firing offhand with a long barrel than they can with a short one. Rifle barrels are usually shortened on hunting arms for the purpose of better handling on horseback and in the brush. One-fourth inch of barrel length at the muzzle of a Springfield rifle of the service type weighs 128 grains. To find the weight of a round bar of steel, square the diameter in inches and decimals of an inch and multiply by .2225; the result will be the weight in pounds of a section 1 inch long. To find the weight of a rifle barrel or a section of such a barrel, first find the weight of a bar of the outside diameter of the barrel and subtract from it the weight of a bar the diameter of the bore.

Barrels for .22 caliber rim-fire cartridges can probably be made as light as 0.600 inch at the breech and 0.400 inch at the muzzle if made of good steel. A barrel measuring 10 inches long fired from a machine rest may group as closely as one inch at 50 yards with suitable ammunition. The .22-long rifle cartridge seems to give its maximum muzzle velocity in a barrel between 18 and 22 inches long. It is doubtful if any increase in accuracy results from increasing the length over 24 inches or the diameter over that given for the Springfield sporting-type barrel. Both weight and length are given to .22 caliber barrels to give proper appearance and balance, and to maintain a weight and swing that will enable the shooter to hold the rifle steady. The Model 52 Winchester rifle has quite a heavy barrel of 28 inches, and the expert shot finds it very convenient from the standpoint of hard and steady holding in all positions. Still, the same rifle could probably be fitted with a light 18-inch barrel, and from a machine rest test, a short barrel should give as good average groups as the long and heavier barrel.

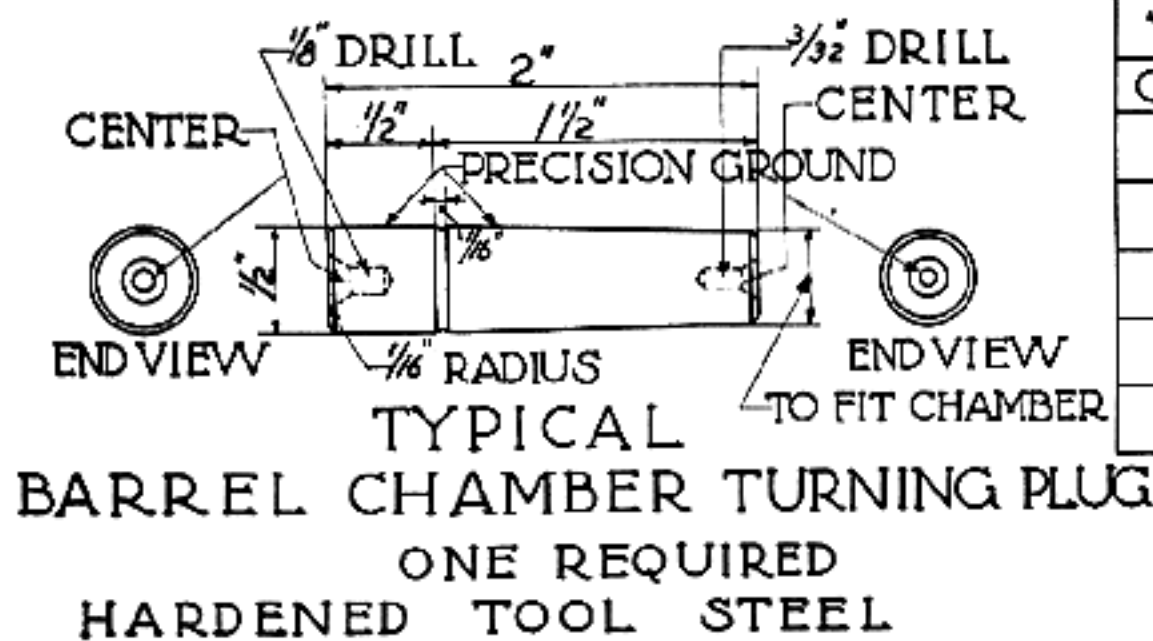
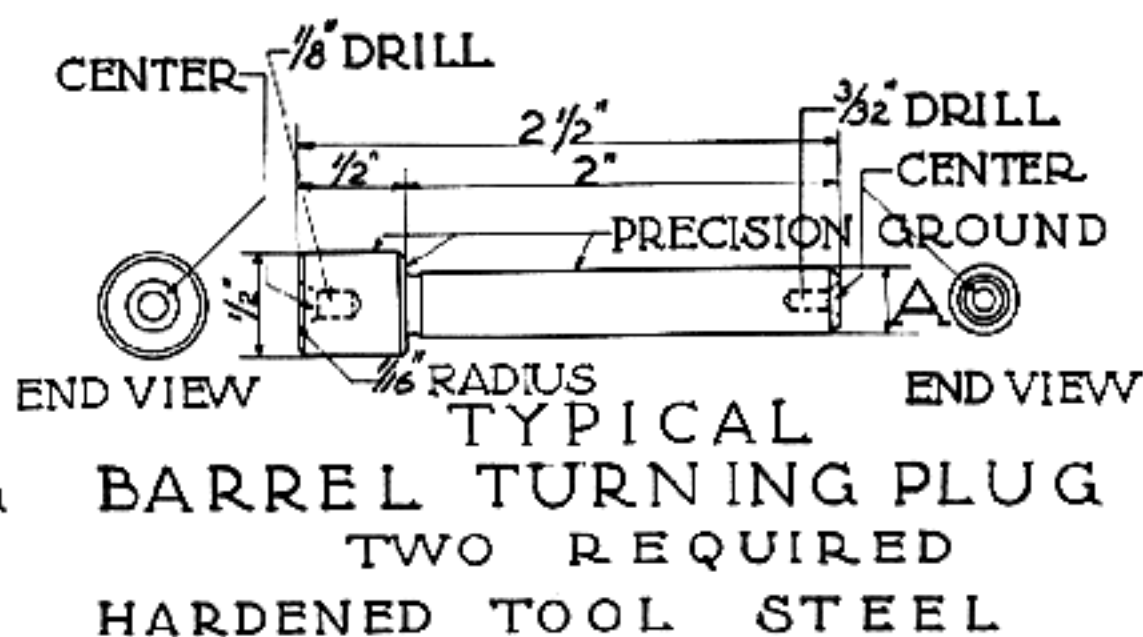
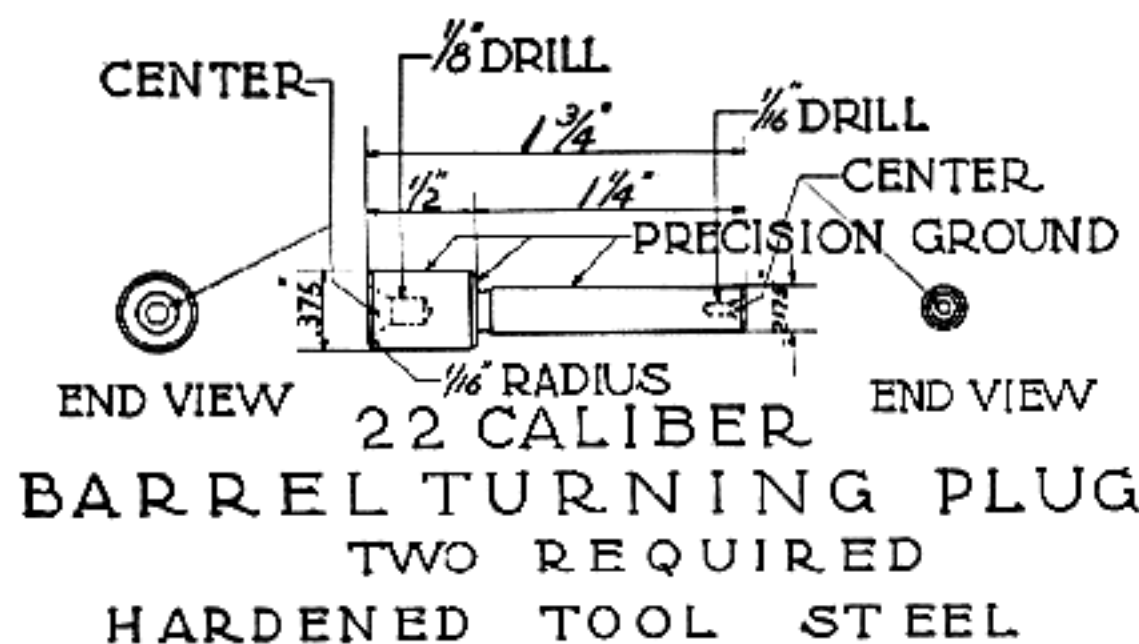
Turning Barrels—The modern barrel design not only calls for a lathe-turning operation, but a milling-machine set-up as well, in order to perform the various cuts illustrated in the drawings. All this work must be done after the barrel is drilled. Turning down a rifled barrel such as the Springfield or any other of private manufacture, to reduce

its diameter and thus lighten it, almost invariably results in releasing strains in the steel to such an extent that the barrel will be bent considerably. When a military barrel is turned without using a well-ground lathe tool, the heat generated from the tool will cause the barrel to spring continually, and before the tube is down to the correct dimension it will be out in some cases as much as 1/2 inch. This must be straightened before it can be used. If military barrels are only turned the slightest amount—for instance, where the rear-sight fixed base has been removed—this exposed spot looks very unsightly left in the form when the base is pressed on. The barrel should be placed in a lathe and this rough place turned to a neat radius or a long angle, and then the splinc-cut filled in with four 8 x 36 screws. The tap drill should only go down to a depth of a little more than 1/8 inch. After the holes are tapped, the screws are set in place and cut off about 1/16 inch higher than the surface and then hammered over and filed flush with the surface. After all this is finished the barrel is draw-filed and polished for the bluing operation.

Before the barrel can be turned, barrel plugs must be made as illustrated in Figure 51; one for the chamber and one to fit into the muzzle. These must be hardened and ground on centers. If made of soft steel they are liable to gaul in the bore, thus ruining the barrel to the length of the plug.

The straight portion which fits into the bore must be just a free push fit on the top of the lands, and the center must be lapped so that it does not cause undue friction on the dead center.

In the turning of any barrel, I am assuming that the person has the necessary machine-shop experience to enable him to perform this operation successfully, and to know the essential moves to make; but the first time one attempts the turning of a military barrel it is well to know some of the correct methods employed. The first stage of the operation is to place the chamber and muzzle plugs into the barrel and run the barrel between centers, attaching a lathe dog to the breech end and tightening the driving plate with a belt lace wound around the dog and back of plate, holding the barrel tight against the live center. With the barrel running between centers, the question arises, What amount of metal should be removed? If a considerable reduction in diameter is to take place, it will be necessary to employ the steady rest and place it well back against the breech end. Turn a true spot and locate the steady rest there, the adjusting arms just touching the turned spot on the barrel. When this is in place, draw back the tail-stock center and see just how true the barrel is by the way it runs out at the muzzle. If it is an absolutely true barrel, the muzzle plug should run perfectly true. Having thus made this set-up, proceed with the turning operation.



STANDARD SIZES FOR TYPICAL PLUG			
CALIBER	A	CALIBER	A
.22"	.2175"	.35"	.3497"
.25	.2495	.375	.367
7 M/M	.2755	.404	.403
.30	.3000	.405	.414
.32	.3110	.505	.504

Fig. 51

Barrel turning arbors. Many barrels are ruined if these centers are not used when turning a barrel on a lathe

Sometimes when a barrel only needs to be trued up, a steady rest is not necessary, for there is not enough metal removed to generate sufficient heat to spring it any; therefore the complete turning can be done. A coarse feed is best to use in all barrel-turning, even tho a light chip is removed, for this reduces friction to a minimum. The turning tool must be ground to a very small round nose, and the rake must also be ground well back so that when a cut is taken the chips removed will come off the barrel as tho you were cutting a piece of lead with a wood chisel; the cuts should come off long and slender. The setting of the tool must be well above center so that it is possible to remove such chips. With a long piece of steel between centers, as soon as a barrel becomes the least bit warm, expansion takes place; therefore the dead center must be loosened often to take care of this, for in many cases it is the cause of a barrel being sprung. When purchasing a Springfield Model 1903 rifle, it is best to specify the National Match rifle for the purpose of remodeling; these barrels do not have as much metal to remove as the standard sporting barrels, and it is therefore possible to make them into lighter sporting arms having a finer balance.

Barrel Turning — If a barrel is drilled and then rough-turned, provided the proper "normalizing" process has been adhered to, there should be very little spring to the steel. If it does spring, the bore must be made perfectly straight again. Whenever a piece of barrel steel has been rough-turned, causing it to heat up, thereby releasing strains, it is important that the bore be made straight and held that way throughout all operations; this can only be done by the proper heat-treatments. When a barrel is completely finished it should never be straightened; for when straightening takes place after a barrel is heated in the act of firing, these strains are released again and the barrel begins to walk back to its original position or vary in this position. More often a crooked barrel has a light and heavy side, and such a barrel invariably fails to hold its true sighting aim. It is almost impossible to keep the correct sight adjustments as the barrel becomes heated from firing, and the expansion of the thicker wall being greater than that of the thinner wall, the barrel naturally bends itself in the direction of the thin-walled side; and the warmer it becomes the more it leans to the thin side. The only cure for such a barrel is to straighten it in the bore and reduce it in size to make it concentric. (See Chapter X.) If an extremely bad condition is encountered, it is best to make a new barrel.

Rifling — The depth of any rifling should not be more than is necessary to grip the bullet and prevent it from "stripping" within the barrel. The nearer any bullet is to a perfectly cylindrical form, free from deep grooves produced by the rifling, the less will be the resistance to the air in flight; for this reason depth of grooves must vary according to the caliber used. Ever since the introduction of the breech-loading system, with its use of cartridge case and bullet, we have seen various methods of barrel rifling. Each has had its advocates, and each new idea has been tried and proved with exhaustive tests, until today we have an even number of square lands and grooves which answer the purpose very well, particularly when fine accuracy is the prevailing argument for its keeping. Figure 48 illustrates the standard calibers as well as some of the special calibers of rifles from which remarkable accuracy has been secured. I do not have all targets to prove my statement, but the reason is obvious from the figures; the land and groove widths vary and were made in order to secure the finest accuracy; the depth of the grooves varies according to caliber. Long experience has proven that in a .22-caliber rim-fire cartridge, grooves should be 0.0025 inch deep; .25 caliber, 0.0035 inch deep, for both lead and jacketed bullets. For the .30 caliber and larger the depth should be 0.004. Large-bore Magnum rifles using jacketed bullets have a depth of between 0.004 and 0.005 inch.

It has often been remarked that grooves should be at least as wide as the lands. This only works out in theory, and it is much better to make the lands as narrow as possible to eliminate all undue friction as the bullet passes through the barrel and into the air—especially when accuracy is required at long ranges. Four grooves are sufficient for calibers from .22 to .30. Above .30 caliber it is best to employ six grooves. There is no advantage in employing any greater number of grooves except when the caliber is above .500, and then only because it is much easier on the rifling head and cutter. The fewer the number of grooves employed the less friction experienced in bullet flight and also in barrel manufacture. The odd number of grooves would work best on the theory that no groove would be opposite another and this would relieve friction to the lowest point as the bullet passes through the barrel. Having lands and grooves opposite each other does not give the bullet a chance to relieve itself in its passage through the bore. But a barrel made with an odd number of grooves and lands, such as 3, 5, or 7, will reduce friction. If this proves out in the free use of an odd-fluted reamer or tap in operation, the same naturally applies to rifling. Nearly all barrels have right-hand rifling—

except pistol barrels, which mostly have left-hand rifling; but when a new barrel is being made it is best to have the right-hand spiral.

The diameter of the finished reamed bore before it is rifled is called the "bore" or "land" diameter. The diameter of the bottom of the grooves is called the "groove diameter"; naturally it exceeds the land diameter by twice the depth of the rifling.

The groove diameter of any barrel has considerable influence on accuracy and barrel life; therefore it must be understood by the beginner who would concern himself with design and specification for rifle barrels, that groove diameter should always be made to one particular standard. Barrel manufacturers require a standard, so there should be no occasion for private gunmakers to try to adopt or copy some private company's tolerance of manufacture; for such companies must have a working limit on their tools. The only part to be considered is bullet diameter; accordingly, groove diameter should always be considered in connection with the diameter of bullets that are to be used in the rifle. Because bullets are not of a fixed size, different ammunition manufacturers having more or less tolerance to work by, it is best to find out the average diameter of all bullets and then use bullets that their figures correspond to for the groove diameter of the rifling. The groove diameter should be 0.0003 inch smaller than the maximum diameter of any bullet for the best accuracy. All bullets must be resized in the course of manufacture to hold them to a certain size. Since lead has no expansion, the lead core then will measure between 0.002

and 0.003 inch smaller than the jackets because of the compression. Then when such a bullet is forced into the rifling of the barrel it will be resized instead of being free, as it would be if the grooves were cut large. The lands also have a certain effect upon this resizing of a bullet, but not enough, for they cut a clean groove into the cylindrical portion of bullet without forming any marked impression on the under side of the jacket.

The width of groove and lands, as you will note, varies; but the latter should be held as narrow as possible and the groove width be made as wide as it can be without becoming impractical for the rifling cutter or weakening the rifling-head cutter box. You will note that in the case of the caliber .30-03 rifling the groove is three times as wide as the land; therefore the cutter box in the rifling head is cut out rather thin, and for this reason more grooves are often required, tho still holding the narrow lands except in larger calibers. This is assuming that all rifles are using the jacketed bullets, for which the lands are made a trifle wider so that it is impossible for them to turn over and be rounded when a number of shots are fired through the barrel—as is the case when softer steel is used in the barrels rather than the standard recommended.

The form of groove is also another important point to be considered for the finest results in accuracy. One side must be sharp to the bottom of the groove, while the opposite side must have a slight radius. The radius is placed on the driving side of the land, which reduces friction again as the

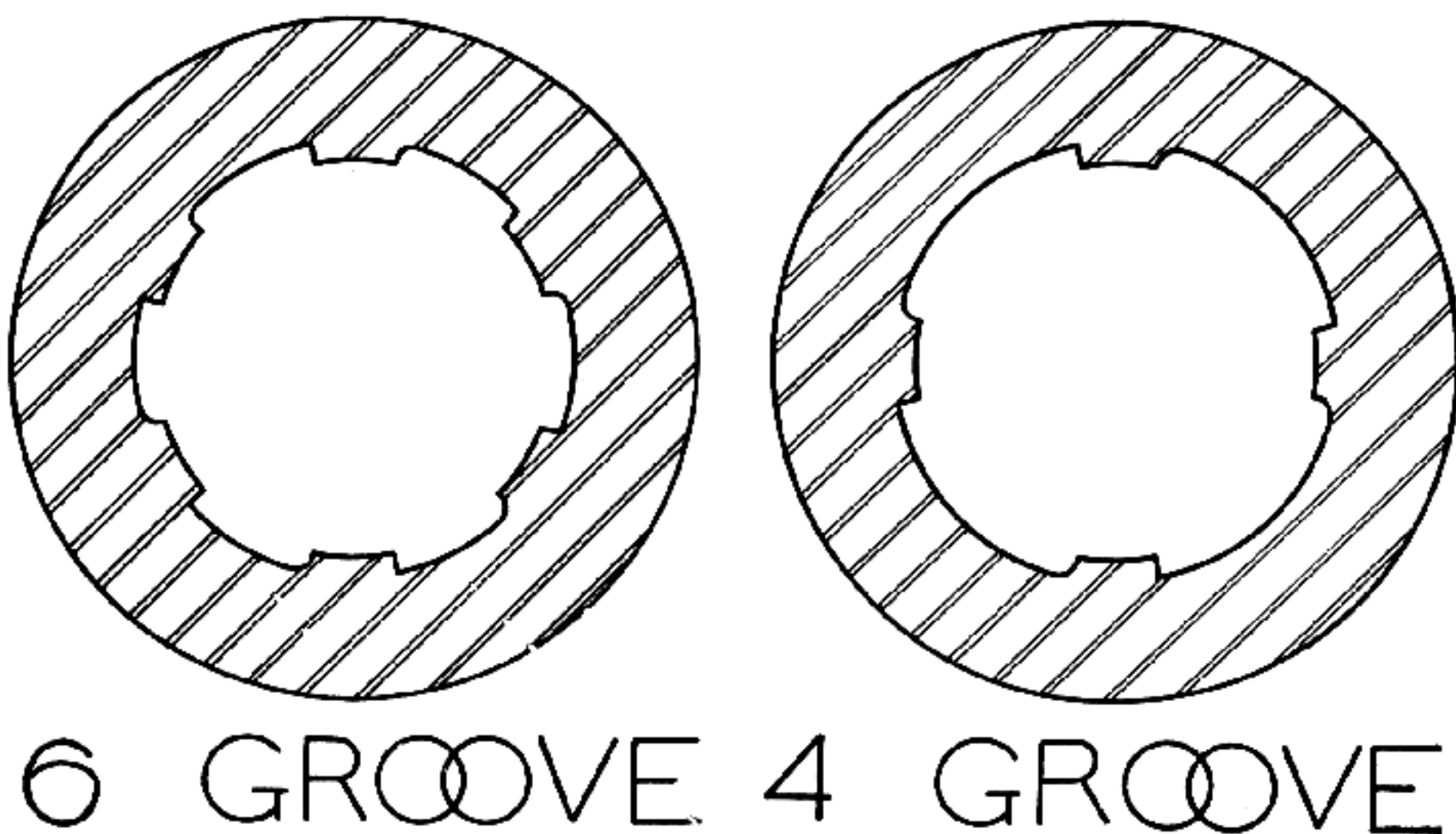


Fig. 52

Rifling. Note small radius on driving side of the lands. This type is productive of the finest accuracy

bullet is being forced through the bore; this small radius is also in the grooves of the bullet jacket and in its course of flight has no retarding action in the air as a sharp groove would have during its tremendous spinning motion through the air (similar to that of a flat propeller in water). A satisfactory form of rifling has been found and adopted, and for this credit is due to Henry, Medford, Lancaster, Rigby, and others who have had strong convictions and labored to suit the conditions of their times. In the future, some one may find a better system of rifling, but until then we shall bow to them. (See Figure 52.)

Twist of rifling must also be taken into consideration. As Figure 48 is studied you will notice that there is a variation of twist between one turn in 10 inches and one turn in 16 inches. The 10.75 mm. has a twist of one turn in 13.4 inches, which is the most practical twist or spiral for the form and weight of bullet used. There are certain elementary truths which every one who uses a rifle should be acquainted with; among them is the value of the rifling—the object for which certain twists are given to various rifle barrels, and why these twists secure the finest results. The main object of rifling is to prevent a tendency of the bullet to rotate upon its shorter axis—a tendency produced by air-resistance. Rifling, therefore, is of more importance when a conical or elongated projectile is used than when a bullet is spherical. It follows the law that the greater the length of a bullet in proportion to its diameter, the greater the need of a spiral rifling; and because other points are equal, the greater must be the speed of rotation.

The degree of twist may be correctly figured, but in common practise it is generally fixed by a number of experiments—assumed or figured either in the number of inches or feet in which a complete turn is made, or in caliber; the latter being the more exact, for it is evident that if a .40 caliber and a .30 caliber each have one turn in 12 inches, the rifling cannot be identical, but if the two barrels made the complete turn in the same number of their calibers, the twist of the rifling would be the same. It is not the intention of the present writer to attempt any explanation of the theories of mathematicians, or to explain the almost insurmountable difficulties which the problem presents. Full particulars of the formulas used to figure velocities and values are given in most gunnery textbooks. It would be well for the reader to know some of the problems a barrel maker faces, and to have a brief understanding of the different laws which govern rifling, including the one which spins a bullet on its axis during its flight. The resistance of the air varies with difference in the sectional area, shape

and velocity of the bullet, and density of the atmosphere. The sectional area of an elongated bullet is circular, and the resistance increases as the square of the diameter. The increase of resistance due to increase of velocity is regular, but no law has been discovered which accurately accounts for its degree of variation. A number of theories are advanced on this subject, one of which is that rifling has a controlling influence, or bullet cylindrical bearing in the rifling and balance in relation to the bullet used, etc. The variations due to changes in atmospheric pressure or density are not inconsiderable in long-range shooting or in high altitudes, and allowance is made in sight arrangements.

Twist in rifle bores has been experimented upon so much that the person who is going to carry out certain barrel designs has his problems worked out by the tables before him. Whatever he works out must be of a radical nature and a complete departure from what has been done in the past.

Chambers and Fitting—Very few men judge a rifle by its internal appearance; the outside is the prevailing factor when passing judgment, while the most essential parts, the chamber and bore, are seldom thought of. In the fitting of a rifle barrel to an action there are either one or two shoulders to be fitted. In the Springfield Model 1903 action and other actions of a similar nature there is only one shoulder on the barrel to be considered, but on the Mauser action there are two: one on the shoulder back of the threads, and one on the face of the barrel. When fitting a barrel to the latter action, the two bearing surfaces must be a perfect fit against the face and shoulder of the barrel. On an action of the Springfield type, the thread fit must be perfect and the shoulder must be wide enough so that a tight union can be secured when the barrel is given the final tightening pull against the receiver. With tight threads and perfect union against the shoulder a barrel will never have any variations in point of impact. A barrel badly fitted to a receiver is as bad as a crooked barrel which constantly changes its grouping.

A chamber placed in a barrel in which a cartridge is at rest when in the act of firing should have a burnished, mirror-like finish when it is viewed through the action. A chamber with the least indication of circular grooves sooner or later causes trouble in the extraction of fired shells, especially in a high-velocity arm, as the brass cartridge case will make a complete moulding in any slight groove and cling to the walls of the chamber. Often lodged cases in a chamber cause the extractors to be broken in trying to remove them. If the extractor holds,

it usually slips over the recess and tears part of the head away from the case and a cleaning rod must be used to remove it. A bulged chamber will also do the same thing, and a chamber bulges easily if the proper steel is not used. I have often seen this happen on some of the magnum chambers where the wrong steel was employed. Chambers should be made with the properly designed barrel having a radius at the starting of the shoulder at the neck. At times the inexperienced tool maker, in making chambering reamers, will neglect to incorporate this radius at this point in the grinding operation and in the completed chamber; the result is a sharp corner which causes the neck of the case to part. The radius at the top of the shoulder is an easy matter to stone on the reamer, but in some chambers this is neglected. Another important point is the correct headspace, but this is taken up in another chapter. To look for perfect chambers you must look for a mirror-like polish free from any circular marks, and the final test is the firing and complete examination of the fired cartridge case. When all these check up to standards together with a perfect bore and groove diameter the barrel should perform well.

Ribbed Barrels — Refer again to Figure 49, which illustrates a ribbed barrel; this design is very appropriate when perfect outlines are desired. The Mauser factory in Germany turns out some of the finest barrels of this nature, and because of the long experience and proper tools and fixtures of these gunmakers there are few who can compete with them for perfect design of a solid-ribbed rifle barrel. It is possible to make one of these barrels on a milling machine by using various set-ups and a vertical milling head. In order to secure the angles or taper on the rib, a false plate must be made and fastened to the table of the machine, for the universal arrangement of the table will not take care of this. If one contemplates making such a barrel it is necessary to figure on three days' steady work; but the design, when completed in accordance with the drawing, is very unusual.

Bullet Fit in Barrels — When considering the relationship between groove and bullet diameter, we shall select the .22 caliber first. In .22-caliber barrels the best results are obtained when the bullet diameter is slightly larger than the grooves. Since bullets and barrels vary in diameter, different makers' products vary slightly from standard, but from the standpoint of difficulties encountered, the bullet should be from 0.0005 to 0.0015 inch larger than the groove diameter of the barrel to expect good work in .22-caliber rim-fire rifles. Most bar-

rels will vary from .2225 to .2235 inch in groove diameter, and most bullets will run from 0.222 to 0.225 inch maximum diameter of bearing. Practically the desired fit can be obtained by trying various makes and lots of ammunition in the particular rifle, and selecting the lot which gives the best accuracy.

In .25-caliber high-power rifles, the groove diameter will vary from 0.2565 to 0.2585 inch. Generally, however, the barrels run between 0.257 inch and 0.258 inch. Bullets will vary between 0.2565 inch and 0.2585 inch (usually the former size). An ideal combination of both groove and bullet diameter should be between 0.2570 inch and 0.2575 inch. Excellent results can be obtained if the bullets are no smaller than 0.0005 inch, in relation to the groove diameter.

More is known in regard to bullet fit in the caliber .30 model 1903 Springfield rifle than in any other size, and in the caliber .30 the bullets which are made specially for the 30-06 cartridge run closer to standard measurements and are better than any other class of bullets when made at the Frankford Arsenal. This is one of the reasons why better results are obtained from 30-03 rifles than from any other caliber. 30-06 bullets run very regular in size, which is between 0.308 inch and 0.3085 inch, and will give extreme accuracy in rifle barrels having a groove diameter between 0.308 inch and 0.3085 inch, and still give fair accuracy in barrels which measure in the groove diameter between 0.3085 inch and 0.309 inch.

When lead bullets are used with smokeless powder in calibers larger than .22, another principle of bullet fit applies. Bullets should be cast of a rather hard alloy and should be larger than groove diameter for the best results. In .25 caliber barrels, such lead bullets should be from 0.001 to 0.003 inch. It does not appear to matter just what size the bullets are, providing they come within these figures; but, of course, a given batch of bullets must be uniform in diameter, and they also must be of a size so that when seated in the case the chamber of the rifle will receive the cartridge without undue crowding. Bullets smaller than groove diameter do not give good results with smokeless powder, altho they give fair results when black powder is used. The reason for this is that the ignition of black powder hits the bullet a sudden blow and expands it to the bore size even before it starts out of the case. But in many cases with black powder, better results will be obtained if the bullets are slightly larger than groove diameter.

Bullet seat or throating of any chamber should be so that a slight impression is given to the bullet as it seats itself in the rifling. This applies to fine

target rifles, but for sporting rifles this seat should be made just a trifle longer so that a bullet will not pull out and lodge in the rifling upon the removal of a cartridge case. Bullet seat is an essential part of any chamber. A bullet should not have a free space between the neck of the case and the rifling; if it has, it will jump into this free distance, producing not only inaccuracy but very bad erosion as the gases rush ahead of the bullet into the steel at this point. A long throated chamber not only causes inaccuracy but a loss of pressure and velocity, and an increase in erosion.

Rebored Barrels—The question often arises whether it is possible to rebores a barrel to a larger

caliber. It is possible, provided the rifle and barrel are suited to the particular cartridge selected. If you have the right equipment, it will be well to do this yourself; to have it done by a regular barrel maker would cost just as much as a new barrel of that particular caliber.

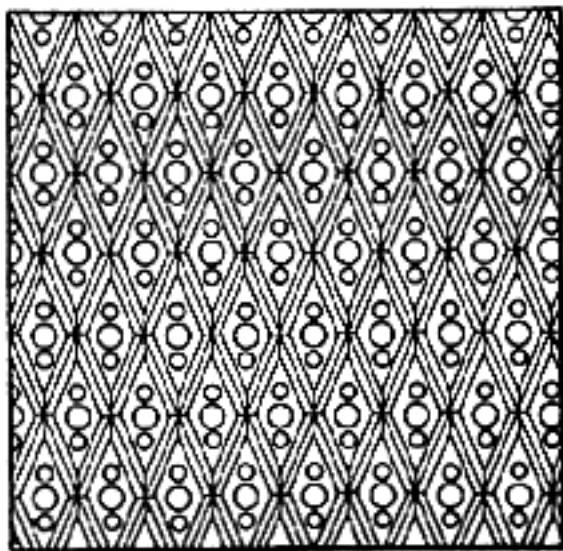
The following table comprises a selection of the most popular American, British and German cartridges. It will be noted that a number of obsolete calibers have been discarded which require special cases and can only be obtained from one source of supply. When a sportsman selects a rifle for sporting purposes, he should select a modern caliber so that ammunition is procurable in all parts of the world.

CALIBER AND CARTRIDGE	MAKE	Groove Diameter Inches		Bore Diameter Inches	Twist of Rifling 1 Turn in — Inches
		Min.	Max.		
.22 Short, R. F.	All	.22	.2238	.2175	20
.22 Long Rifle, R. F.	All	.222	.2238	.2175	16 to 17
.22 W. R. F.	Winchester	.2255	.226	.219	14
.22 W. C. F.	Winchester	.2235	.2241	.218	16
.22 Baby H. P.	Niedner	.223	.2235	.2175	16
.22 Savage H. P.	Savage	.226	.2265	.219	12
.25-20 S. S. & W. C. F.	Winchester	.257	.2575	.250	14
.25-35 W. C. F.	Winchester	.257	.2575	.250	8
.25 Rem. Auto	Remington	.257	.2575	.250	10
.25 Niedner, Spg. & Krag.	Niedner	.2565	.2575	.250	12
.250-3000 Savage	Savage	.257	.258	.250	14
6.5 mm. Mannlicher	Austrian	.263	.264	.256	7½
.270 W. C. F.	Winchester	.278	.2785	.270	10
7 mm. Mauser	German	.2854	.2874	.276	8.66
7 mm. Mauser	American	.2845	.2855	.276	10
.280 Jeffery's	British	.289	.290	.280	8.66
.30-30 W. C. F.	Winchester	.308	.3085	.300	12
.30-30 Rem. Auto	Remington	.308	.3085	.300	12
.30 Krag	U. S. Gov't	.308	.310	.300	10
.30-06 Springfield	U. S. Gov't	.308	.3085	.300	10
.300 Savage	Savage	.308	.309	.300	10
.30 Magnum	H. & H.*	.3083	.3085	.300	14
.32-20 W. C. F.	Winchester	.311	.3115	.305	20
.32 Win. Special	Winchester	.320	.3205	.312	16
.32 Rem. Auto	Remington	.319	.3195	.312	16
8 mm. Mauser	German	.318	.326	.312	14
.303	British	.310	.311	.303	9 to 10
.303 Savage	Savage	.308	.309	.300	10
.32 Win. Self-Loading	Winchester	.321	.322	.312	10
.33 W. C. F.	Winchester	.338	.3385	.330	16
.35 Win. Self-Loading	Winchester	.351	.352	.334	12
.351 Win. Self-Loading	Winchester	.351	.352	.344	16
.35 Rem. Auto	Remington	.356	.3565	.348	16
.35 W. C. F.	Winchester	.358	.3585	3.50	16
.375 Magnum	H. & H.*	.375	.376	.368	12
.38 Short, Long and Extra Long, O. L.	All	.358	.359	.350	36
.401 Win., S. L.	Winchester	.407	.408	.400	14
.404 Magnum	Jeffrey's	.423	.424	.414	14
.405 Winchester	Winchester	.413	.4135	.405	14
.45-70 Winchester	Winchester	.456	.458	.450	20
.45-70 U. S. Gov't	U. S. Gov't	.451	.458	.450	22
.505 Magnum	Gibbs	.5045	.5055	.494	16

* Holland & Holland.

CHAPTER IX

Barrel Tools and Their Construction



Barrel Tools and Their Construction

THE high degree of accuracy necessary in the construction of certain classes of tools and gauges for barrel making has made it requisite for tool makers and machinists to employ various methods and appliances in order to work to the prescribed precision. Since the work of the tool maker requires an unusual degree of skill and refinement it is of the greatest importance that not only he, but those who perform the making of these tools and gauges, have the greatest interest in their work. I must emphasize one particular point, and that is the proper machinery to make these tools correctly. Never lose sight of the fact that a well organized tool room means the success of any product manufactured. Owing to the varied nature of tools required for barrels and the manufacturing of interchangeable parts, this industry involves the most exacting refinements in general tool-making practise. It is surprizing that so little has been written pertaining to tool making for firearms and cartridge manufacturing. This chapter does not attempt to cover completely those methods and operations which are fundamental to the production of firearms or ammunition; it seeks to cover only one small part of the industry—barrel tools, which require the closest of precision work.

I do not wish to convey to the ambitious, mechanically inclined reader that the making of tools for this operation can not be performed by him; on the contrary, he can develop as great refinement in his work as the most experienced tool maker who is just starting to do this class of work himself. I have seen some very good tool makers fail to master some of the simplest operations, while others with far less experience became very successful and very valuable men in this work. Accuracy is essential to practically all tool-making operations, and when the experienced rifleman takes up this branch of the work, the same extreme accuracy he insists upon in shooting will be in that most essential part of a rifle—the barrel. His conception of these requirements will lead him to develop the same patience as shown on the range. Accuracy, as every tool maker knows, requires time and more time; accordingly, all time elements must be forgotten to produce the best; one must know

why every move is made before even a cut is started. Consider the conditions under which you are laboring and be guided by your best judgment.

Reamers — If it were possible to have space for this one subject alone it would fill at least three chapters, for reamers are among the most essential tools in the construction of a rifle barrel. If reamers are to produce round and smooth holes they must have cutting edges not only correctly spaced and formed but stoned or honed to a sharp cutting edge free from saw teeth. For this reason the correct steel must be selected. A common defect in reamers is chattering. This is usually caused by incorrect spacing of the cutting edges, excessive rake, or improper stoning of the flutes, which allows too much clearance for the lands or tops of the teeth. When a reamer has too much rake, it cuts too readily and produces a rough interior surface, hardly noticeable to the naked eye; whereas, excessive clearance of the lands causes chattering, and the reamers do not have proper support. The purpose for which any reamer is to be used must, of course, be determined first, for in barrel making there are three different forms of reamers: roughing, finishing, and burnishing. Some of the principal points connected with these reamers are mentioned in the following paragraphs for the benefit of those who may only have a small shop.

Strong teeth or flutes of sufficient depth are necessary to give room for chip clearance, which is one feature of the construction of a reamer regardless of its mission or nature; both these features depend on the number of teeth and the shape of the fluting cutter. In the smaller sizes such as the barrel reamers, we only have two selections in regard to the number of teeth, for the roughing both in the barrel and chamber. A finishing reamer works well with less than six flutes, and should not have more than six. Burnishing reamers always have six sides, and these are set as a standard. When constructing a roughing reamer with four flutes the lands at the top of the teeth may be left rather heavy, which gives greater support to the reamer. The lands on the finishing reamers, however, should be rather narrow. Figure

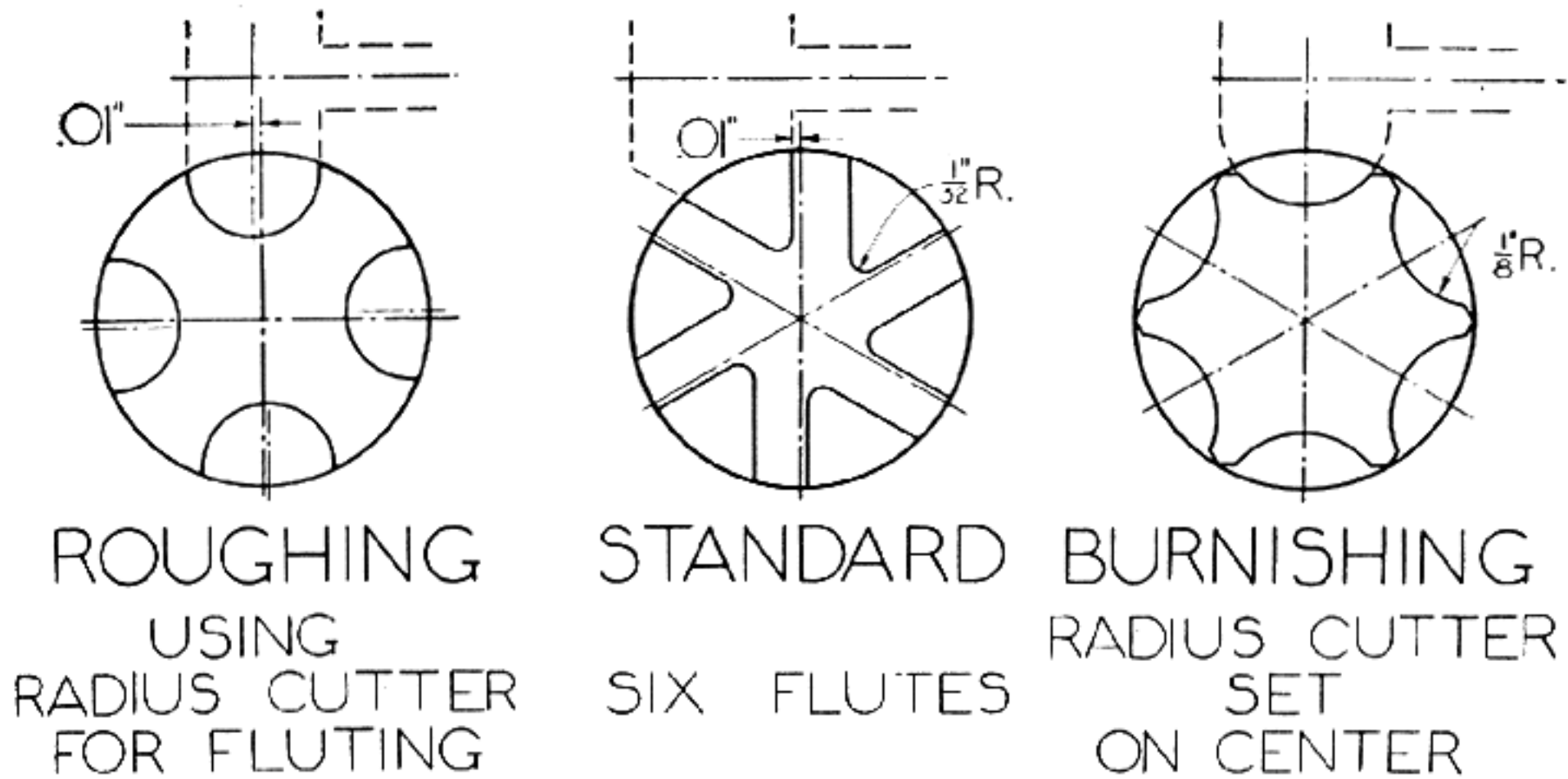


Fig. 53
Reamers. Flutes commonly used, and offsetting of flutes for milling set-up

53 illustrates three different reamers and flutes.

When fluting reamers, the cut is so set with relation to the center of the reamer blank that the tooth gets a slight negative rake; that is, the cutter should be set about 0.010 inch ahead of center as shown in Figure 53. In the construction of some reamers it is necessary to "break up the flutes"; that is, to space the cutting edges unevenly around the reamer. The difference in spacing should be very slight and need not exceed 0.002 inch for each flute. The breaking up of the flutes is usually accomplished by first setting the sides of the angle cutter 0.010 inch off center and the dial on the cross feed at zero. The first cut will be to the extreme limit. As the index head is revolved for the next flute, move the cross slide in toward the center 0.002 inch; accordingly each successive flute is cut likewise until all are cut, and the last flute will only be 0.002 inch ahead of center. When a reamer is provided with spiral flutes as shown in the finished barrel reamer, the angle of spiral should be so that the cutting edge makes an angle of about ten degrees with the axis of the reamer. A spiral reamer so constructed makes one of the best forms of reamer for finishing purposes. Such a tool reduces chattering to a minimum, but is a little more difficult to make.

Burnishing reamers are cut on the exact center with a radius cutter. The cutter selected must be wide enough to mill out the flutes and produce the desired depth. It must also allow a sufficiently flat surface when the flats or sides are formed or milled off, forming a sharp six-sided hexagon. Figure 53 illustrates the method used in the milling operation. After the flutes are milled the reamer is hardened, and then the temper is drawn to remove all hard-

ening strain. It is now ground to a cylindrical form and only the points at the sharp edge are removed. This leaves a slight radius, and 0.002 inch oversize is left on the outside diameter for lapping purposes. The flat surface of the hexagon is lapped on all sides until a nearly sharp edge is produced on the cutter. The diameter is still 0.002 inch oversize, and the reamer is now lapped on the nearly sharp edge, removing 0.001 inch on each of the six sides or placing a faint flat upon the cutting edge. This is the edge which produces the fine burnished surface. If, in the first cutting trial for correct size of bore, it is a little oversize, more lapping may be done to reduce it to the exact diameter. A fine Arkansas stone lightly rubbed over the cutting edges will keep the burnisher free from minute scratches of pick-ups. This should be done before the reamer is started in the bore.

Barrel reamers are never ground for clearance, but stoned. Production reamers are ground, and the amount of clearance depends somewhat upon the type of reamer and its size. Such operations are very easy and simple if the proper reamer grinders are at hand. The finishing of barrel reamers must be done by hand with oilstones of various grades and sizes. The stoning operation on reamers requires practise to know just the right movements to make in order to obtain the desired results.

After a reamer is ground cylindrically, allowing between 0.0005 inch and 0.001 inch oversize, the top of each tooth is given a coating of coppering solution. This will show the exact location and movement of the oilstone at all times and the distance left at the cutting edge. Hold that small fractional edge until the final finishing, which is the fine cutting

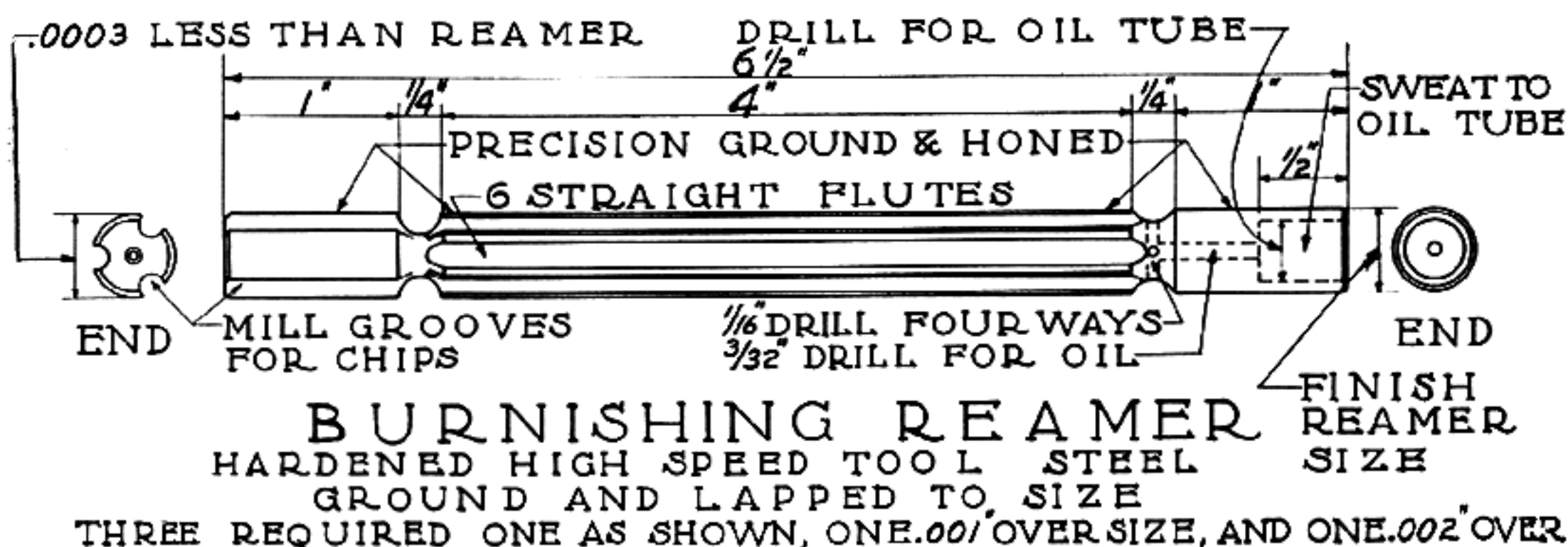
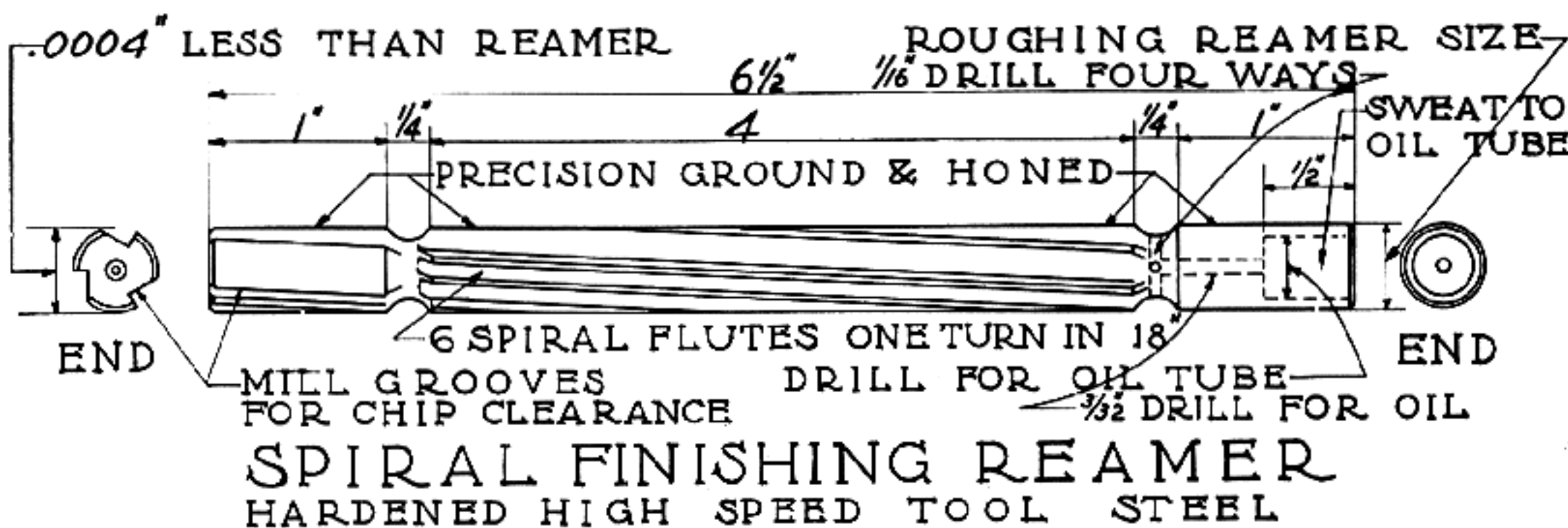
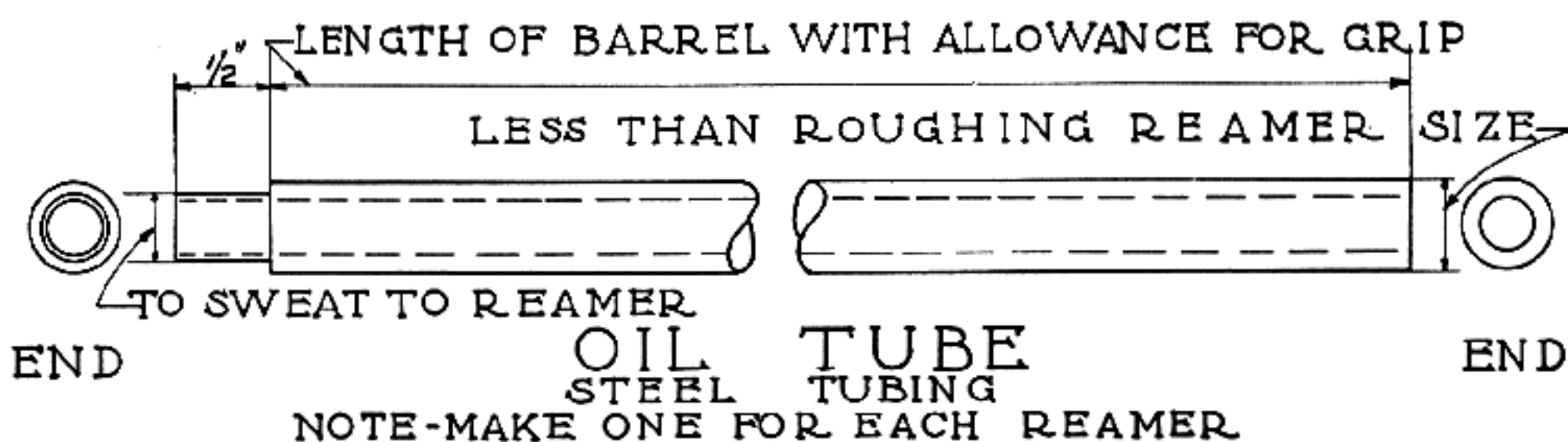
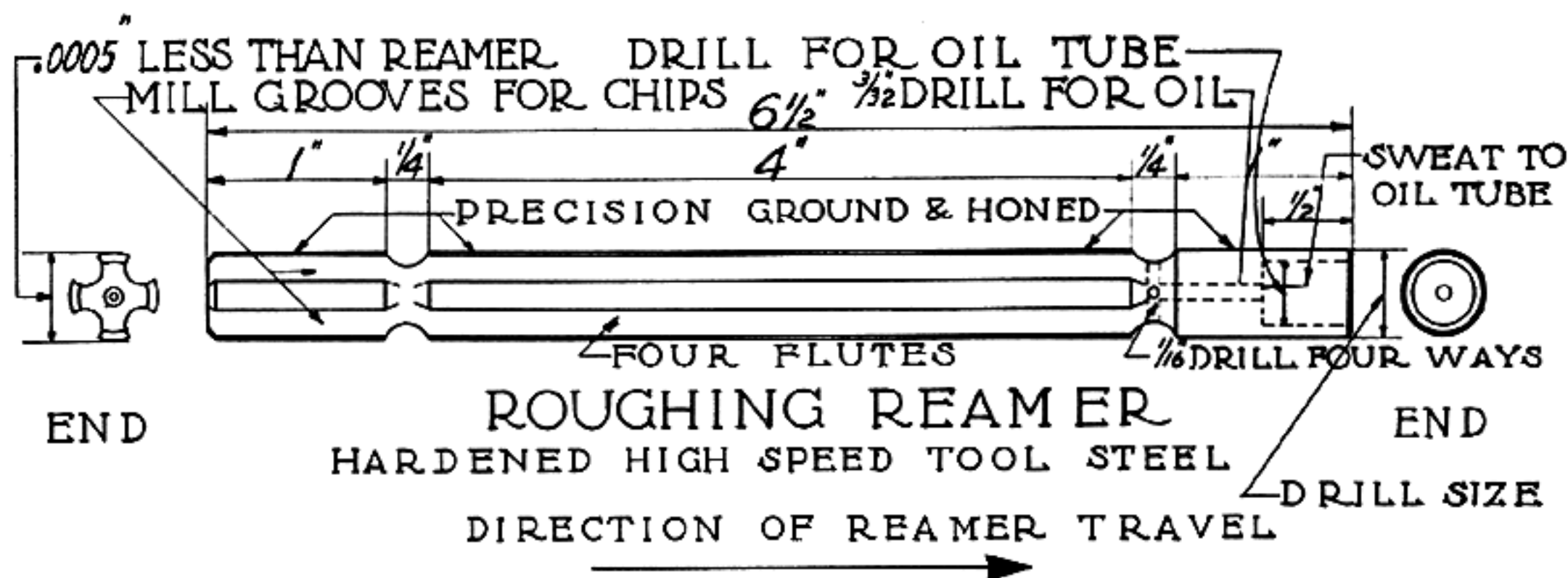
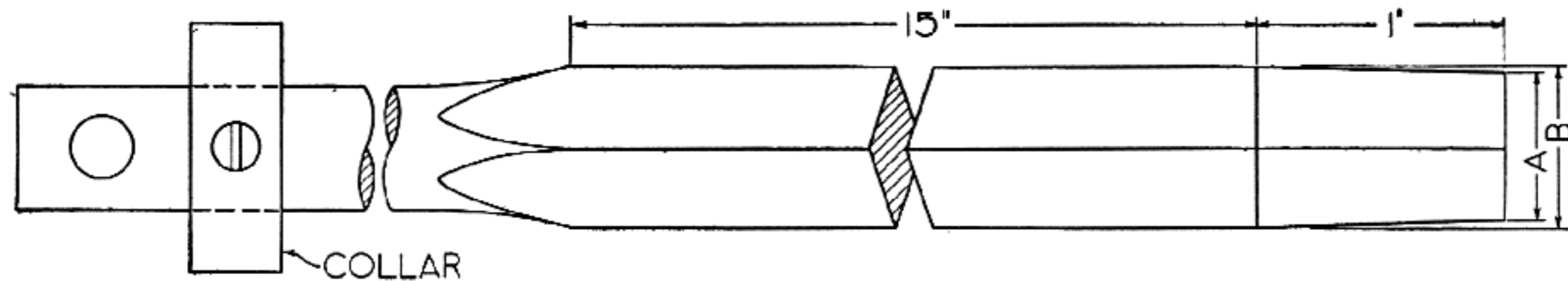
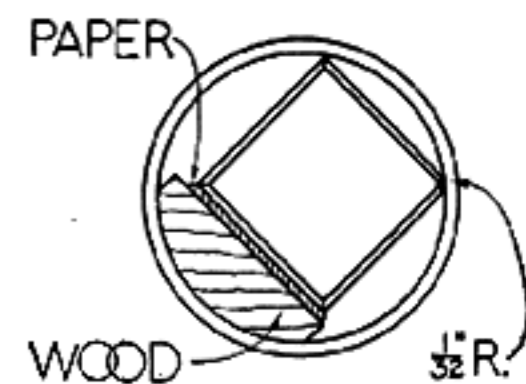


Fig. 54

Improved designs for gun-barrel reamers



FINE BORING TOOL



GAUGE A B.

8 0.676 0.726

10 0.646 0.696

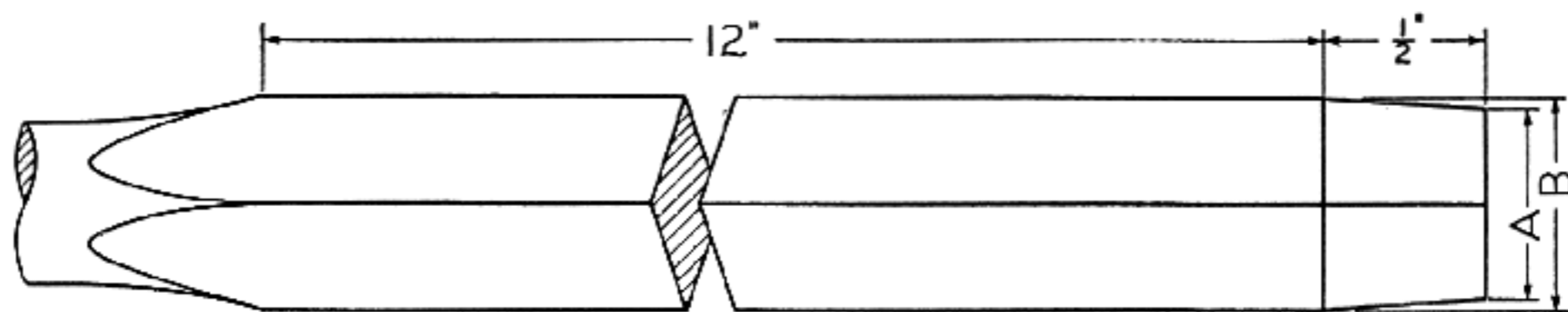
12 0.600 0.650

16 0.533 0.583

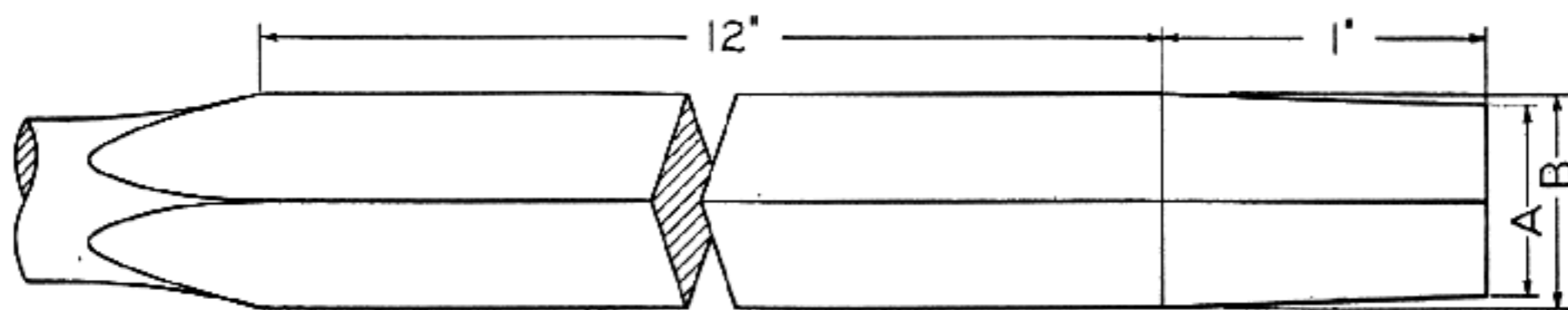
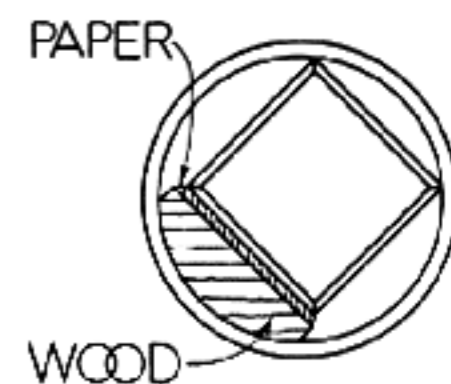
20 0.486 0.536

28 0.421 0.471

410 0.281 0.331



ROUGH BORING TOOL



CHOKE BORING TOOL

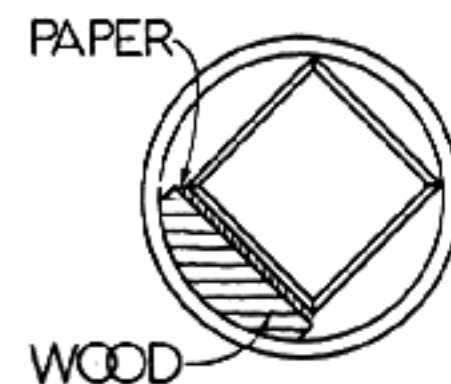


Fig. 55

Shotgun boring tools—commonly called boring bits in the gun shop

edge. Barrel reamers require a leed or taper as they are pulled through the barrel, and the leed must be stoned even and true after it is backed off by the oilstones and brought down to the desired size. A leed is commonly stoned on the draw-in side. This leed may be of various lengths to suit conditions; it may be very short, or it may be almost entirely absent in the case of the burnishing reamers; but a little will be required in the form of a slight angle. The roughing reamer should have a leed of about one-half inch in length. The taper should measure between 0.005 inch and 0.007 inch on the side. The rear end of the reamer is also slightly tapered to prevent the ends of the teeth from scratching when they pass through the bore. Finally, the face of each flute is stoned until the cutting edge is free from any indications of milling cutter marks.

Reamers should measure from 0.010 to 0.020 inch oversize before they are hardened according to the size and the normalizing methods used with the steel selected. Those illustrated in Figure 54 are the improved style of barrel reamers with pilots on both ends. They obviate any tendency to chatter, and if there should be any little kinks or crooks in the bore they will remove them, whereas the old-style reamer would pass around them. Reamers having such lengths and undercuts must be given the proper heat-treatment so that they will only be out very slightly, if any, after they are hardened. Too much attention can not be paid the pilots to prevent them from becoming oversize from wear of the reamer. When that happens the reamer usually lodges in the bore and must be driven out.

Since any reamer will wear, pilots may be eliminated and a straight fluted reamer used as illustrated in Figure 80, No. 4. The construction of these reamers is simpler than that of the spiral reamers, but as experience is acquired the reamers with pilots will be used; then satisfactory ring gauges will be made to check all wear so that the flutes will never wear down to the pilot's size.

One reamer which may be used as an all-around reamer is the general shotgun boring bit or boring tool illustrated in Figure 55. These reamers can be made to ream any straight hole from a .22-caliber rifle barrel to the standard shotgun bore. They are used in a rifle barrel the same as they are for a shotgun barrel, except that they are pulled through the barrel; therefore it will be necessary to place a lead on the square tool near the shank end. As an illustration, suppose a reamer is to be made for a .22-caliber barrel. For better results two would be required; one as a roughing reamer, and one as a burnishing reamer to remove 0.003 inch. The roughing reamer would only be

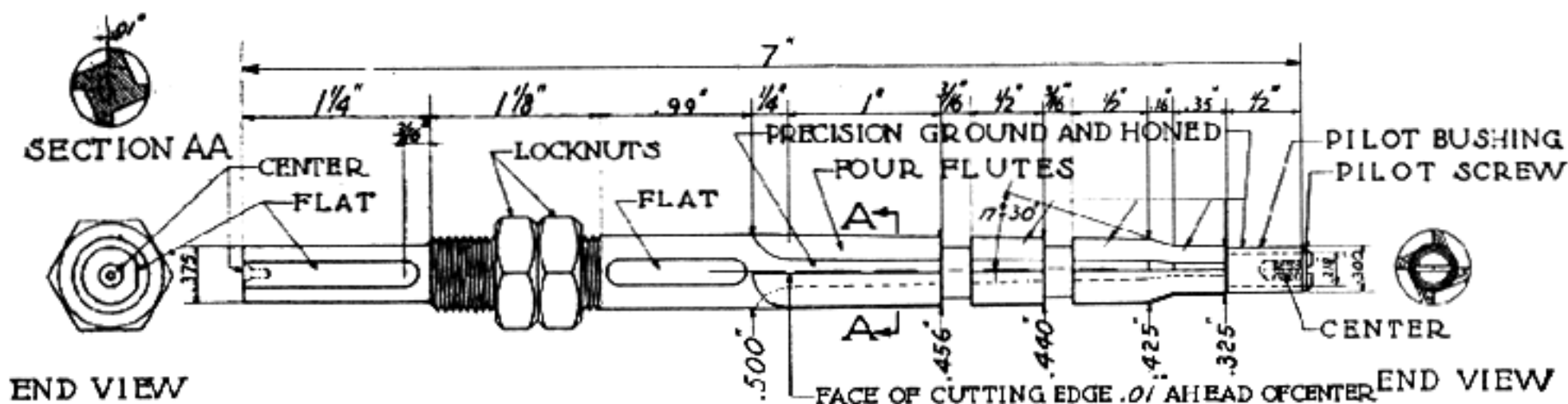
cutting on the one side, as the illustration shows for shotgun bores.

Making one of these square reamers is very simple if one has access to a surface grinder. The tool is first shaped or milled until it measures 0.015 inch over the highest point of the square, which leaves a sufficient amount of material for grinding purposes. A shank is turned on one end, long enough so that a length of drill rod can be welded on; 1.5 inch is sufficient. The length of the tool or reamer on its cutting portion should be as long as possible without causing undue warping during hardening. As an example, a tool made for a .22-caliber should be between 6 and 8 inches in length and larger calibers longer; for the greater the length the truer will be the reamed hole and bearing surface of the reamer upon contact with the interior of the barrel.

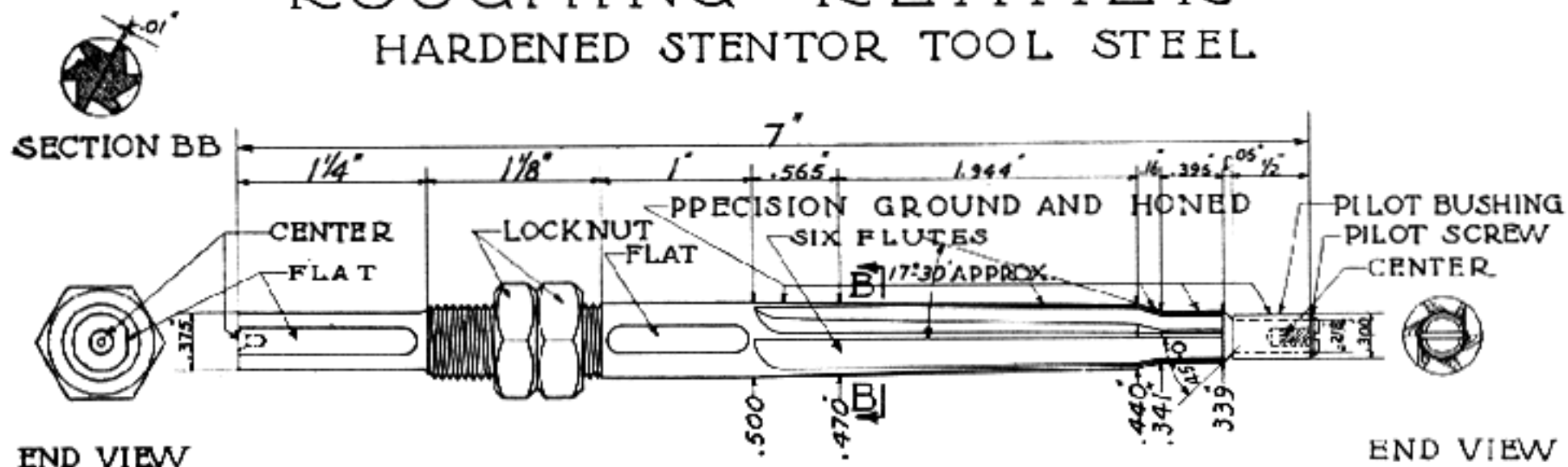
The burnishing or finishing reamer is made the same as the standard burnishing reamer, except that one side is given a small radius and the opposite side is the cutting edge; this has the small 0.001-inch flat lapped down from the sharp cutting edge. Instructions for the use of fluted reamers are given in Chapter X, but if this type of reamer is once used, it will take the place of a fluted reamer, which is only used when experimental barrels are constructed.

A newly stoned reamer has more tendency to chatter than one which has been used for some time. If there should be too little clearance the reamer will not cut freely, as the lands will rub against the walls of the barrel. In many instances the result will be a lodged and broken reamer and sometimes a ruined blank. An eccentric relief is that which is stoned on the flutes of a reamer; the land back of the cutting edge is convex rather than flat, and is used in all barrel reamers. This type of reamer holds its size longer than others.

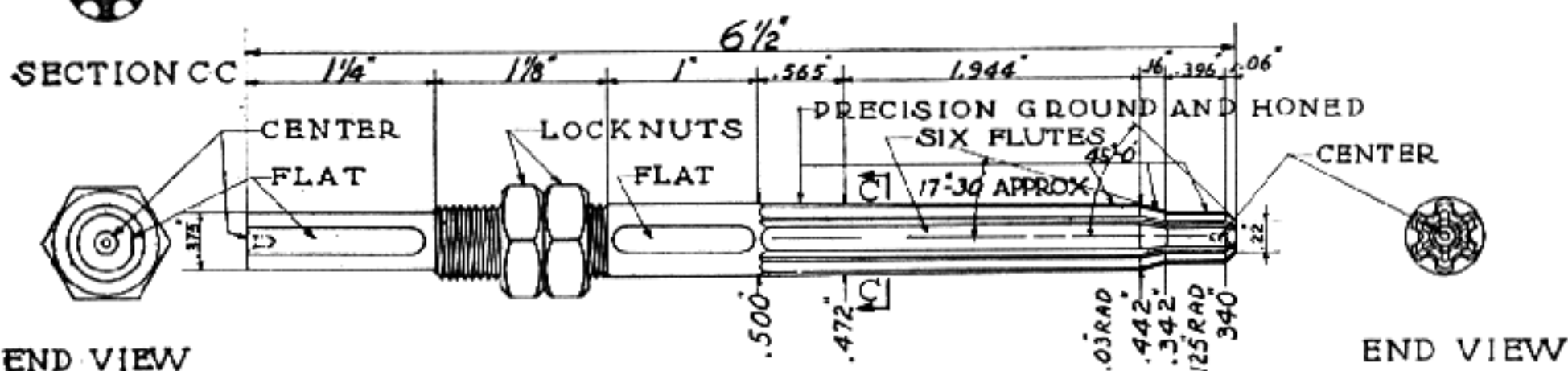
Chambering reamers are the most difficult to construct, particularly the burnishing reamer. The roughing reamer is made similar to a counterbore, except that it is in steps, as Figure 56 illustrates. This tends to reduce the metal in the chamber, leaving the second reamer with only a minimum amount of metal to remove. Both roughing and No. 2 reamers could be made spirally, but this would be more difficult. With reamer No. 2, when made with a right-hand spiral of the cutting edges, especially when there is considerable taper, the inclination of the cutting edges in the direction of the turning movement tends to draw the reamer in and gives a better cutting action. Ordinarily, however, the flutes of both roughing and No. 2 reamers are made straight. Reamers for roughing purposes are sometimes made in a series of cylindrical steps.



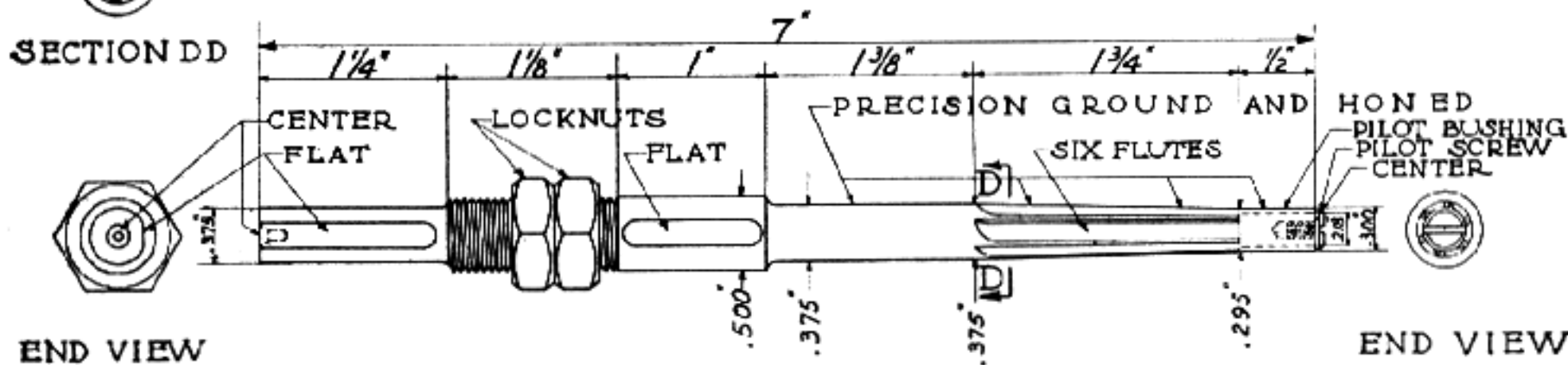
ROUGHING REAMER
HARDENED STENTOR TOOL STEEL



FINISHING REAMER
HARDENED STENTOR TOOL STEEL



BURNISHING REAMER
HARDENED STENTOR TOOL STEEL



THROATING REAMER
HARDENED STENTOR TOOL STEEL

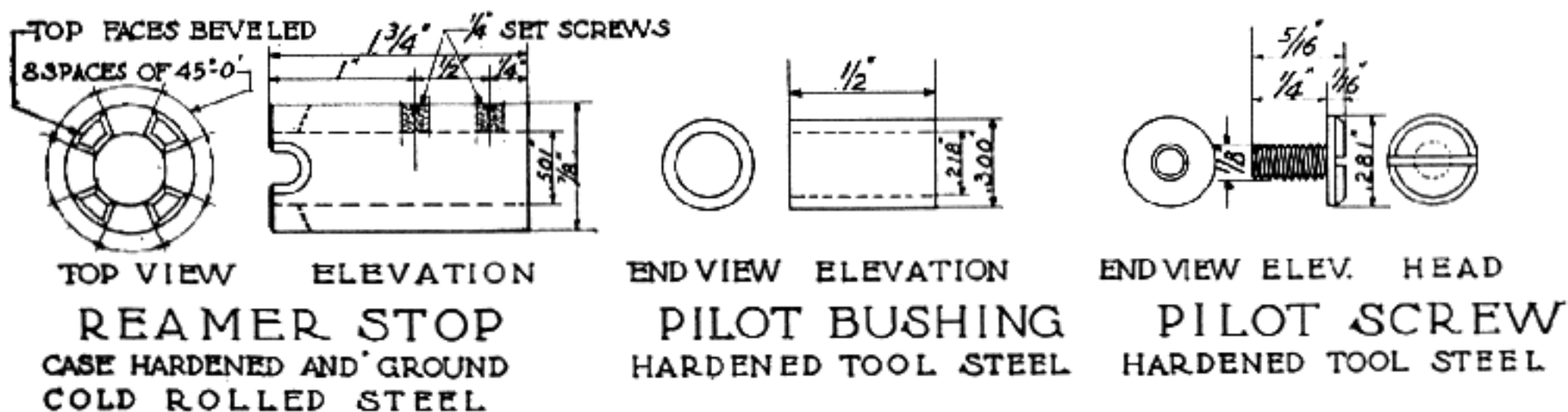


Fig. 56

Standard chambering reamers used in manufacturing caliber .30 Model 1903 Springfield rifle barrels. The same designs may be used for any other type of barrel-chambering reamers, by changing dimensions

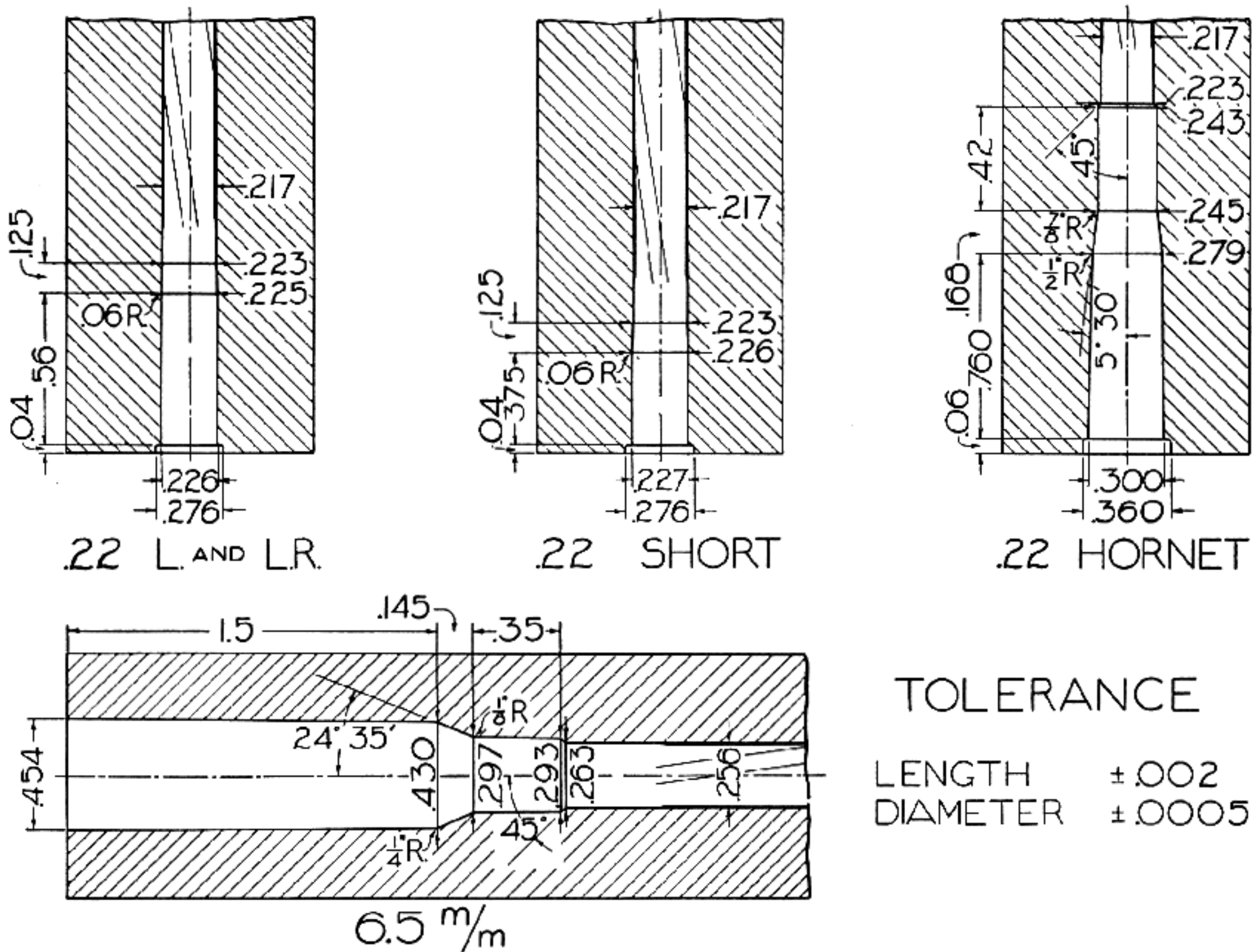


Fig. 57
Chamber sizes for the construction of chambering reamers

When making such a reamer, first turn the blank to the correct taper; then use a round nose tool and cut a series of grooves about $\frac{3}{16}$ inch apart, $\frac{3}{32}$ inch deep and about $\frac{3}{32}$ inch wide. Having completed these, turn each one straight, just touching the cutting edge. These dimensions may have to be modified according to the size of the reamer. In this way a taper reamer has a gradual increase in diameter by steps, the same as the roughing chamber reamer. When using the second reamer, the tops of the serrated under-surface are easily removed. The step reamer as shown will answer for nearly all general purposes.

Chambering reamers constructed as shown in Figure 56 are of the best design, and this general outline of construction may be followed for any form of chamber. A careful study of these reamers, pilot bushings, stops, etc., will be self-explanatory; therefore, whatever caliber or cartridge is selected, only the new figures are required in their respective places.

Figures 57, 58, and 59 illustrate various chambers with the correct diameter to construct the

reamers intended, and since all reamers for chamber work are made on the principles given in Figure 56 it will be simple to follow the general outlines of construction. Figure 58 illustrates the chamber dimensions for the caliber .30 model 1903 (Springfield) chamber. On the chamber diameter in Figures 57, 58, and 59 headspace has been left out, and the lengths given from the shoulder to the end of the chamber are for reamer sizes only. This end measurement together with the given length is for the purpose of measuring the reamer on the taper at this point, which gives the correct angle to grind it; therefore, the balance of the taper is free only to cut in space. For the purpose of correct headspace cartridges must be selected.

Unfortunately it is difficult to give a detailed drawing of all the standard cartridges used in connection with these chambers, for it would take up too much space; moreover, very few students would have any use for such a drawing. Future writings may make this possible.

It is possible in most instances to arrive at a very close approximation of the diameter of the

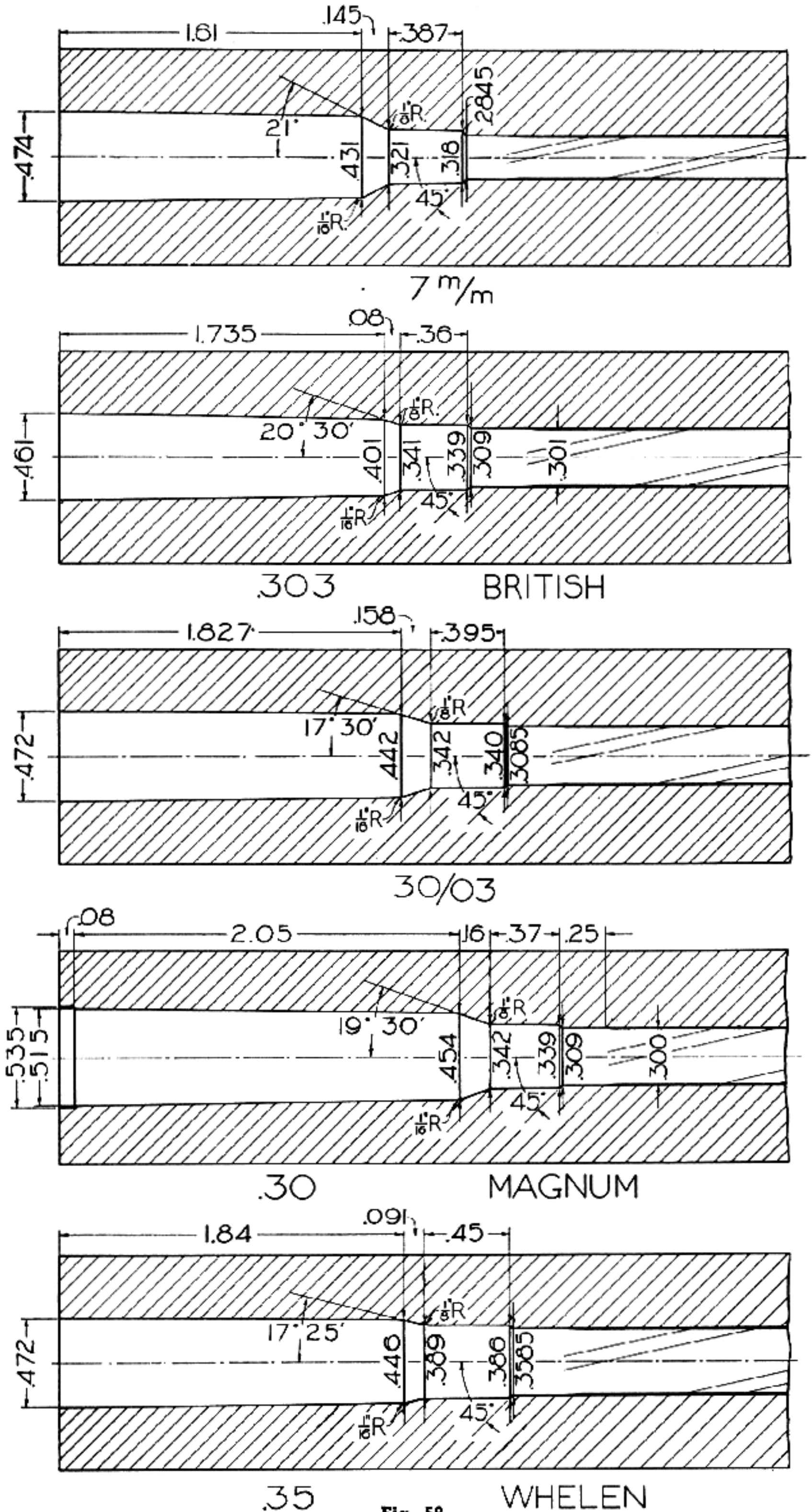


Fig. 58 Chamber sizes for making chambering reamers

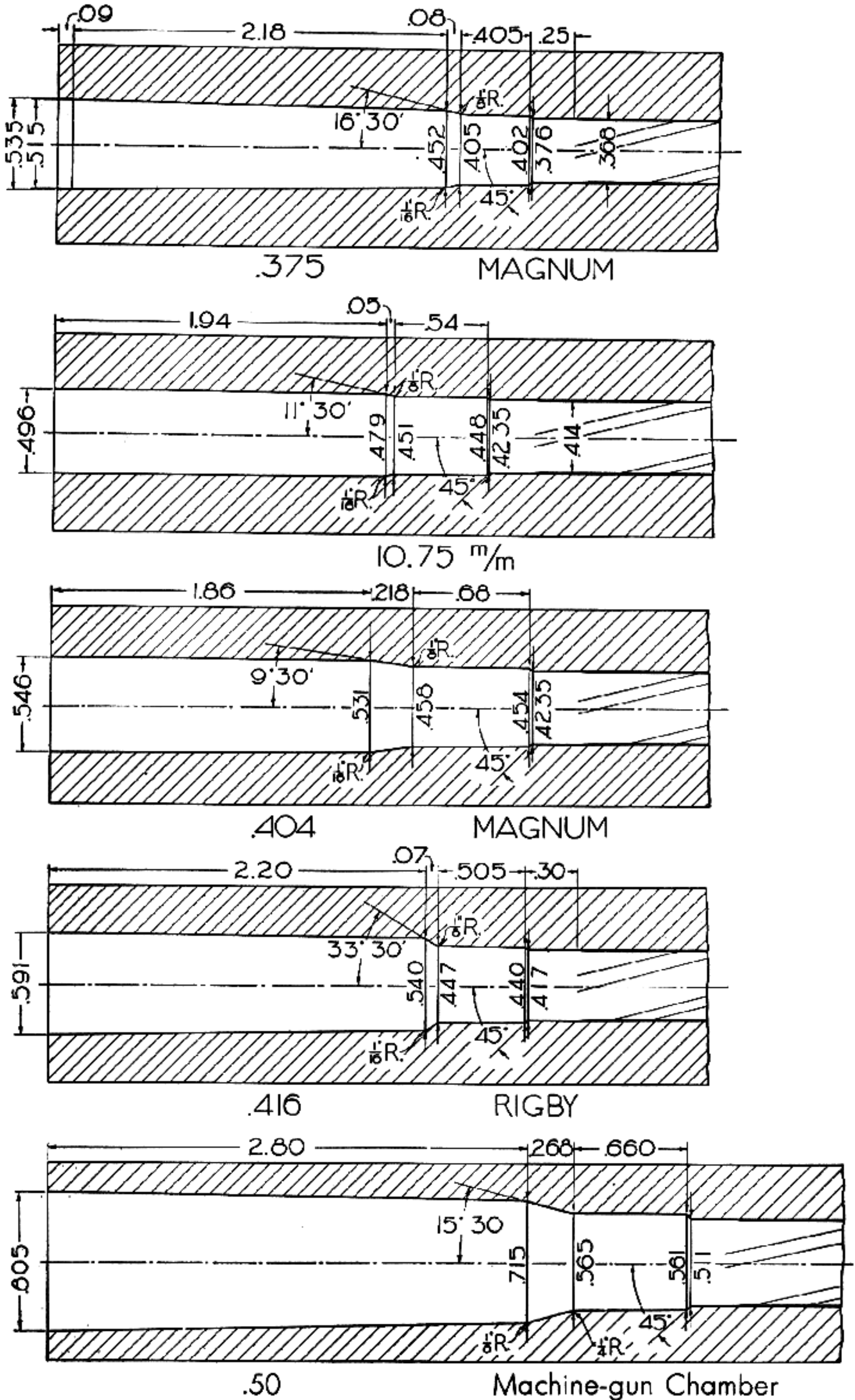


Fig. 59

Chamber sizes for making chambering reamers. Finishing reamers are made to these figures

maximum cartridge for the measurements of a number of standard cartridges of the different manufacturers. The mean of the measurements which may be taken as the average or mean cartridge should not be taken from cartridges of only one manufacturer, for these may differ from those of some other make very slightly. A chamber should be satisfactory for cartridges of all standard makes. When starting to design a set of chambering reamers, one should first obtain at least ten cartridges of all makes of that caliber, and the varieties loaded with different weight bullets. For comparison, using the figures given in Figure 60

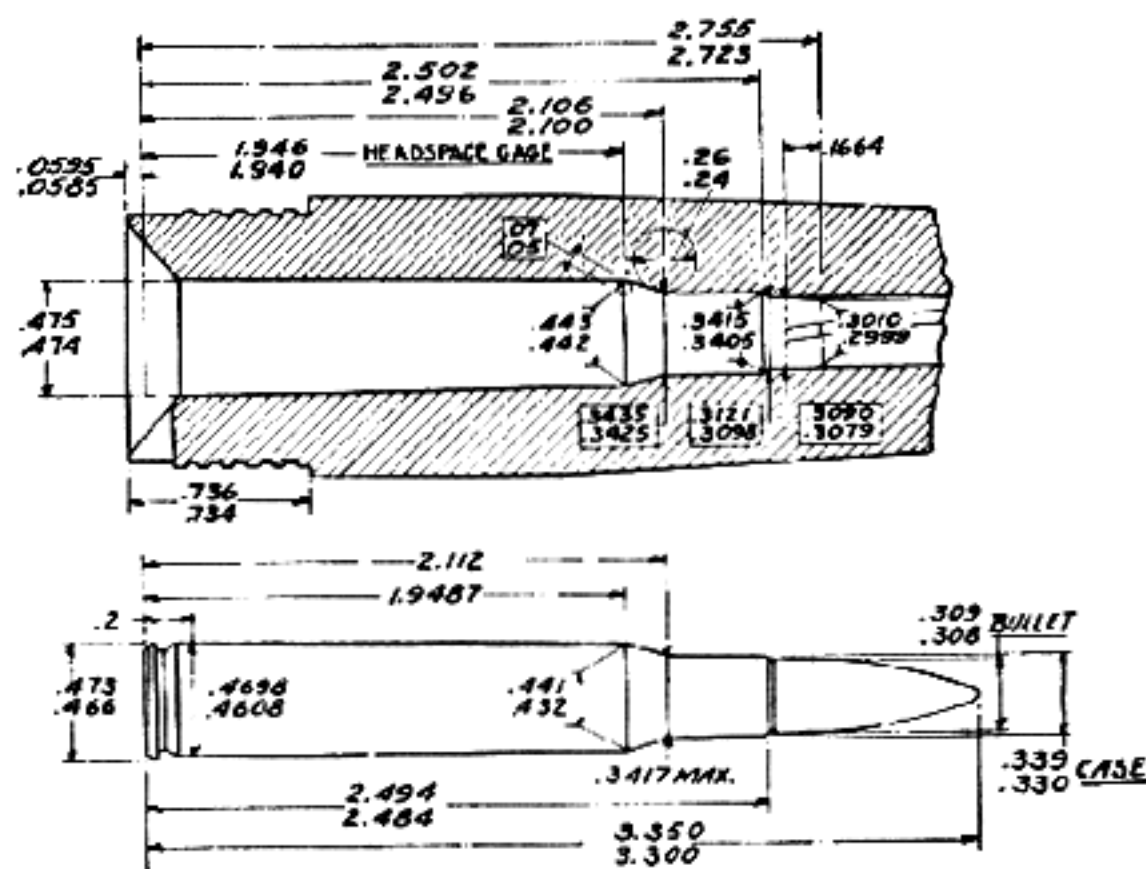


Fig. 60

Caliber .30 Model 1903 rifle chamber, and caliber .30 Model 1906 cartridge. Maximum and minimum dimensions for manufacture of case

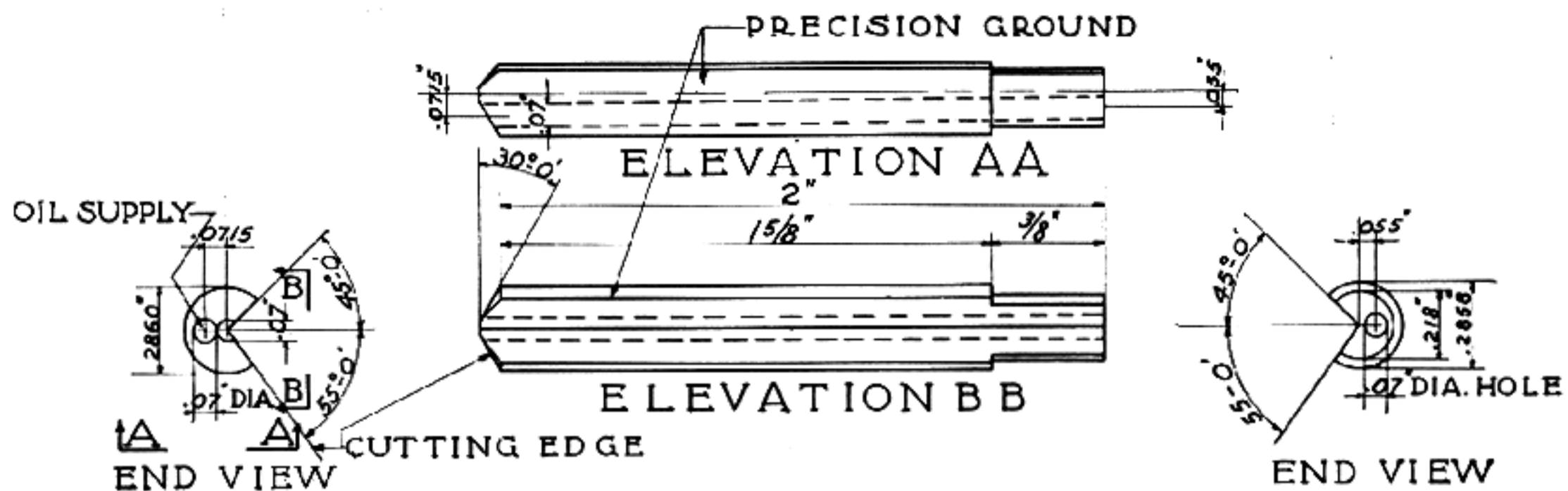
select the same caliber of cartridge as for these chamber drawings, measure the sizes, and see just what tolerance has been left between a cartridge case and a chamber; such an allowance can often be carried out for any cartridge case not listed. If the chamber is to be reamed for some particular cartridge other than those listed, there should be the same tolerance between the maximum cartridge selected and the finished chamber reamer as there is between the maximum cartridge and the maximum chamber in these drawings. The finishing reamer should be made to cut the maximum chamber and kept well stoned with a fine Arkansas stone. This reamer will cut hundreds of barrels and if made correctly will last the careful gunsmith for years.

Most target shooters want barrels with tight chambers; that is, a chamber with a tight neck. At one time I had three different sets of reamers for the caliber .30 model 1903 chamber and could give a customer any chamber he wished, even to one on which it was necessary to turn the necks of the cartridges on a bench lathe to fit such a cham-

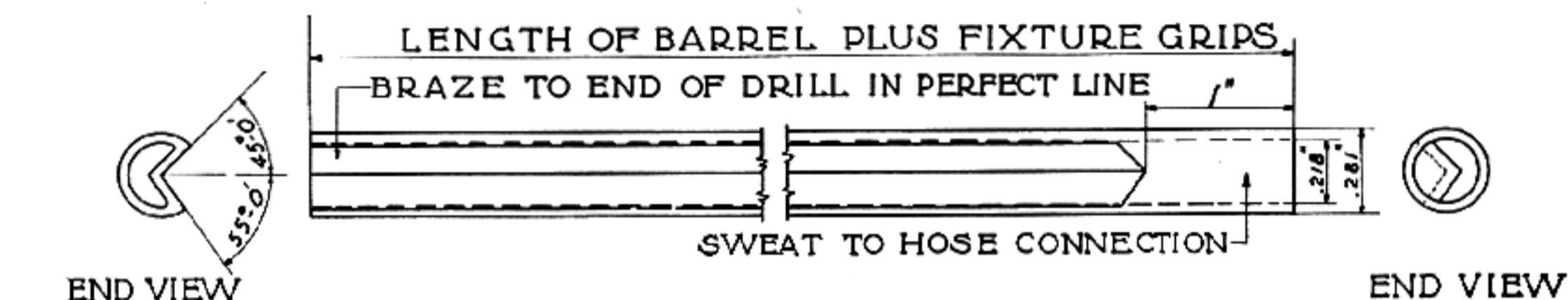
ber. Tests were made from all three different chambers produced by these reamers with the rifles clamped in the machine rest, and it was found that the standard chamber as made in the Springfield rifle gave just as good results as these special chambers. Tight chambers are considered undesirable, tho they are fairly accurate when special bullet jackets can be selected that only have a variation of 0.001 inch from being concentric, and assembled in special accurate bullet dies made to the correct diameter for the special barrel. Chambers reamed with the relative diameters shown in the drawings are the most accurate and satisfactory chambers known. Nearly all American makers of rifle barrels are now designing their chambers for any new cartridges with tolerances between maximum cartridge and minimum chamber very closely approximating those shown here, and I cannot too firmly impress upon the student that he should follow these as a guide.

The cutters used for fluting reamers consist of two forms—the radius or convex, and the angular cutter. The convex cutter—used to cut roughing reamers and also burnishers—has a width equal to one-fifth to one-fourth the diameters of the reamers themselves. The depth of the flute should be from one-eighth to one-sixth of the diameter of the reamer. The width of the land of the cutting edges should be about one-fifth the distance from tooth to tooth. The most satisfactory method is by trial. An angular cutter is often preferred to a convex cutter for milling the flutes on the cylindrical portion of barrel reamers because of the form of tooth; therefore, an 80-degree angular cutter, slightly rounded at the point, may be used. Angular cutters for chambering reamers vary between 60 and 70 degrees with the ends and are given a slight radius or are slightly rounded to reinforce the bottom of the groove. Angular milling is usually done with an included angle between the teeth of 40, 50, 60, 70, and 80 degrees. Special ones which I made up consist of 60, 65, 70, 75, 80, and 85 degrees in both right and left hand. This offers a wide selection to choose from when making any form of reamer.

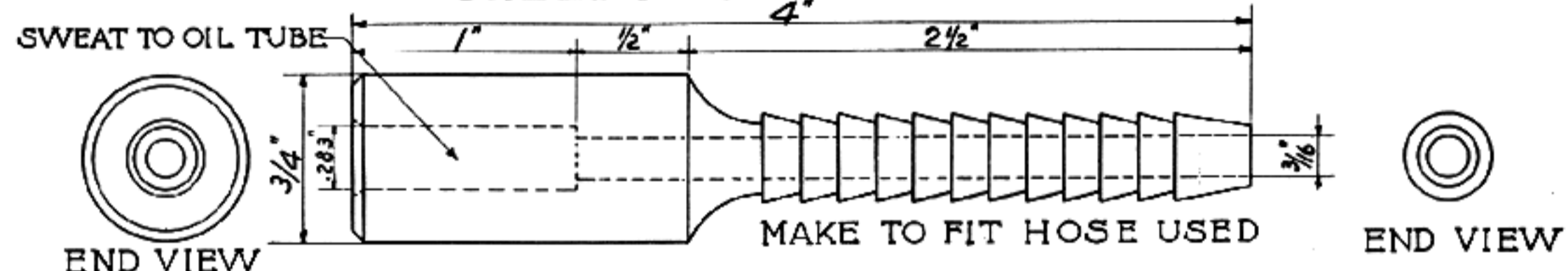
The chamber-burnishing reamer is one of the most difficult to make. This reamer has no pilot like the other reamers shown in Figure 56, as the greatest amount it removes is between 0.001 inch and 0.002 inch, and it is used after the No. 2 reamer. Instructions may be followed as given for the barrel-burnishing reamers, with the exception that it must be stoned completely because of the angle at the shoulder. The straight taper may be lapped to a certain extent, but better time is made with



30 CALIBER BARREL DRILL
HARDENED REX AAA HIGH SPEED STEEL



ELEVATION OF OIL TUBE
SHELBY STEEL TUBING



ELEVATION OF HOSE AND OIL TUBE CONNECTION
COLD ROLLED STEEL

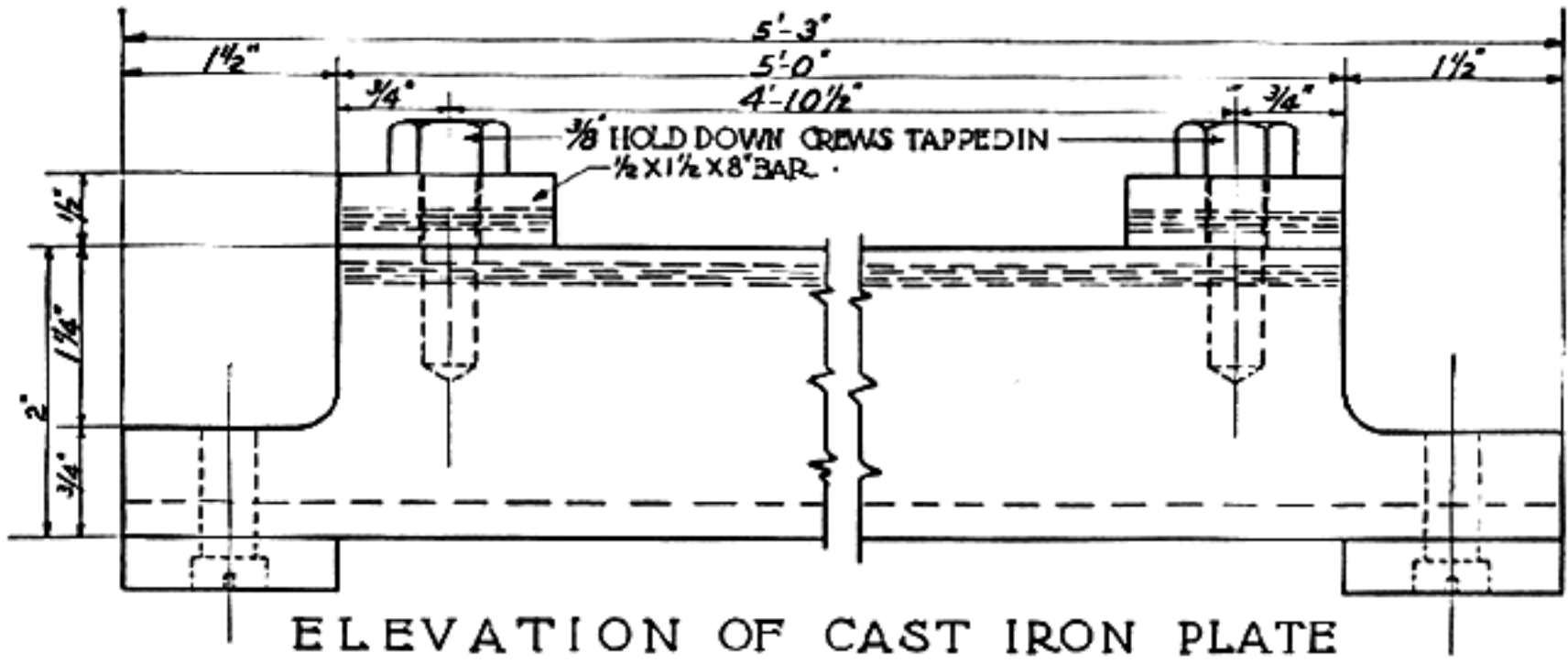
Fig. 61
Typical barrel drill and connections

a good oilstone after the cylindrical grinding takes place, allowing 0.002 inch oversize for the stoning operation to bring it to a flat sharp cutting edge.

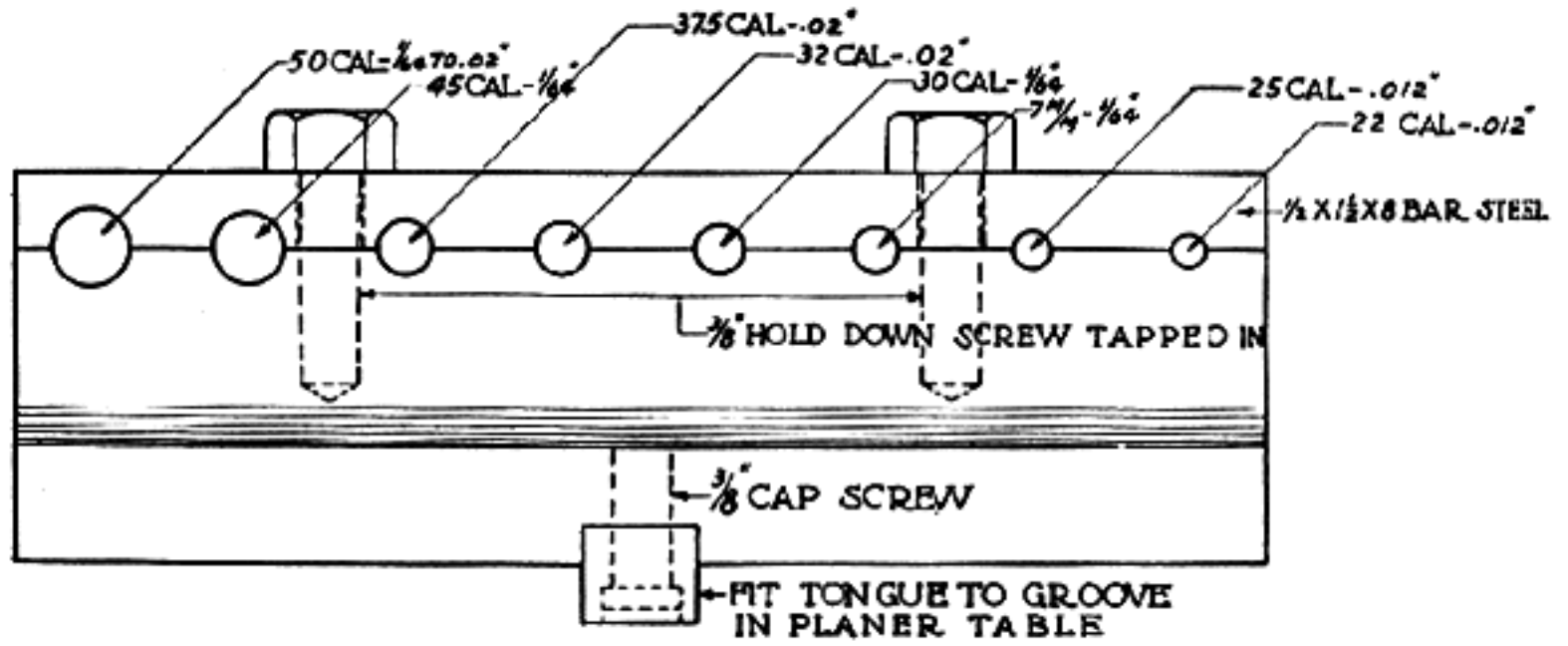
Barrel Drills — Drills used to drill deep holes are designed very differently from the standard production drills which most mechanics use. The bits or drills constructed for barrel work are made short and brazed to the end of a grooved length of tubing. Figure 61 illustrates the drill and tubing, and Figure 62 illustrates the grooving-tool holder and tube fixture which is clamped to a planer bed. It is also necessary to make a form cutter using the figures shown in the design of the roller in order to mill a similar groove in the barrel drill. These drills are made of Rex AA or AAA

high-speed steel and hardened with a very high temperature in order to keep their cutting edges as they pass through bars of alloy steel.

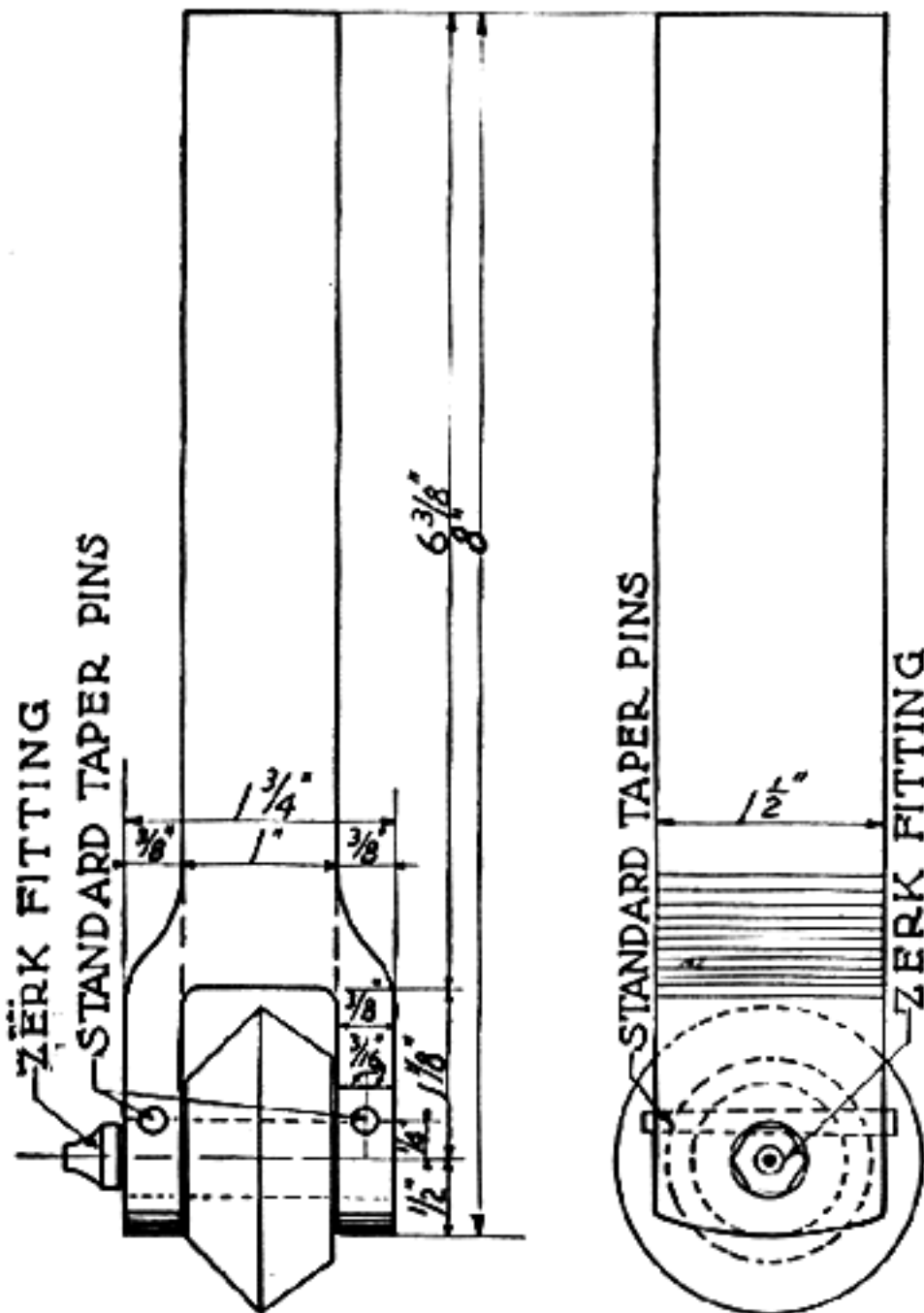
After the blanks are turned on a lathe, the small oil hole is drilled. The most practical and convenient place to drill these holes is on a set-up in the bench lathe, using a small angle plate with the drill clamped in a V; once the angle plate is set up for this operation a number may be drilled. The blanks are left long enough so that a center can be placed on one end and they can be ground in the bench lathe or a grinder having draw-in collets. A high-speed drill press may also be used to drill the oil holes by clamping the drill blanks in a V-block or an angle-plate having an accurate V in the center of it. After the oil holes are drilled



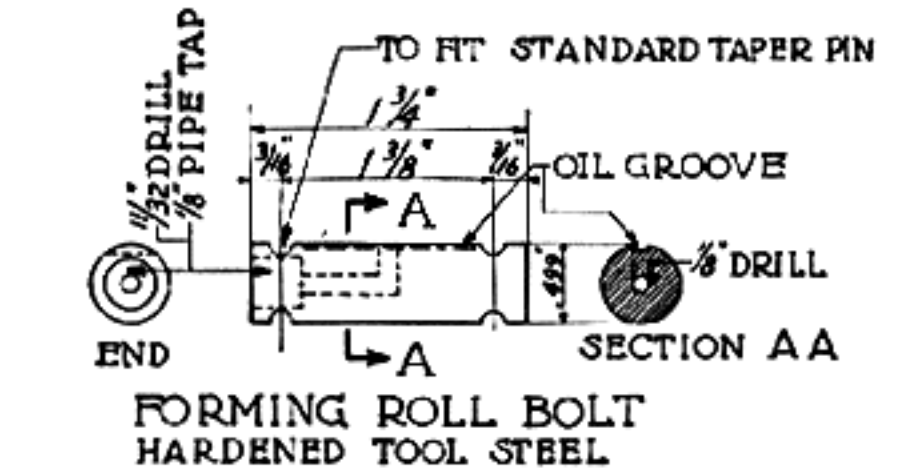
ELEVATION OF CAST IRON PLATE
OIL TUBE FIXTURE



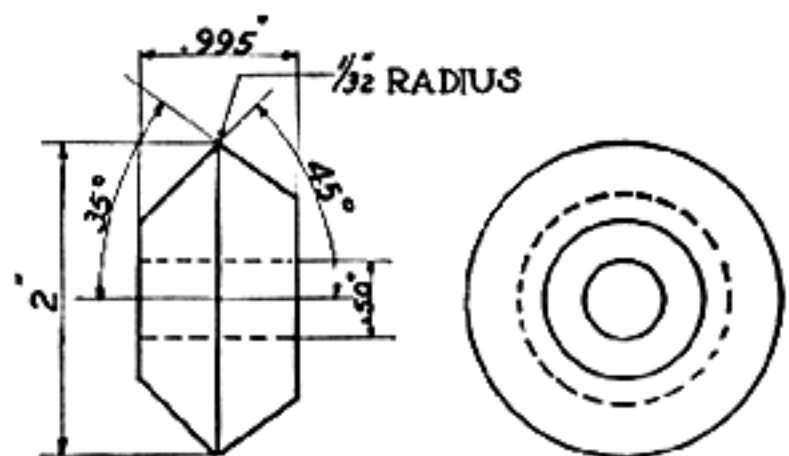
END VIEW OF CAST IRON PLATE



PLANER TOOL
FOR GROOVING OIL TUBE FOR BARREL DRILL
TOOL STEEL



FORMING ROLL BOLT
HARDENED TOOL STEEL



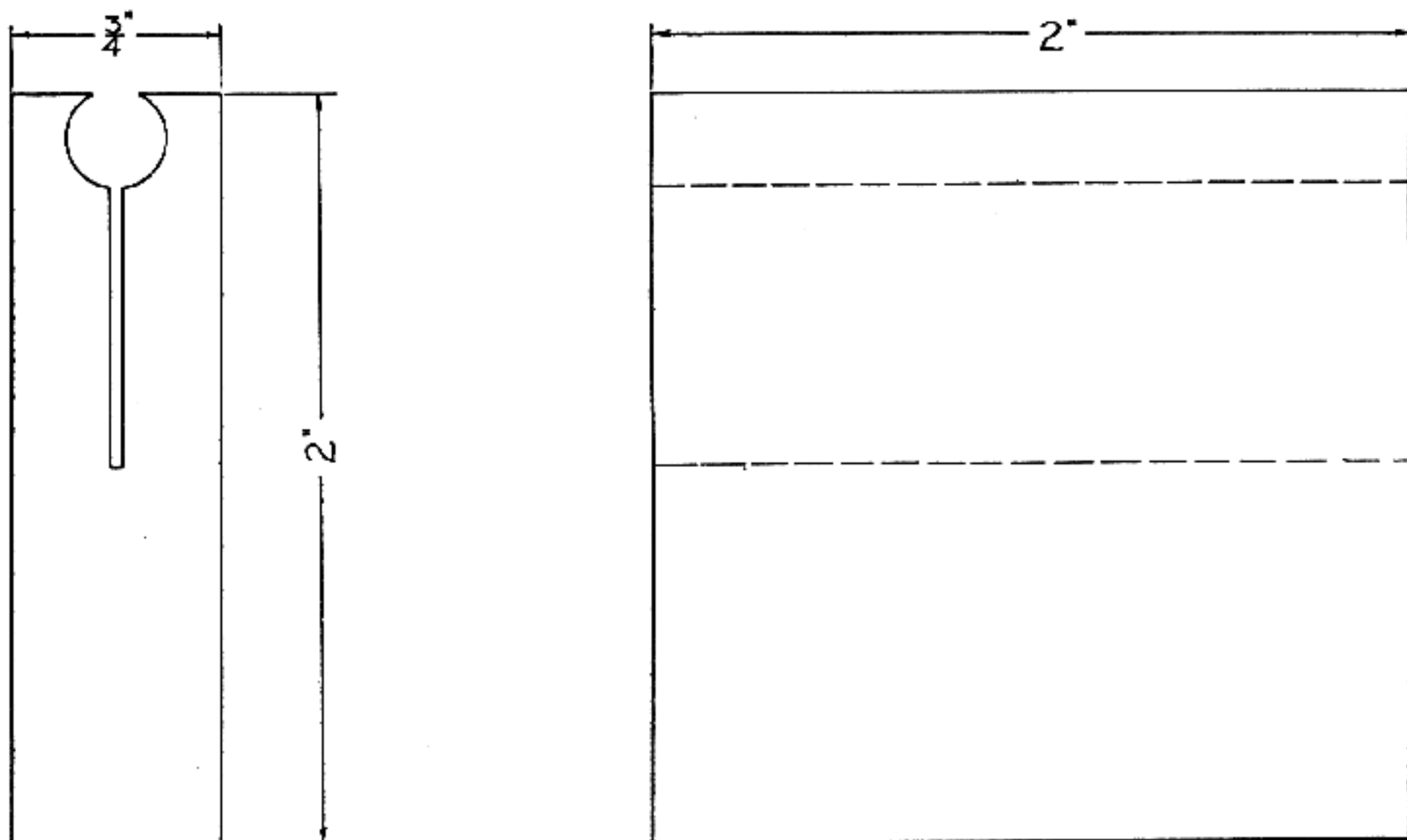
FORMING ROLL
HARDENED TOOL STEEL

Fig. 62

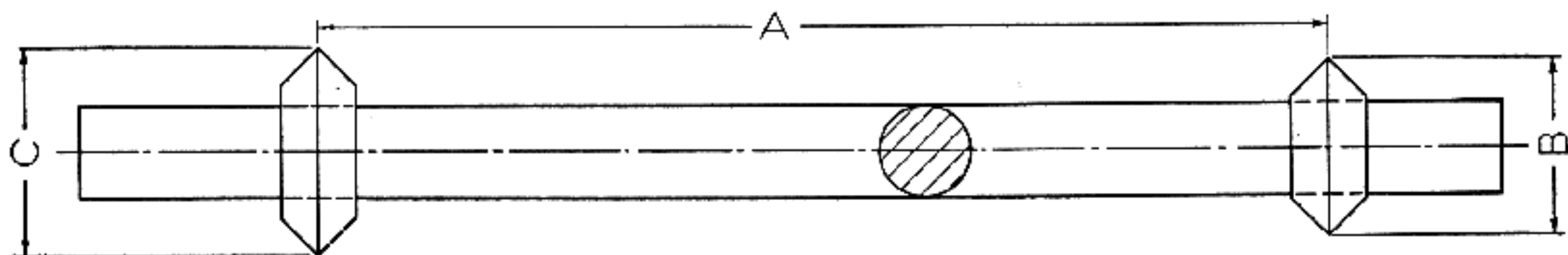
Tool and fixture used to form chip clearance in oil tubes. A planer is used for the operation

the blank is caught in the collet, a small center is drilled, and the blank is nicked on the same angle as the cutting edge, allowing enough web in the center for the following operations. When the blank is centered and nicked it is reversed, and the end is turned to a diameter which will conveniently fit the grooved oil tube. The blank is then milled for the chip clearance.

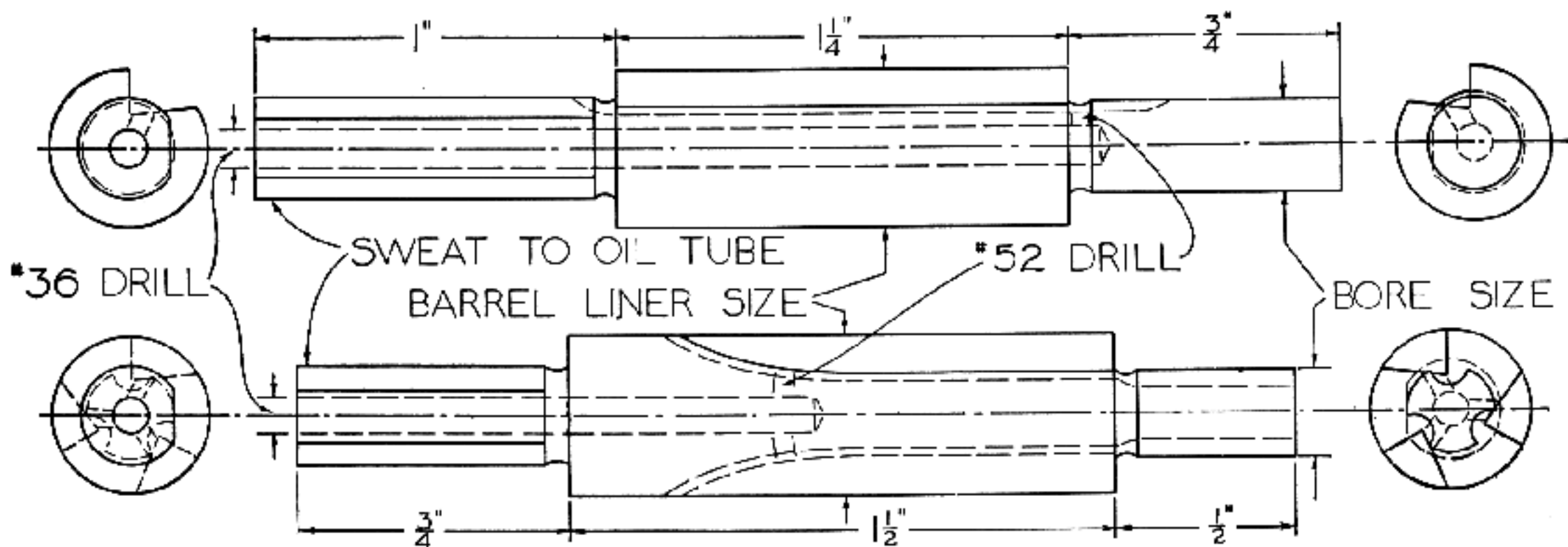
First, it will be necessary to make a drill holder which is only a piece of $\frac{3}{4}$ x 2 inch cold-drawn steel; the length is governed by that of the drill. A hole is accurately drilled and reamed close to one end of the steel to the size of the drilled blank. It is then split to a depth of $1\frac{3}{4}$ inch with a slitting saw; the width should be narrow, but it makes no material difference. While the drill holder is still in



BARREL DRILL HOLDER



GAUGE FOR GRINDING TAPERS



BARREL COUNTERBORES

Fig. 63

Gun barrel accessories, such as barrel drill holder, taper grinding gauge, and barrel counterbores

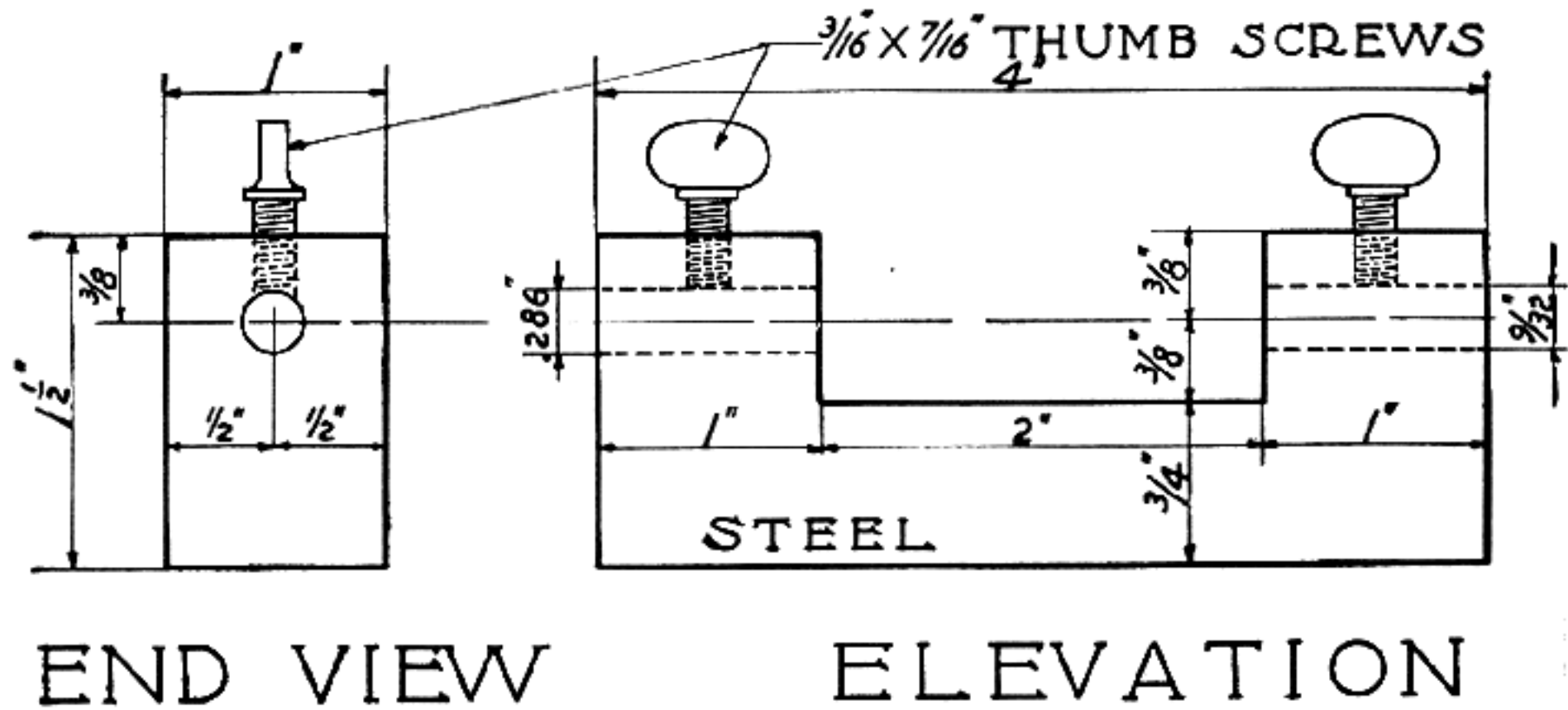


Fig. 64

Jig for brazing barrel drill to oil tube

the milling machine vise, the holder has the top milled off, exposing it to a depth of three-fourths of its diameter which is sufficient to hold the drill while the groove is being milled. Figure 63 shows this holder.

Having thus prepared the holder, the drill is set in place with the oil hole at the bottom and clamped in the milling-machine vise with only a fourth of the drill blank exposed. A piece of drill rod or any round steel bar is set against the holder, and the top of the vise clamps the blank solidly for the milling of the chip groove. The cutter should be placed as close to the center as possible and milled to a depth which will be just 0.002 inch above center after it is ground. The depth the groove is milled must be determined so that it will be correct after the drill is ground to size. After the drill is hardened and ground to size it is brazed into the end of the oil tube. Figure 64 illustrates a simple brazing fixture for this operation.

By clamping the drill close to the holder and only exposing the shank, there is no danger of annealing, for it is well protected from the flames of the brazing torch. At the same time the tube and drill can be held in perfect alignment. After they are completely brazed and cool, the surplus spelter is filed off and the drill and tube removed from the holder and finished. Below the drill also, the groove is cleaned of spelter and a drill carried through the oil hole to make positive that it is open for the flow of oil. The cutting edge is now ground and with an end connection sweated in place the drill is ready to drill a barrel blank.

Oil Tubing—The best oil tubing should be selected for drills, reamers, rifling heads and counterbores. Shelby tubing may be used in a number of instances, but the steel tubing made by Ellwood

Ivins* is the best, for they make all their tubes of a high-carbon steel; therefore they have greater strength and resistance when placed under actual working conditions and twisting. Figure 61 illustrates an oil tube as it is grooved for the barrel drill, and Figure 62 shows the planer tool which performs this operation, together with the oil-tube plate to be fastened to the planer bed. It really is not necessary to make such a fixture if there is an old planer in the shop equipment, for grooves can be placed in the face of the bed for the intended caliber, and other grooves made when needed. The form roll is made and a suitable holder constructed as shown in Figure 62. The roll is made on the same angle as the groove in the drill, and when these are brazed together there is a straight channel for chips and oil return. A groove thus formed in an oil tube as on the drilling operation reinforces the tube as much as twenty-five per cent more than the plain round tube. A piece of cold-drawn tubing may be used successfully for this operation.

The oil tubing used for barrel reamers should be as heavy as possible, and also the tubes connecting the rifling head. Figure 61 illustrates the oil-tube connector made for both the .22 and .30 caliber rifling heads; connectors intended for other calibers are made on the same principle. When oil tubes are sweated on barrel counterbores they should be as heavy as possible to give the greatest strength, for when the surplus metal is removed from the interior of a .22-caliber barrel it requires a very rigid tube.

Reamers, rifling heads, and counterbores are sweated to the tubes together with the connections necessary for the flow of oil. The sweating of these must achieve a very good union, and the heat applied to the tubes, connections, and tools

* Ellwood Ivins Tube Works, Oak Lane Station, Philadelphia, Pa.

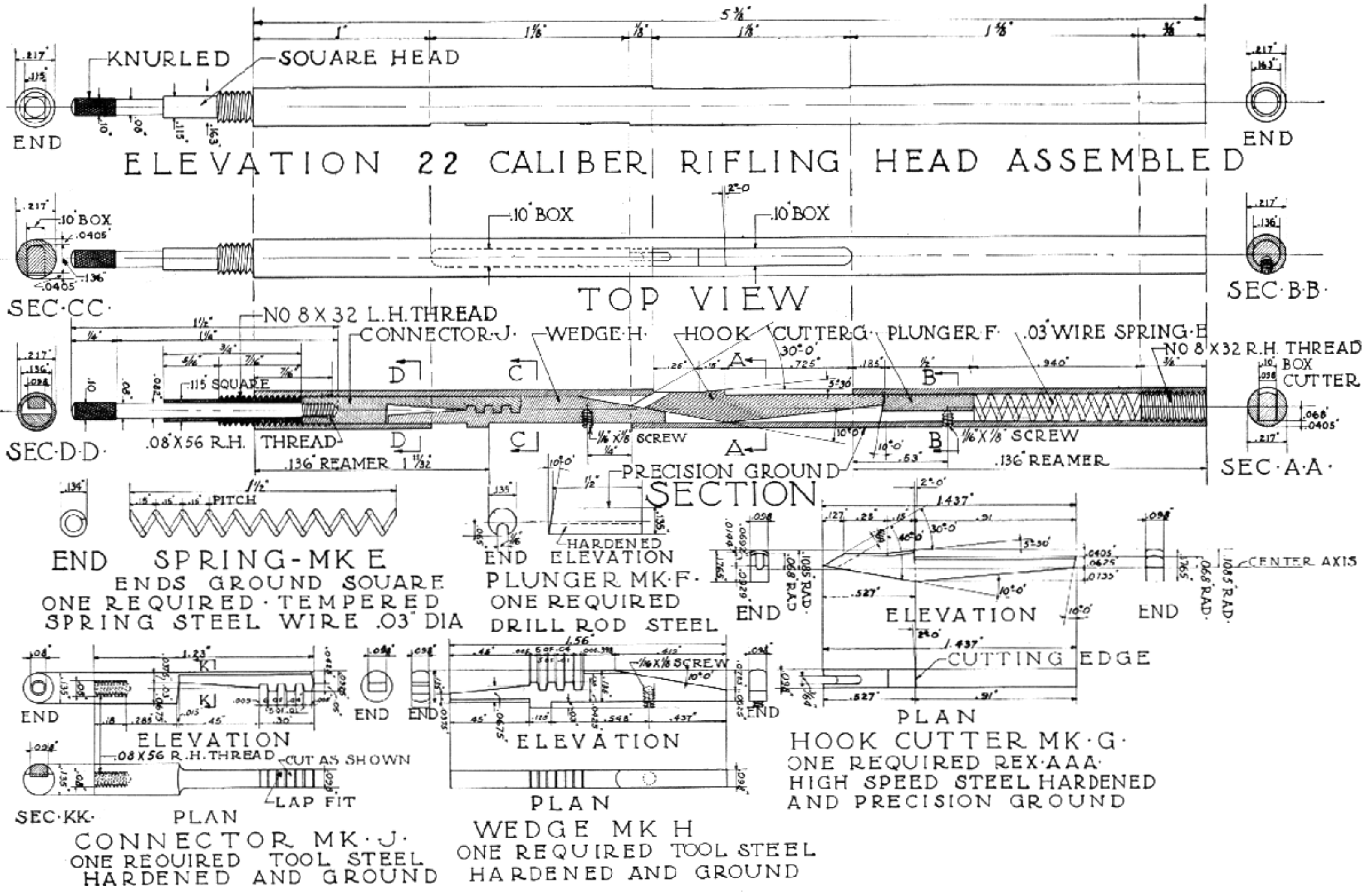


Fig. 65
 Caliber .22 hook-cutter rifling head

must only be high enough for the solder to run freely.

Rifling Heads — There are two forms of rifling heads: hook and scrape cutters. Figures 65, 66, and 67 illustrate one .22, one .30-caliber hook cutter, and one .30-caliber scrape-cutter head. The illustrations of the .22 and .30 caliber heads are similar except for the sizes; heads of this nature for any other caliber are made in proportion. A rifling head is one of the most difficult tools to make for barrel manufacture. The scrape-cutter head is the simplest, and for this reason I recommend it for the beginner to make and use. Some people think it is the best because a barrel made by this form of cutter produces the finest results in accuracy. This might be true if it were possible to use a diamond as the scraper. It is very difficult to hold the fine edge required on hard alloy steel barrels, but if a diamond were set in the holder a good many barrels could be cut with such a tool. A perfect groove would be produced, free from longitudinal grooves such as a steel cutter leaves. The use of diamonds in making barrels is a future possibility, for in this operation great accuracy and precision are the primary requirements. The diamond is the only material that would answer this purpose completely. A scrape cutter becomes worn rapidly and loses its shape to such an extent on hard steel that the results produced are inaccurate, which causes con-

stant interruption of the operation to keep it stoned. It is a well-known fact that the diamond tool is indispensable for truing grinding wheels, and that diamond dust is commonly used for lapping or grinding small precision work in various tool rooms where great accuracy is required. Then why not in the rifling of a barrel? Some day an enterprising barrel maker will have all his rifling cutters made of diamonds, and his barrels will be known the world over.

As we study Figures 65 and 66—the .22 and .30 caliber rifling heads, which are hook-cutter heads—we see that the principle of adjustment is very simple. The cutter is in its released position, and as the head passes through the barrel, the wedge projection comes in contact with the release, moving the wedge *H* back. The tension on the spring *E* causes the cutter to be moved back by the plunger *F*. The cutter *G* has a 10-degree angle on the rear portion and a 30-degree angle which also corresponds to the same angle in the body of the head. As the adjustments take place for a new cut in the groove, the adjusting screw is given a slight turn corresponding to a scraping cut of 0.0001 inch or slightly more, and the connector *J* is moved forward carrying the wedge *H*. The cutter *G* is moved higher on the angle of the wedge and causes the former to remove the desired amount of metal from the groove. Only the one setting is required until all grooves are cut and another adjustment takes place, but upon its re-

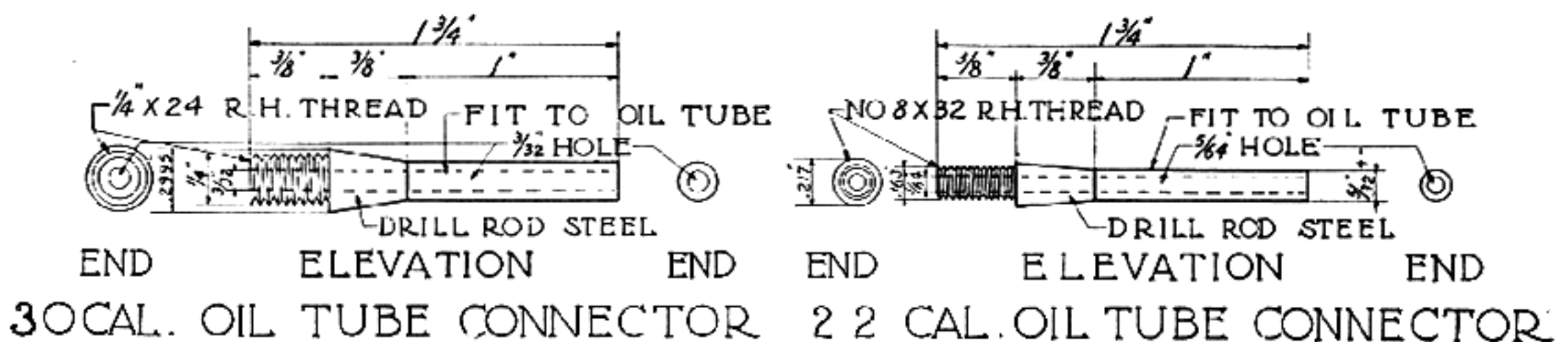
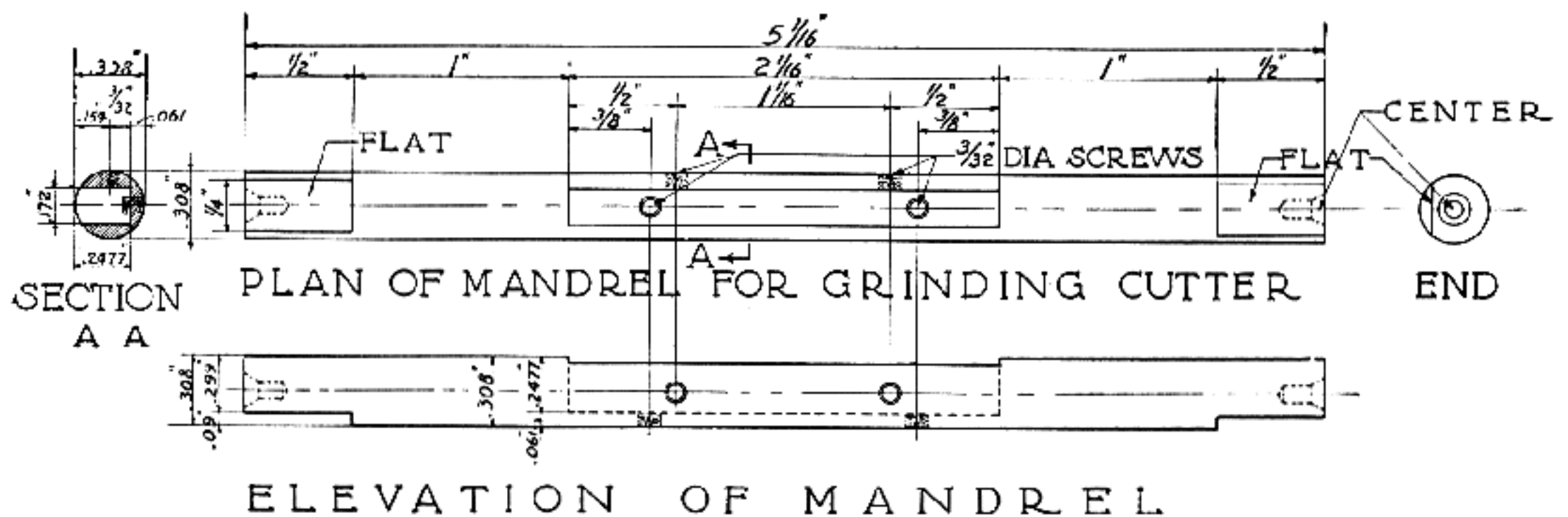


Fig. 68

Rifling-head oil-tube connection and mandrel for grinding rifling cutter

turn through the barrel it is released so that the cutter does not come in contact with the metal to dull the cutting edge. A constant supply of oil is coming through the groove in the plunger *F* and flowing around the cutter from the box. The oil-tube connectors shown in Figure 68 screw into the forward end, compressing the spring *E*. It will be noticed that the adjusting end of the head has a left-hand screw, whereas the oil-tube connector end has a right thread. It is well to sweat the latter in place after a head is adjusted and working properly.

In the plan view of the cutter it will be noticed that a groove is cut in the rear portion. This is used to insert a hook to remove the cutter whenever it needs stoning or sharpening. There is shown in Figure 68 an arbor for grinding the radius on a hook cutter to the exact diameter of a maximum groove in the barrel. This arbor is required for each caliber of barrel made; therefore, one of these is also necessary, as well as the rifling head itself.

The drawings of these rifling heads are as complete as it is possible to make them; still there are points and a number of figures which must be made by the person who attempts them. When making the rifling head it is best to make three, especially for the .22-caliber size; one may be lost or even two in the hardening. On the larger sizes it is advisable to make two, and if an accident should happen there is always the extra body to fall back on.

A difficult part to complete is the 30-degree angle between the cutter and the wedge box; this must be filed in as it is impossible to work any form of cutter in the small opening between these two boxes. The milling of the cutter and wedge requires a high-speed vertical-head attachment to the milling machine and very fine cuts must be taken. Since these two boxes are opposite each other, the body is held in the dividing head chuck, and after one box is finished the head is turned 180 degrees and the other box is milled.

The making of the wedge and connector requires the closest of precision work, for these two must fit together without any lost motion between the teeth; also, the length must check between the cutter, wedge, and connector. The $\frac{1}{16} \times \frac{1}{8}$ inch screw which is placed on the forward end of the wedge is for the purpose of removing the wedge from the box; otherwise it would be difficult to lift it out.

The tapping of both ends of the head must be done with care to have them perfectly concentric and also to be the full depth of thread. All parts of a .22-caliber head are rather small, so more

care should be used in their construction. The most satisfactory steels found to make the body are either Stentor oil-hardening steel or Sanderson high-carbon tool steel. Both must be given annealing treatments or normalized after the blank is roughed out to remove all strains from the steel before the hardening operation takes place. If these annealing treatments are not given the steel the heads usually run out in the center, which is the weakest part of the body.

The construction of the standard scrape-cutter head shown in Figure 67 will be self-explanatory to the experienced tool maker, as it is one of the most simple forms of head to make. The cutter itself is worked up from the center by a wedge effect made possible by the adjusting screw with a long tapered pointed rod acting between the cutter and a projection left in the center of the head with a similar projection on the cutter *A*; therefore the cutting effect is relied upon by the spring or give of the cutter itself with the adjustment in the center of the tool. This cutter works in both directions through the barrel, or cuts in both directions of its stroke.

Figure 83 illustrates an angle on the cutter which should be made as shown. The drawing illustrates a straight cutter, the easiest to make, but if this is set off at an angle of 20 or 30 degrees to the cutting edge better results are made possible. When constructing one of these cutters it is well to change from the straight cutter to the angle cutter mentioned. The cutter only requires a gradual adjustment of the screw in order to move it up against the walls of the bore after it begins to form its grooves. The depth is only a matter of a number of passes through the barrel, actually being only 0.004 inch. The spring of the cutter caused by the wedge adjustment is practically nil. The same instructions may be followed as given for the hook-cutter rifling head, but because of the simplicity in the construction of this head I will presume that the reader has the required mechanical knowledge to complete either head without much effort, provided he has the proper machine tools at his disposal. Without these it will be found very difficult to have the accuracy and precision necessary to complete them as they should be. There is always one point to be remembered when finishing the cutter and that is to have a flat portion of about 0.001 inch on the top of the cutter. This advice applies to the burnishing reamers as well.

Figures 69 and 70 illustrate a new design in rifling heads; one is for a .22 caliber and one for a caliber .30. These heads are made on the scrape-cutter or burnishing principle, except that the full

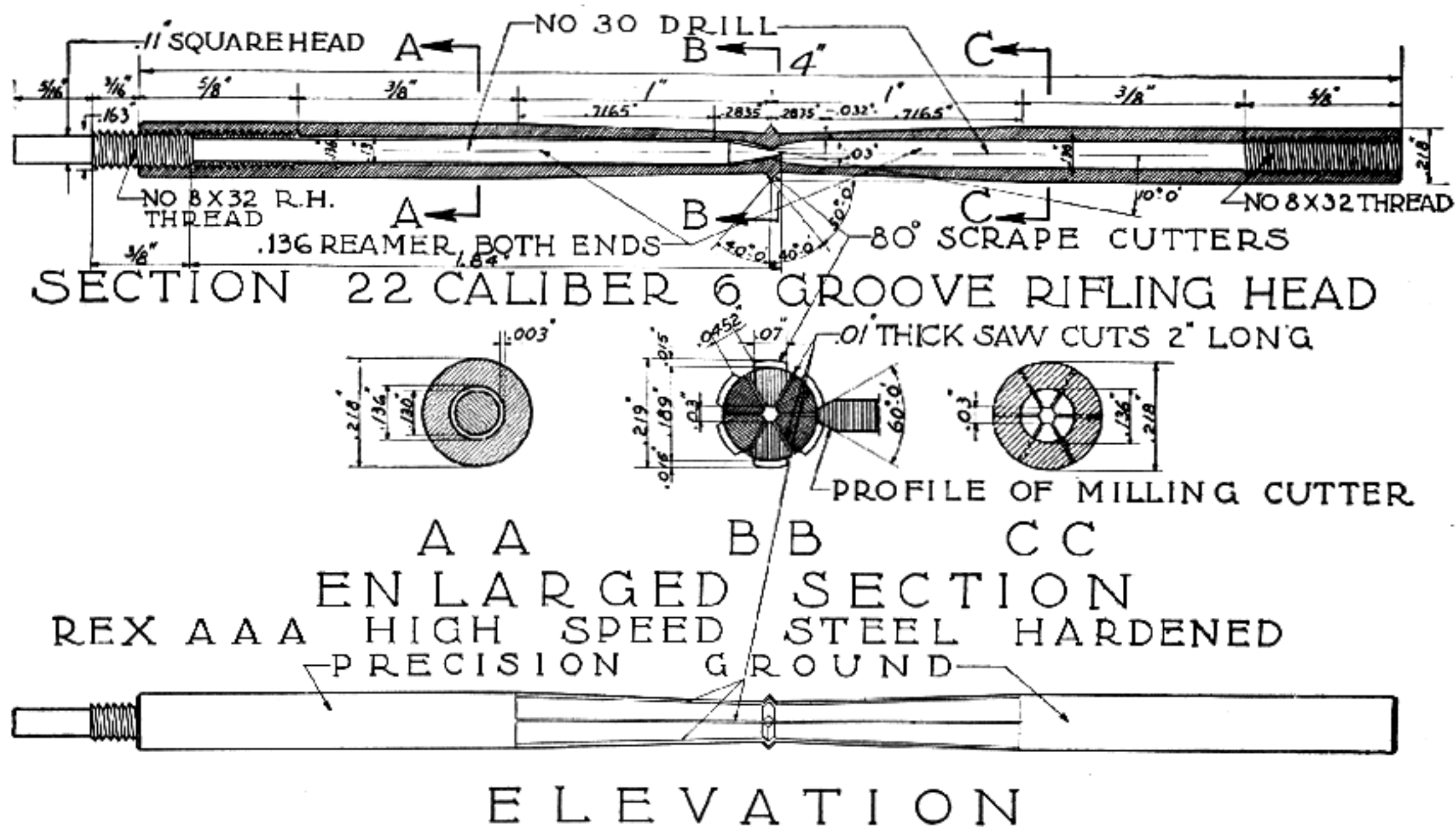


Fig. 69

Design suggestion for six-groove caliber .22 scrape-cutter rifling head. Any caliber may be made on these principles

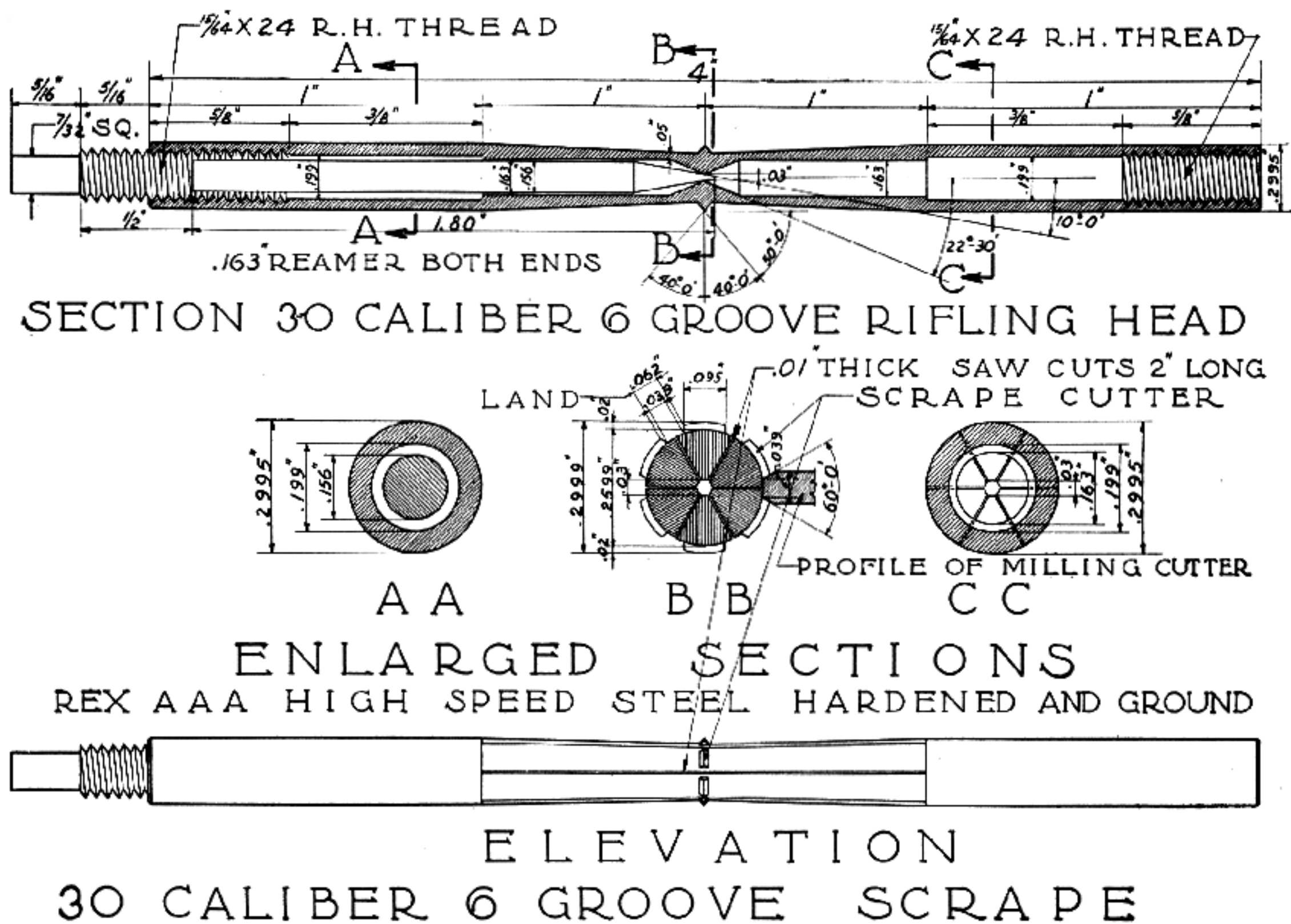


Fig. 70

Design suggestion for six-groove caliber .30 scrape-cutter rifling head for cleaning out rifling

number of grooves are cut without moving the index head either on the milling or rifling machine. Simplicity is the keynote of these heads and it is possible for the average mechanic to make these providing he has the equipment. I have never used them in the construction of a rifle barrel, but because of the demand for a cheaper tool this was designed. The real difficulty will be found in the hardening, as a high-speed steel is used; but since most large cities have heat-treating shops there will be no trouble, nor will there be any in the small shop, providing the equipment is such that it can be done there. This tool may also be used to clean a barrel that has been neglected—by fastening it in the lapping head as shown in Figure 85.

Gauges — While any tool or instrument used for securing or taking measurements may properly be called a gauge, this term, when used by tool or gauge makers, is usually understood to mean tools which conform to fixed dimensions and are used for testing sizes but are not provided with graduated adjustable numbers for measuring various lengths or angles. There are exceptions, however, to this general classification; measuring instruments, such as the micrometer and vernier caliper, are indispensable because they can be used for determining actual dimensions, and being adjustable, cover quite a range of sizes. Any form of adjustable measuring tool, however, has certain disadvantages for such work as testing the sizes of duplicate working parts, especially when such tests must be made repeatedly, and then solid or fixed gauges are commonly used. There is less chance of inaccuracy with a fixed gauge, and it is more convenient to use than a tool which must be adjusted; but, owing to the necessity of having one gauge for each variation in size, and because of the cost of a set of buttons covering a wide range of sizes, the simple type of gauge is usually selected. There are two separate gauges made for a maximum or minimum length for testing head space in a rifle chamber. The button type of gauge will cost almost twice as much as the micrometer gauge, but it is positive and can stand a great amount of pressure, whereas the micrometer standard must be used with great care in order not to strain the threads with undue pressure upon the camming action of the bolts.

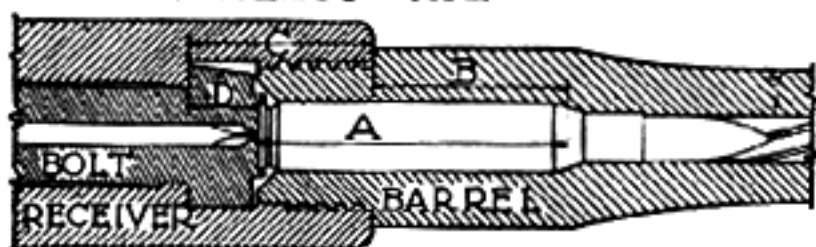
Construction of the gauges shown in Figure 71 requires practically all of the measuring instruments used by tool and gauge makers. They may be divided into two general classes: the tools for measurement of length and those for the measurement of tapers or angles. In these two general classes of instruments for length and angular

measurements, there are many different types and designs. For instance, there is the adjustable type which is graduated and used for taking direct measurements in inches or degrees; then there is another type which is fixed and cannot be used for determining various sizes of angles, but simply for gauging or testing one particular size. There are also tools for taking approximate measurements and others designed for very accurate or precise measurements.

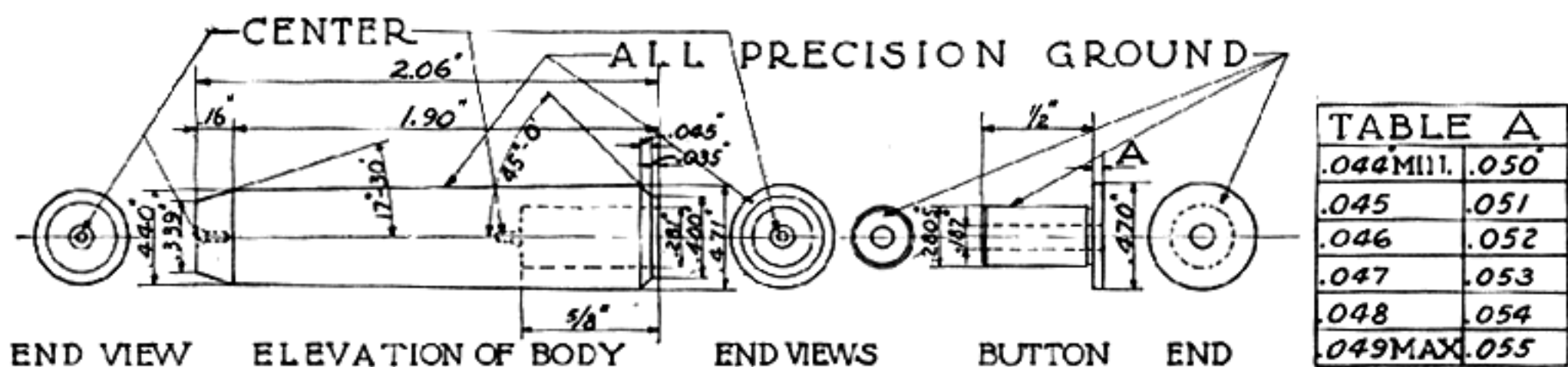
The instruments necessary for the construction of accurate gauges for barrel and other work pertaining to rifles are: the vernier caliper, such as the height and depth gauge, and the caliper micrometer, bevel protractor, sine bar, indicator, etc. With these it is possible to make tools and gauges calling for fine precision measurements given in these drawings. In the construction of gauges, it is a well-known fact that hardened pieces of steel will undergo minute but measureable changes in form during a long period of time after the hardening has taken place. These changes are due to the internal stresses produced by the hardening process which are slowly and gradually relieved. To eliminate slight inaccuracies which might result from these changes, steel used for gauges and other barrel tools requiring a high degree of accuracy is allowed to season before being finally ground and lapped to the finished dimensions. To relieve the stresses and overcome the long delay of storage seasoning, the hardened tools and gauges are heated in oil at a temperature of about 325 degrees Fahrenheit for a period of ten hours; thus the internal stresses which cause the changes are practically eliminated. Of course, you can use the old method known as the hot and cold water bath. The steel so treated is rough-ground quite close to the finished size and is then immersed in a bath of boiling water, which causes the gauge or tool to expand; then it is dipped in a bath of ice-water. The repeated expansion and contraction cause the molecules to settle into a permanent form.

A number of various gauges for the chamber of a rifle are also necessary if many barrels are to be produced. Figure 72 shows a complete set of chamber gauges made for the .30-06 chamber. I do not want to give the reader an impression that he must make a set of gauges for all chambers; on the contrary, if you have the proper confidence in your own ability to make correct measurements it is not necessary to construct so elaborate a set of gauges for one or two barrels, or even a dozen; but it is possible to make a few temporary gauges of soft steel to check measurements that you may be in doubt about. Plug gauges are necessary to

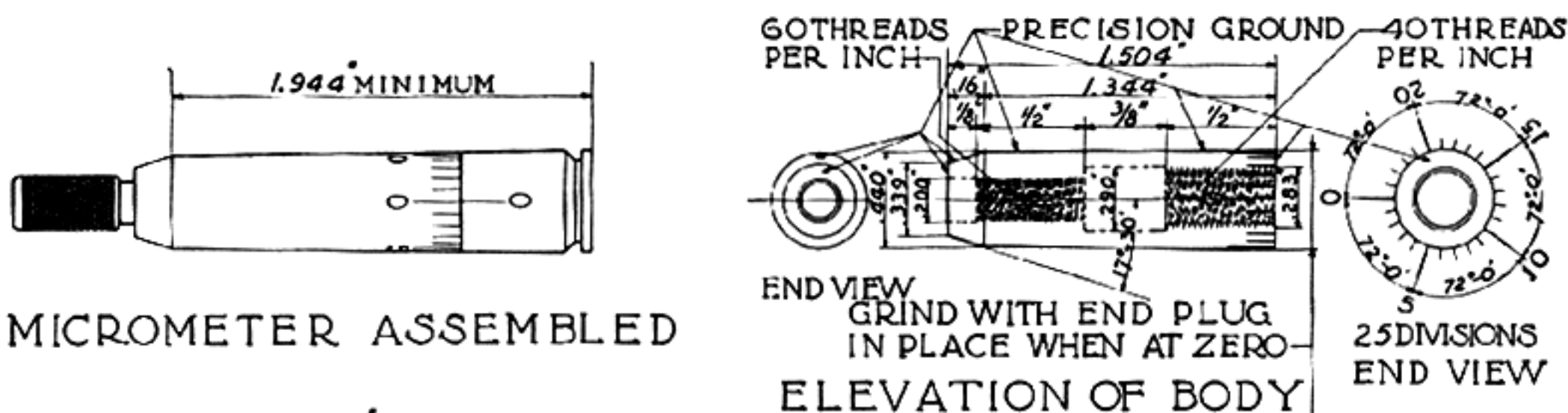
RIMLESS CASE



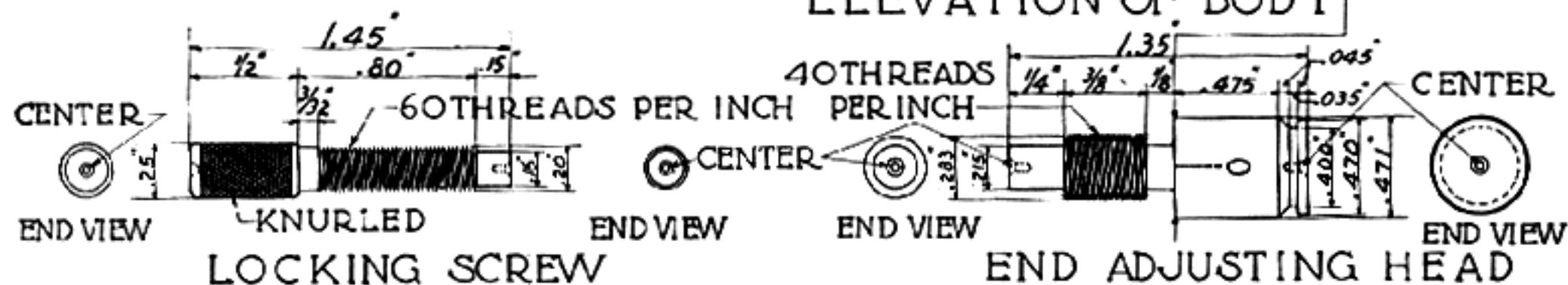
HEAD SPACE MEASUREMENTS



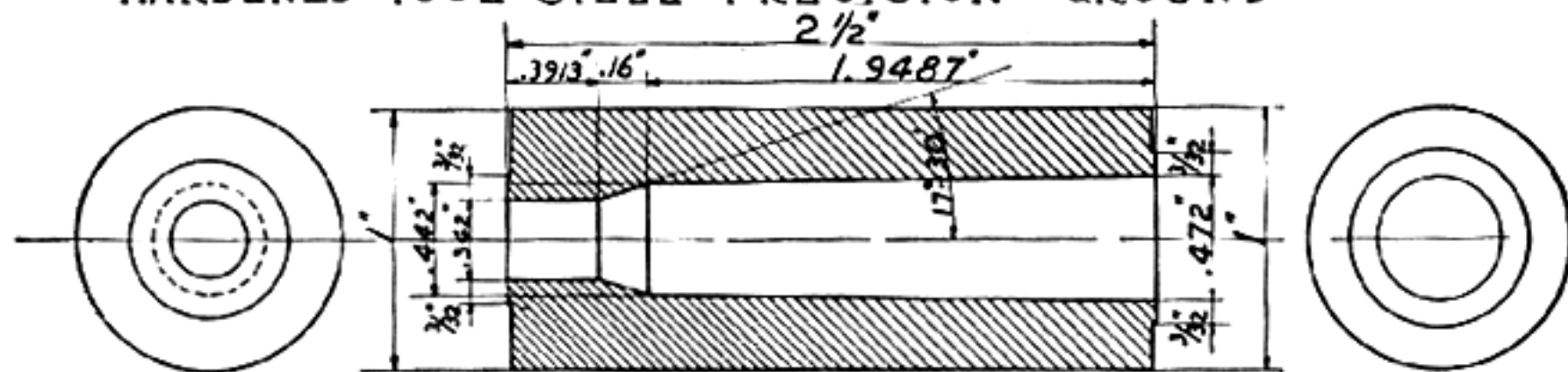
30 CALIBER MODEL 1903 HEAD SPACE GAUGE AND BUTTON
 SAME STYLE CAN BE USED FOR ANY RIFLE USING A RIMLESS HEAD CARTRIDGE
 HARDENED TOOL STEEL
 BUTTONS .05 TO .055 THICK ARE FOR CHECKING SET BACK AFTER FIRING



MICROMETER ASSEMBLED



MICROMETER HEAD SPACE GAUGE FOR MODEL 1906 CARTRIDGE
 SAME STYLE CAN BE USED FOR ANY RIMLESS CARTRIDGE CHAMBER
 HARDENED TOOL STEEL PRECISION GROUND



END VIEW CROSS SECTION END VIEW
 HEAD SPACE MASTER GAUGE 30 CAL. MODEL 1906
 HARDENED TOOL STEEL PRECISION GROUND

Fig. 71

Headspace gauges and master for rimless cartridges. For rimmed-head cartridges, a button gauge is used to take measurements from face of barrel to face of bolt

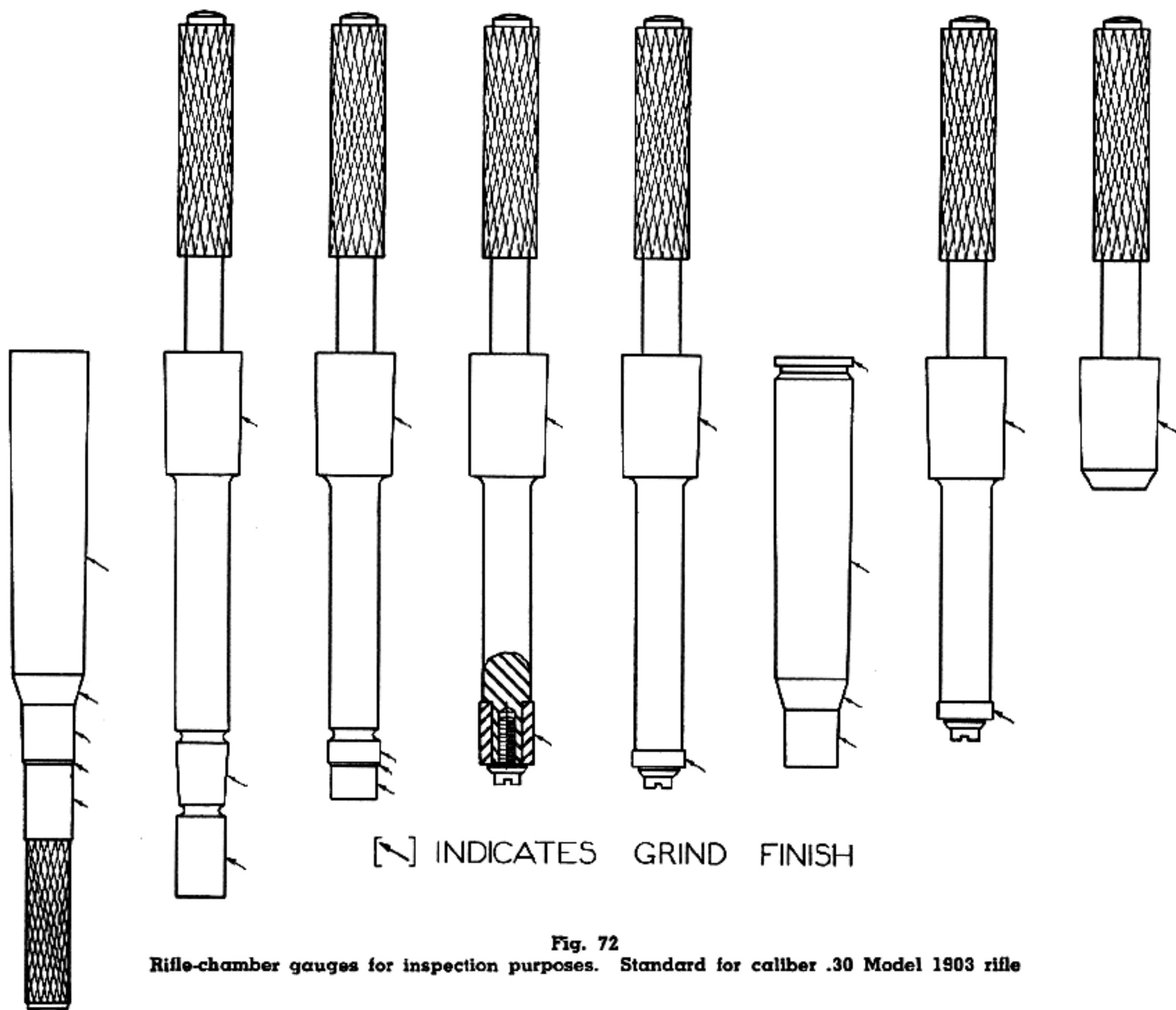


Fig. 72
Rifle-chamber gauges for inspection purposes. Standard for caliber .30 Model 1903 rifle

check the bore of a barrel, especially when pilots are used on the barrel reamers. These gauges are intended as a practical working standard. The internal measurements of a barrel should have a tolerance. Figure 60 gives these, but you may wish much closer measurements, so they may be adopted as standards and the plug gauges made accordingly. The plain cylindrical end of a plug gauge is ground and lapped to the exact diameter; these are the standards and must be adhered to very closely in all barrel work.

Gauges for the depth of groove or the rifling are made in different forms. Plug gauges are also constructed for this purpose with the lead of spiral for the intended twist. When constructing such gauges, only two spirals or gauging points are cut; these are opposite each other and only two grooves are gauged at one time. The construction of spiral gauges is done in a milling machine—shown in Figure 73—and the dividing head is set up to the lead of spiral desired. With a high-speed vertical

milling attachment set in position, a small-end mill is used. First, the width of groove is milled, both top and bottom; then the land clearance is gradually milled out below the depth, which would be equivalent to at least 0.010 inch clearance. The fine end-mill marks are filed out with a fine needle file and the surface is polished. After they are hardened the outside diameter of the spiral is ground to the desired sizes for the depth of the groove. A series of such gauges should be made in steps of 0.0001 inch; with these it is possible to tell if there are any tight or loose places in the grooves, and at the same time know the true size of groove, not only in width but in diameter to the bottom of the groove. There are also the thin checking gauges made from $\frac{1}{32}$ -inch ground gauge stock, as described in Chapter XI; these are used to check the depth of rifling when rifling a barrel.

When making a chambering reamer, two gauges should be made to set the sine bar so that the exact taper can be ground. The ring method of

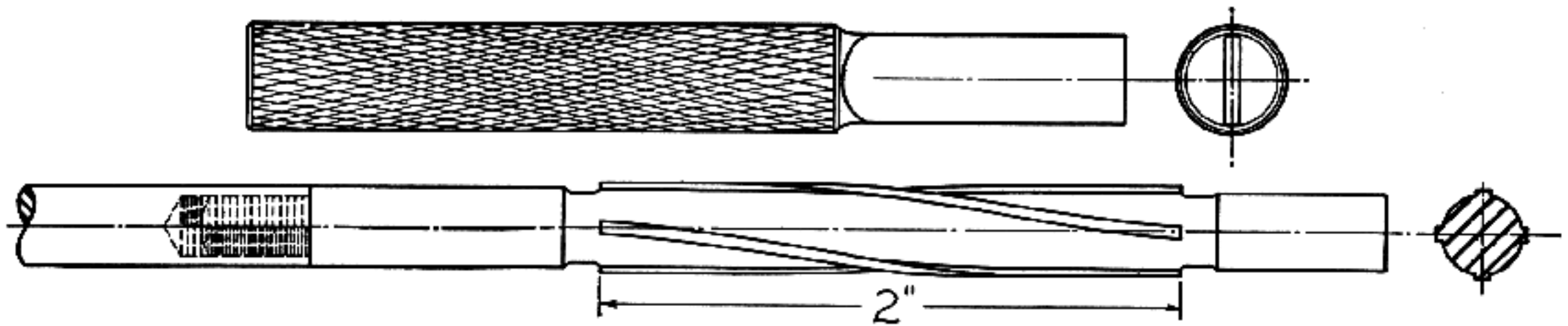


Fig. 73
Rifling gauges

testing these tapers is the most accurate. In Figure 59, illustrating barrel chambers, two sizes are given on the body taper of the chamber. Two rings are made, one for the size of the body at the shoulder and one at the base or end. Figure 63 illustrates this gauge. The test rings are turned to diameters *B* and *C* and located on a ground arbor, allowing the length of the latter to be $1\frac{1}{2}$ inches longer than the greatest distance between two given lengths in any of the chambers illustrated. The rings may be hardened and ground to the exact diameters and the center hole also lapped so that it is just possible to slide the rings along the arbor. *A* is the given distance to locate the rings apart. After setting the rings to this distance, the sine bar is set up on an angle plate and clamped to the surface plate. An accurately ground parallel is used for the bottom gauging point. After adjusting the sine bar until it fits tightly on each ring to the given distance *A*, a small pointed indicator may be set at the point where the small ring touches the sine bar and parallel. Be sure that when grinding the taper this will be the point of the exact diameter, and allow 0.001 inch for stoning. This method of gauging such tapers is positive and eliminates all guess work or trying to measure these two points with a micrometer.

Barrel Counterbores — There are two forms of counterbores used to enlarge the bore in a rifle barrel, and for the purpose of setting in liners or rifled tubes. Figure 63 illustrates the two different forms. *A* is for a large bore where it is only necessary to remove a small amount of material, and *B* is for a small bore removing considerable

stock from the bore. The chips are forced out from the rear with the oil pressure; whereas in *A* the chips are forced ahead through the grooves in the pilot. These tools are sweated to oil tubes so that it is possible to get sufficient oil pressure to remove the chips as the tools remove the metal. These are very simple tools to construct, as the illustration shows, and very practical for such an operation.

Accuracy is essential in practically all of these tools and in gauge-making operations and the standard methods of tool work as carried out in various chapters. Readers of mechanical literature who are mechanics will be familiar with this information, but the man who is just learning this class of work should consult reference books, of which there are many. Many subjects of this nature cannot be covered adequately in all their phases; if I were to cover the subject as it should be, it would be necessary for me to consult such books and merely copy the information. These subjects could be more comprehensive and have more detailed information, but I am assuming that the reader is far enough advanced in mechanics to carry out the ideas I have placed before him.

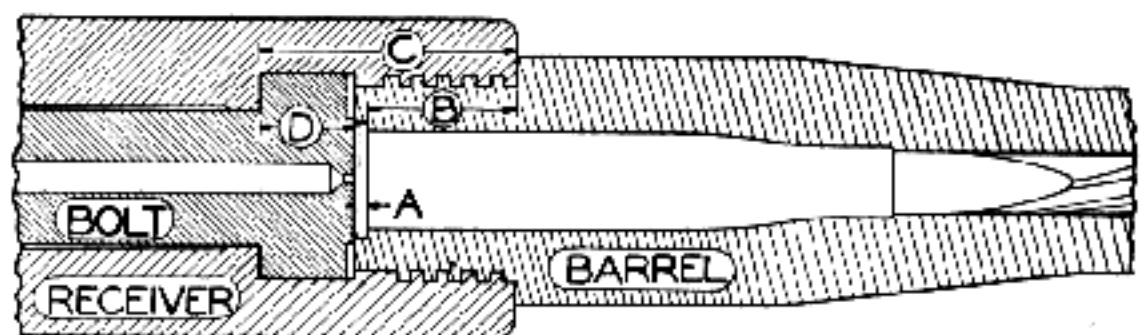
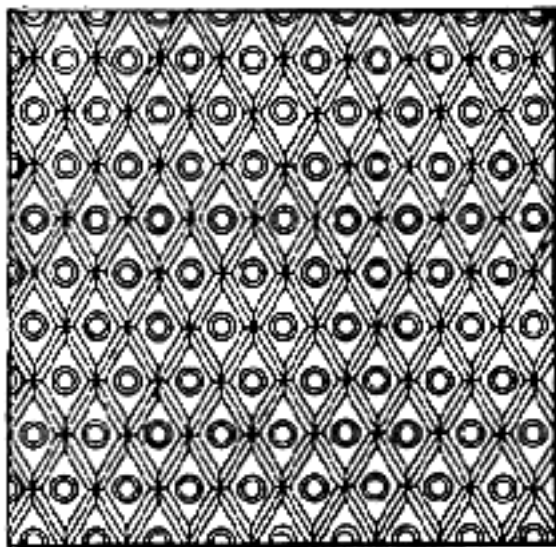


Fig. 74
Headspace measurements. Rimmed cartridge case shown in chamber

CHAPTER X
Barrel Drilling and
Reaming



Barrel Drilling and Reaming

IN THIS and the following chapters I shall guide the student step by step through the art of barrel making from a different angle. The standard machine tools used in modern production will not be employed, but the barrel-making tools will be of standard design. We shall limit ourselves to a lathe and a milling machine. The entire operation may be accomplished on a lathe, but by using a milling machine it is possible to secure any lead of spiral. When a lathe is used altogether it requires many hours of work and necessitates making wooden drums with a cable connecting two dissimilar sizes. Sprockets and chains could be used, or even a rack and pinions on the back of the lathe to turn the spindle; a number of ways can be devised, but the milling machine affords a more simple and practical method.

Undoubtedly, some people will think these chapters a bit absurd, but before any one lets pessimism govern his attitude, allow me to cite, as an example, the barrels turned out by Harry Pope. There are men who would pay any price for a barrel with his name stamped on it; yet if you were to walk into his shop and purchase the lathe on which these super-accurate barrels are made, and were to give him over fifty dollars for it, it would be through the generosity of your nature. Nevertheless, for years he has turned out barrels on this lathe which have never been equaled by modern machinery. Naturally, I do not contend that a lathe should be used in preference to modern equipment, nor am I considering speed, number of operations, or number of barrels produced. This information has been written primarily for the man who cannot afford an elaborate set-up and must do the best he can with what he has at hand. If one is fortunate enough to possess the complete equipment, the chapter on barrel tools will be a standard in both cases.

The drilling of barrels was formerly done by hand and was regarded as a mystery. Today it is simply a mechanical operation differing only in degree from the making of other parts or tools. Nevertheless, the barrel is the most important part of a weapon, and care must be bestowed on it. After certain limits of accuracy in manufacture have been passed, there are no means of knowing

whether the barrel will be an exceedingly accurate one, or whether it will only pass the ordinary test.

When the steel comes from the mill the barrel is rough-turned to the exterior shape or only the end turned, as will be suggested later, and drilled. The drilling may be done "straight through" from end to end in one operation, as Figure 75 illustrates, on a standard barrel-drilling machine, or when a lathe is employed it may be started at both ends and meet in the middle. In drilling and reaming, the drill bits and barrel reamers slide horizontally along the bed of the lathe while the barrel is caused to revolve. Lard oil which acts as a lubricant is pumped into the hole as the work proceeds, and washes out the chips or "swarf." The bore must be straight and concentric with the exterior. Straightness is tested by light and shade effects caused by the multiple reflections of the muzzle down the bore. The slightest lack of concentricity in these repeated circles is an indication that some correction must be made. This correction may be done by means of blows struck on the exterior of the barrel with a copper or babbitt hammer, but modern methods favor the use of a special barrel-straightening press. For testing concentricity of the bore, full details will be given later in this chapter.

In their order, tools are made for the caliber and cartridge intended. For drilling a barrel, the drill and oil tube are made, and then the other necessary work upon the lathe is done, which enables one to carry out the operation without trouble. A lathe can be used for the drilling and rough-reaming without removing the blank from it. Our choice is a lathe with a 1½-inch hollow spindle with two chucks, as illustrated in Figure 76. If you have not a lathe with a hollow spindle as large as this, select one with a long bed in which it is possible to use a three- or four-jawed chuck and steady rest; however, if this is to be a continuous operation it will be advantageous to purchase a second-hand lathe and fit it up, making the chucks as shown in Figure 76. Remove the first adjusting nut on the opposite end of the spindle and make a chuck which will serve two purposes: to hold the barrel and turn the center for a belt connection. This provides a drive to connect a high-pressure oil pump which can be located on brackets fastened to the legs of the lathe.

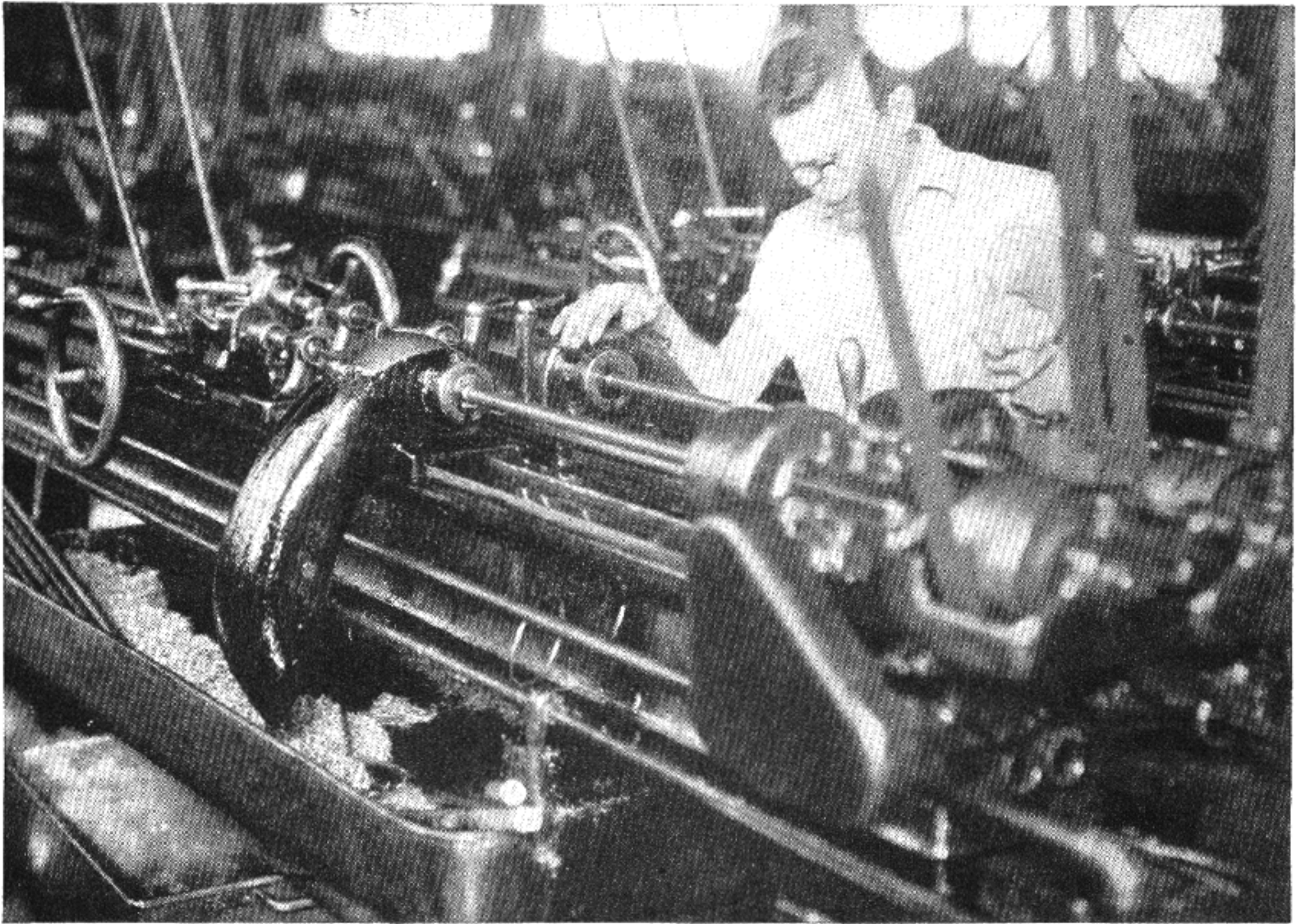


Fig. 75
Rifle-barrel drilling machine in operation

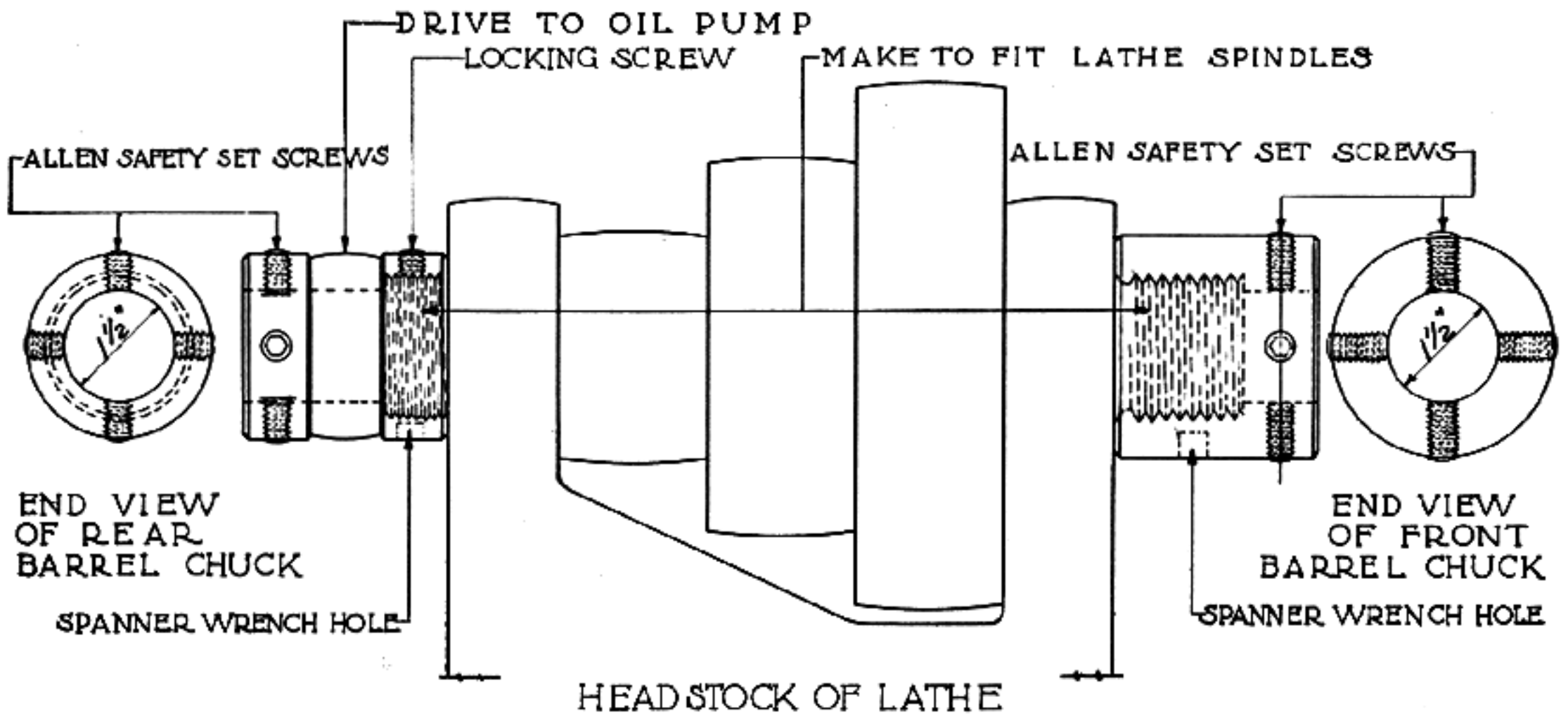
The front chuck can be screwed on the spindle and made either of cast-iron or cold-drawn steel. In making the chucks, four set screws are used in each one (Allen headless screws preferred) to true up the barrel blank.

A suitable pan of tin or galvanized iron is made, both for the back and front of the lathe, to catch oil; also a hood of tin to go over the front chuck with an elongated slot for the oil tube, which can be removed at will; and finally a tank for the returned oil. Suitable oil strainers should be made so that no chips can return to the oil pump and obstruct the flow of oil to the drill. The usual practise is to make an angle plate, as illustrated in Figure 76, to clamp to the cross slide where the tool post is situated. This is made of cast-iron or machinery steel, and since there are adjusting features for height, the correct location for center can always be held. Altho the tubing is comparatively light, construct a wooden frame to hold the drill tube in the center and at the end, so that it will not lag. Wooden brackets may be made in place of the wooden frame, and these can be clamped on the ways of the lathe and moved along as the drill ad-

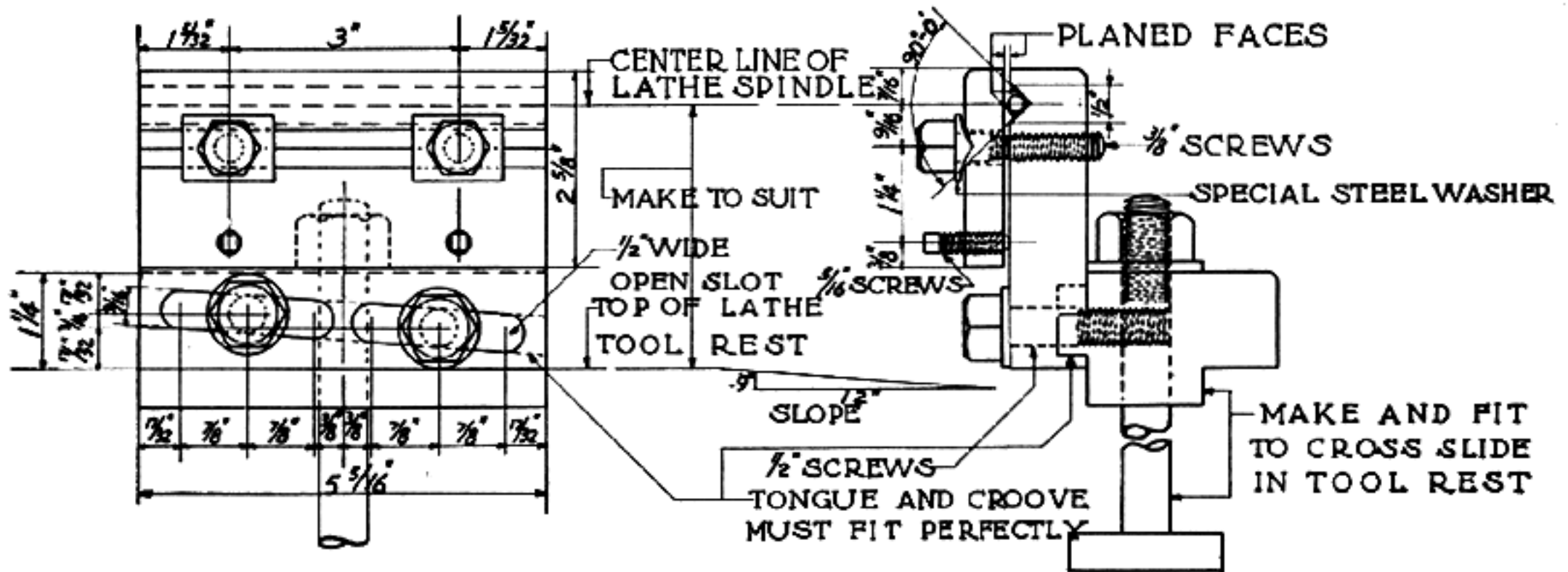
vances in the barrel. A rather heavy rubber hose is connected between the oil pump and hose connection, as shown in Figure 61. Fasten with suitable clamps, which can be easily removed when changing from the drilling to the reaming operation.

Since it is not of importance to use a larger steel bar than $1\frac{5}{16}$ inch diameter, there will be ample room for the adjustment of the set screws; this encourages it to run perfectly true. Before setting the bar in place, center it on one end only; this can also be done before the removal of the tail stock from the lathe or the setting of the angle plate to hold the drill. Turn back a true surface and just remove the scale for about 1 inch. This affords an opportunity to have it run absolutely true between the two chucks with the set screws. Only allow about 1 inch to extend from the nose of the chuck where the drill starts. By turning this straight portion the blank may be trued whenever it is necessary to remove it. It would do no harm to turn the opposite end also for truing purposes.

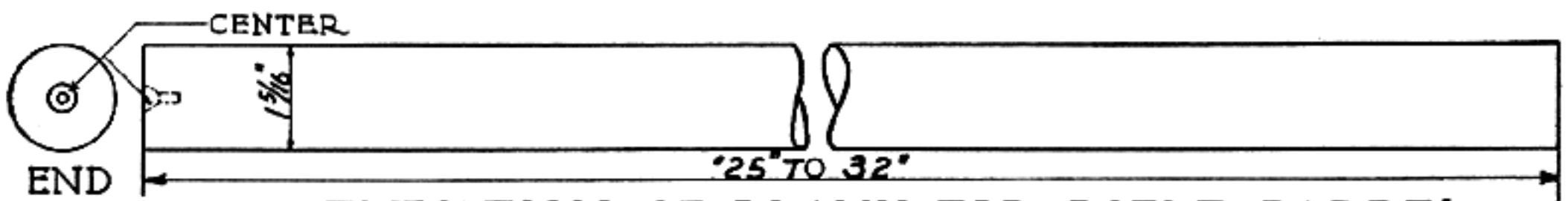
Before drilling, place the steel in a furnace to normalize it and remove all strains in the bar. Hold the heat in the furnace between 1350 and



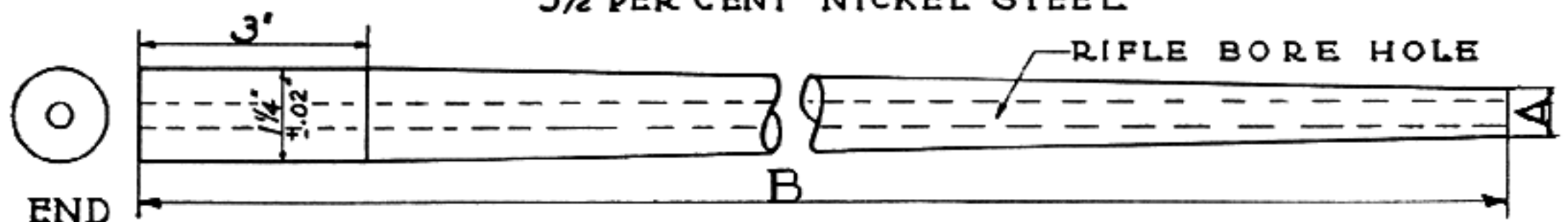
ELEVATION OF CHUCKS FOR FRONT AND REAR OF LATHE
MACHINE STEEL



FRONT ELEVATION END ELEVATION
FIXTURE TO HOLD BARREL DRILL AND
REAMER OIL TUBES
MACHINE STEEL



ELEVATION OF BLANK FOR RIFLE BARREL
3 1/2 PER CENT NICKEL STEEL



ELEVATION OF ROUGH TURNED RIFLE BARREL

Fig. 76

Lathe head and chucks. Oil-tube holder, which is clamped in the cross slide. Barrel blank and table of barrel-blank turned measurements

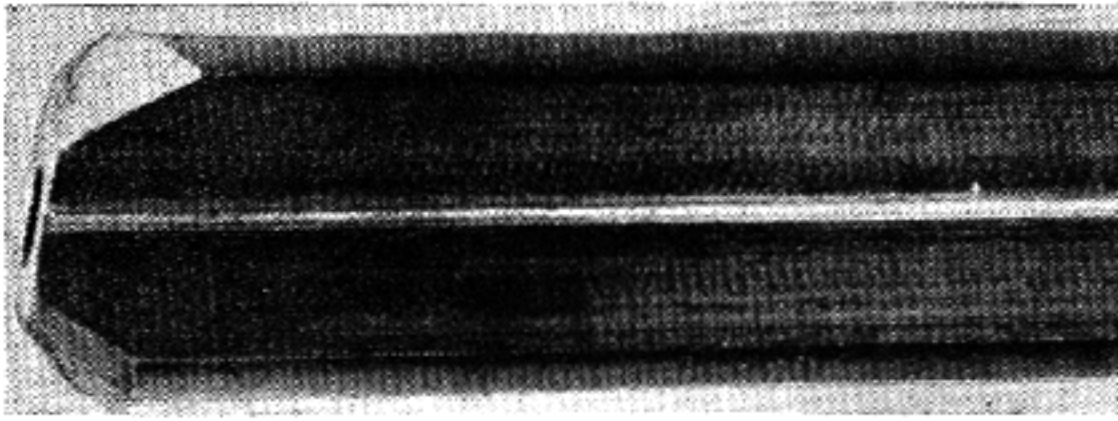


Fig. 77

Barrel-drill end, showing the cutting edge, oil hole, and chip groove. Study this illustration when grinding point of the drill

1450 degrees Fahrenheit for one hour, and then turn the furnace off and let it cool with the bars. Usually the most convenient time to do this is in the afternoon, removing the following morning. To remove any strains that might occur, anneal the bars after rough-turning and reaming. This precaution eliminates any possibility of ever having the barrel change in firing. Frequently you will get annealed bars from the steel mills that have been cut off in powerful shears; in such cases the resulting ends have a tendency to change positions when the barrel is not perfectly normalized before the drilling and turning operation takes place. In general, the necessity of straightening is not due so much to the fault of the steel as to heavy lathe cuts and turning tools which have not been ground correctly. We have had such barrels, after they become warm, change in grouping as much as 6 inches. One, which was tested after being completed, changed in grouping in rapid fire as much as 14 inches. It remained in that position and necessitated the construction of a special front sight.

Assuming that all set-ups are made with the drill clamped into place in the V angle plate, the barrel may be drilled. The finest feed on the lathe must be used and watch kept that the drill does not clog. The feel of the drill in the fingers will give evidence of this. The feed of the carriage must be slow, and the feed locking nut should never be tight; it should have only enough friction tightness so that if any undue pressure is exerted upon the drill it will have a tendency to cause the friction clamp to slip on the feed. A very fine ribbon chip should be maintained, passing out freely with the oil pressure. Lathe speed of approximately 1500 r. p. m. should be maintained. The regular double-head drilling machine can only drill a barrel between 30 and 34 inches long unless two separate drill rods are employed; however, in the operation given above, one is not confined to any specific length, provided the milling machine has a long table. Figure 77 shows the drill ground so that it has a small flat on the point; this will keep a true center and emerge true

at the opposite end of the bar. The chip groove must be only 0.002 inch above center (if not absolutely center), for if it is 0.002 inch below the center a wire will come out through the chip groove; if the wire should catch in the drill tube the entire effort will be destroyed and the drill lost in the barrel. If this should happen, the barrel must be divided to recover the drill at the point of fracture.

In the drilling of the different alloy steels such as 3½ per cent nickel steel, spots will be encountered that are inclined to throw the drill off center slightly, but it will find its position again if the point is ground correctly.

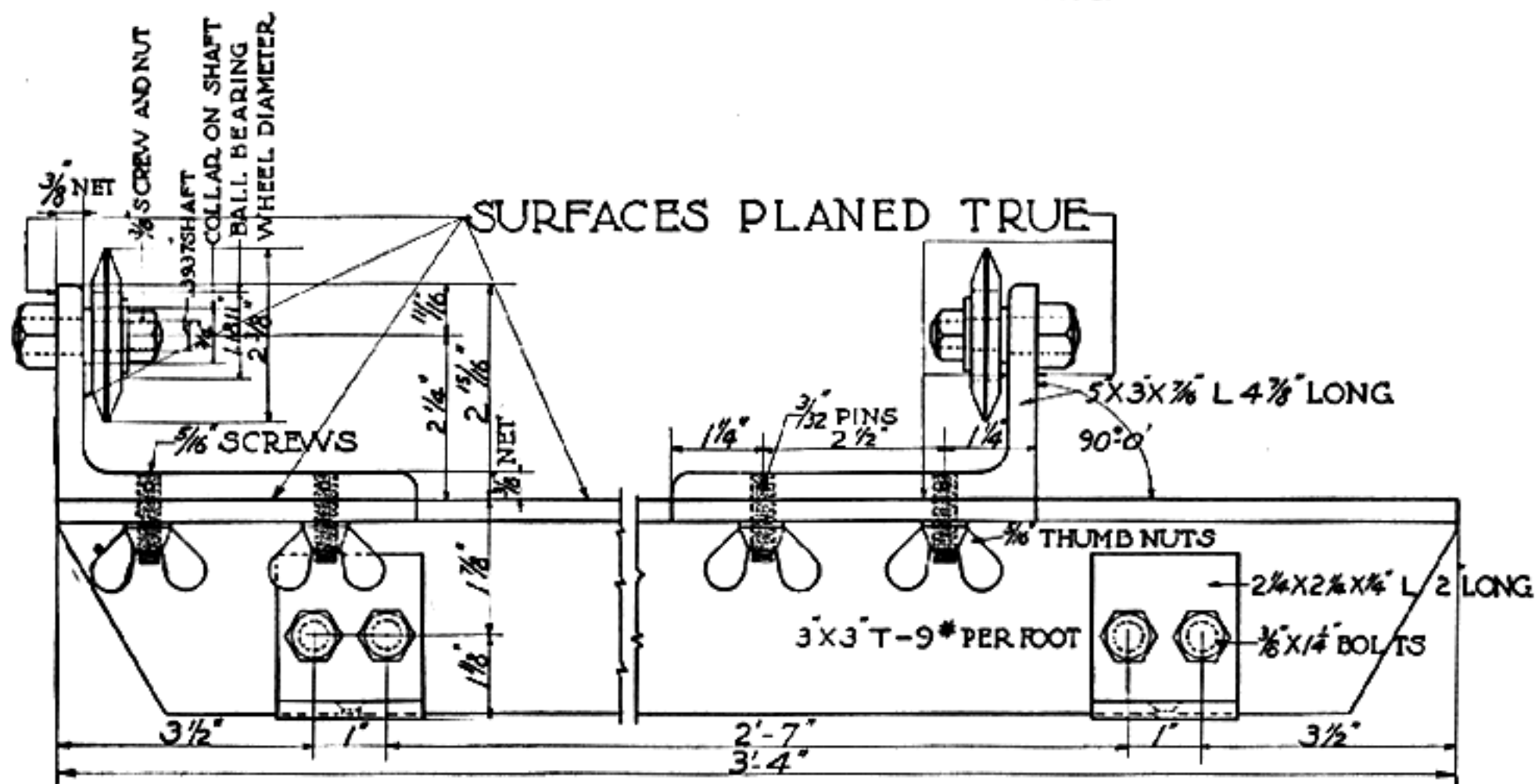
To maintain the speed and feeds recommended in the foregoing, it will be found necessary to use the best grade of lard oil. The friction feed is more satisfactory to use than light feeds, as a straight hole is produced when the drill is forced to such an extent, even tho it is ground perfectly.

After the drill has passed completely through the barrel, reaming and rough-turning follow, and then straightening. You may find that the drill's exit is, say, ¼ inch off at the opposite end of the bar; in that case remove and turn the barrel, using the drilled hole as centers, and starting the taper on the end at which the drill ran out. After rough-turning the barrel to half the desired finish size, check the bore for straightness. If it is very crooked, straighten and normalize as previously described. The succeeding description may seem somewhat technical, but I shall presume that the reader has the mechanical understanding to comprehend it.

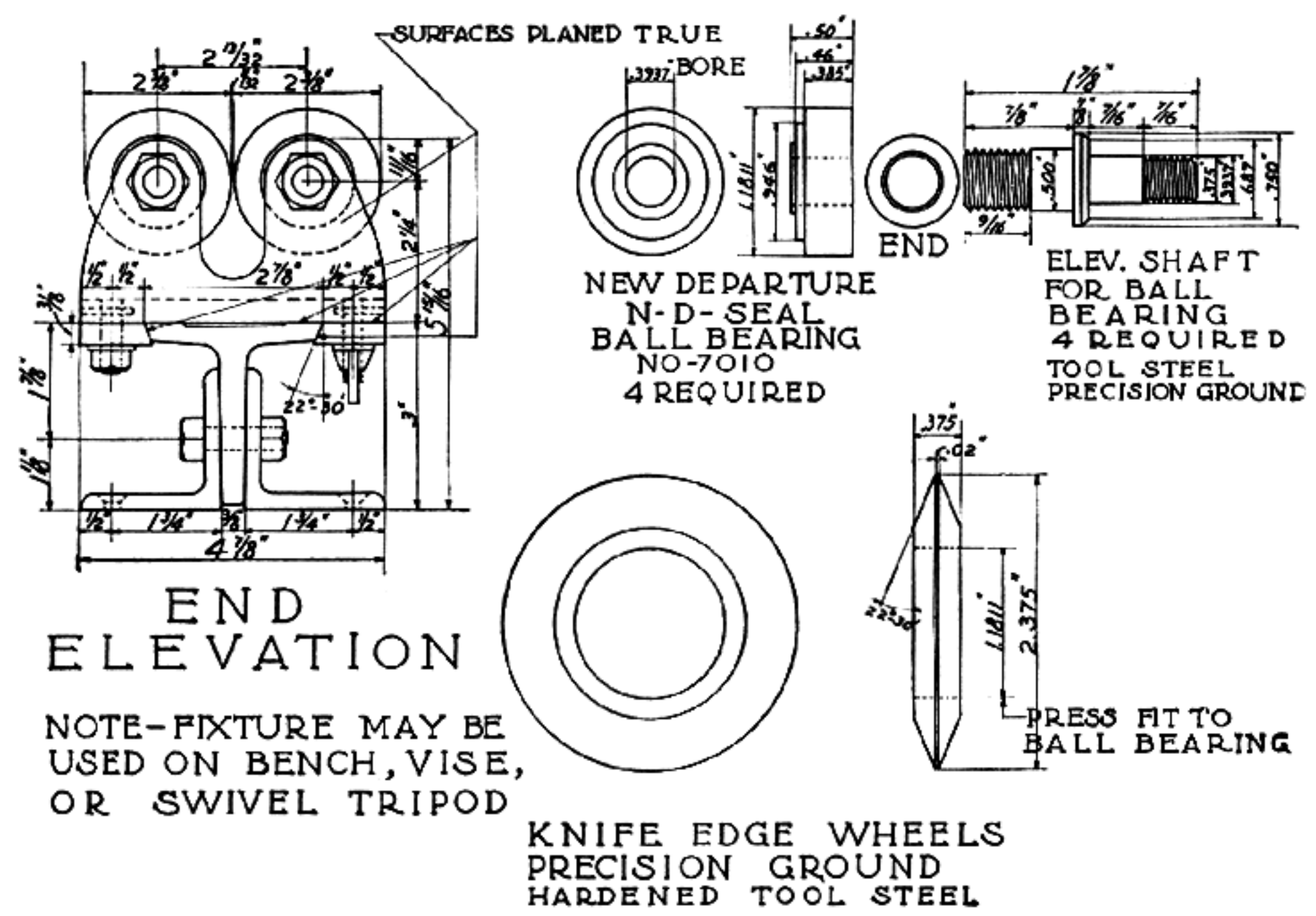
Barrel Straightening — Barrel straightening must be practically self-taught, and to accomplish this it will be advisable to practise by the old method, then by the more modern method, and lastly by the present method—the overhead clamp with three fingers, the two lower ones being stationary and the inner one movable, actuated by a heavy double screw.

The oldest method employed was to stretch a fine steel wire inside the barrel from end to end, touching the sides at each end. One side of the barrel was hammered until it touched all along the wire. The wire was then moved to the opposite side of the barrel and if it touched all along the wire it was straight. The fixture illustrated in Figure 78 may be employed in this operation as well as in others for barrel straightening.

The method of shading the inside of barrels is much better and quicker if once practised. To determine whether a barrel is straight, hold it a few inches from your eye upon the knife-edge rolls shown in Figure 78 with one end of the barrel



ELEVATION OF FIXTURE FOR BARREL BORE STRAIGHTNESS TESTING



END ELEVATION

NOTE-FIXTURE MAY BE USED ON BENCH, VISE, OR SWIVEL TRIPOD

KNIFE EDGE WHEELS PRECISION GROUND HARDENED TOOL STEEL

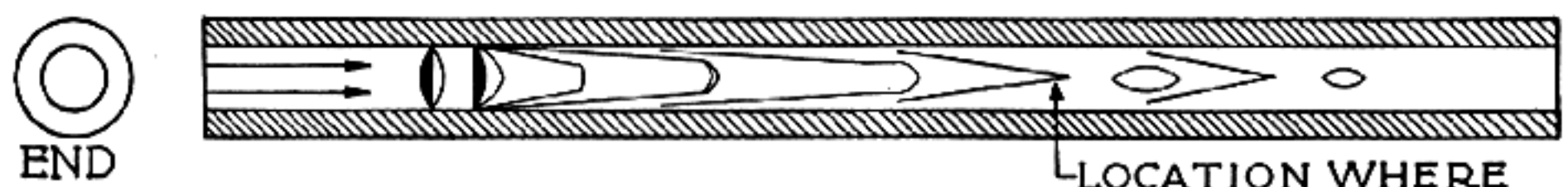


ILLUSTRATION SHOWING SHADOWS IN A BARREL AS YOU LOOK THROUGH DETECTING THE DIFFERENT IMAGES PRODUCED BY THE REFLECTED LIGHT.

LOCATION WHERE BARREL IS BENT EITHER CONCAVE OR CONVEX STRAIGHTEN AT THIS POINT

Fig. 78 Barrel-straightening fixture and illustration of light effect

pointing toward the top of a high shop window. The rays of light being horizontal, and the fixture and barrel at a slight angle, about half the bore will be in shadow; if the shade is irregular the barrel is bent or crooked. If the shade is perfectly level from breech to muzzle as the barrel is being turned around, the barrel must be a perfectly straight one. To straighten a barrel that is already finished, you should note where the swellings appear on the shade, and strike the barrel in those places with a hammer of lead upon a hollow anvil also padded with lead. If it is still in the rough, the padding may be removed for a more solid foundation. It can also be straightened from the indentation of the shade, in which case the barrel must be struck on the opposite side to the one shown on the indentation in the shade. After becoming skilled in this operation you can make a barrel perfectly straight with a few taps of the lead hammer.

A simple expedient for detecting the straightness of a gun barrel is as follows: Place the barrel at a slight angle in the fixture. Make a small frame, cover it with white tissue paper, and place it about six feet from the muzzle of the barrel, facing the window and good light. Point the barrel toward the top edge of the frame, and a dark shade will at once be seen upon the bottom side of the barrel. Turn the barrel around upon the rolls and if the shade keeps a perfectly true edge, the barrel is straight. Place, at any point between the frame and fixture, a lighted candle about three inches below the barrel. This test will cause the barrel to bend, and an irregularity in the shade will be immediately observed; when the light is removed, the barrel will return to its original form or very nearly so. This experiment can be carried out with a perfectly straight barrel. Use the candle a number of times to see the shaded lines and to observe by removing the candle, and the barrel will return to its original straightness.

The following explanation will probably give the reader a better understanding of barrel straightening. The barrel is revolved between the two knife-edged rollers on each end, and it is then possible to see the different light reflections as you revolve it. By this means you can straighten a barrel to a greater degree of precision than by any other process unless you visualize it for deviations from its long axis. Under these circumstances every part of the surface is a mirror and should register an image, true to the laws of light-ray reflection, which, when normal, pronounces it perfect; for the slightest deviation will cause a manifest distortion of that image in the process of straightening barrels, by the reflecting broken lines. After drilling the barrel we have a very rough surface, and the internal

mirror is not secured until a reamer has passed through. Then we proceed to ream the barrel, as described further on. Reaming eliminates a considerable amount of the rough surface and gives the interior a mirror-like appearance; thus the light rays can be detected more easily. Whatever objects are reflected to the eye from any portion that lies beyond a certain distance, will be reflected under very small angles of incidence. Naturally the interior surface of a barrel is not a technically true mirror, and the reflection image can not be correct for the reason that for every 0.001 part of an inch that a barrel may be out, a marked difference is registered. If the bore is straight the image will show a normal distortion, due to the transverse of the mirror. Suppose there are longitudinal flexures or crooks; in this case, there will be abnormal distortion of the image, which will reveal the defect.

When the eye looks through a gun barrel the interior surface appears to be spread out in a circular disc as far from the eye as the other end of the barrel. Through the center of this disc is a circular orifice, and surrounding it, at equal distances from each other, are several well-defined circles dividing the disc; thus the second, third, fourth, etc., are images formed by light reflected two, three, four times. In order to see how these images are formed and to find their respective points of location in the bore, turn the barrel in the fixture and you will see the changes that take place, by the breaking up of these images. It will be observed that these images are located at a certain point in the bore nearest the eye. In two-thirds of the length of the bore, none of these images appear, so it is to this part of the bore that you must direct your attention, for it is here only that you can cause the reflections to appear which disclose the crooks in the tube if any exist. When this part is straightened, reverse the barrel in the fixture and work to the opposite end to see if the images appear pronounced. Figure 78 will give a fairly definite explanation of the above. If the bore is perfectly straight the set will always remain a true and a symmetrical parabolic form growing more and more pointed toward the apex until it reaches the further end of the tube, but if there is even the slightest flexure or crook in it, the parabolic figure of the image will be distorted. If a distortion is discovered, revolve the barrel slowly about its axis after it is retained in the rest on the knife-edged revolving rollers, and you can then easily detect the slightest deviation. Of course it will require experience to tell how far the point of distortion is from the eye, but when that is learned you will be able to place your forefinger at this point, holding it there until you place the barrel on the anvil or overhead press to straighten and to

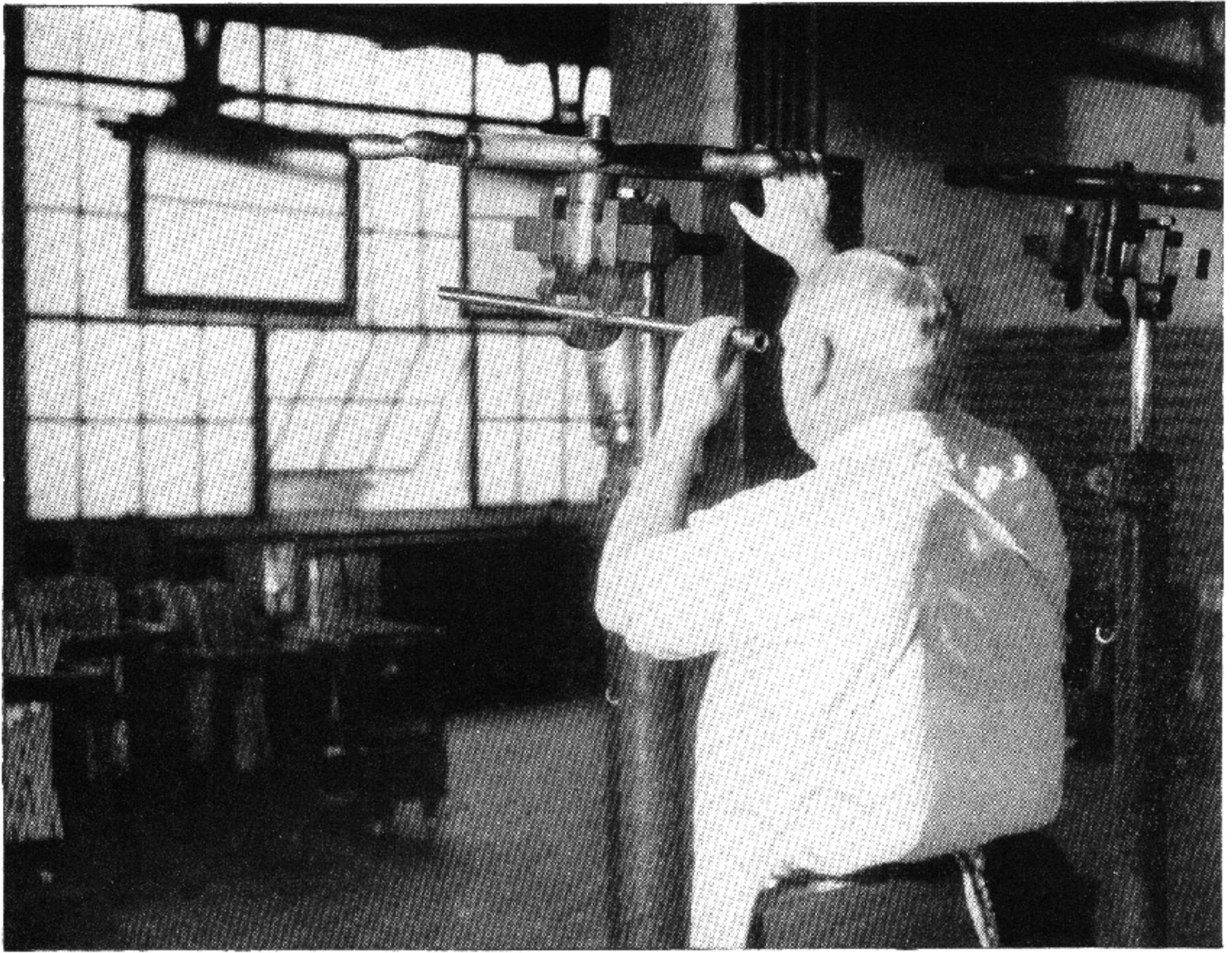


Fig. 79

Standard method of straightening rifle barrels in the Remington Arms plant and other arms-manufacturing plants

know how much elastic limit the steel will require to bend it the correct amount.

Before the overhead screw press came into use, the method used was to place the barrel upon two wooden stands or V's, the barrel facing a window across which a wire was stretched. Where the bend was discovered, the barrel was laid on a hollow anvil in which two pieces of lead were used to protect the finish. The striking was done with a lead hammer at the position of the bend. This method is superior to the modern overhead clamp press when rifle barrels are made from the proper steel and given the proper heat-treatment. A hammer blow does not break the steel structure as does the sudden twist of the overhead screw clamp. The hollow anvil and hammer method is far more difficult to master for the person who is just gaining experience, but once mastered, better results will be obtained. The beginner must learn to regulate the blows of the hammer, making it produce the desired results without any effort. Since weights of barrels vary, the larger the barrel and the nature of

the bend, the heavier the blows that must be struck upon the tube; and because this required force varies so, the truing or straightening will require more time. For the person who is just starting to do this work, it will be convenient to use chalk on the point hammered to tell just where the location was and also to tell just how much good was obtained from the last blows struck.

Nearly all the large arms plants use the overhead clamp press for straightening barrels. Figure 79 shows the clamp in use. The lower side of this device has two heavy steel fingers about six inches apart; between them is the center finger which is fastened to the screw; the pressure is regulated by the large hand wheel. The barrel is pointed directly toward a shop window which has a small rod, lath, wire, or a clearly visible line in front of it, throwing a distinct shadow along the bore at the bottom. If the shadow's edge appears perfectly straight, the barrel is straight in its entire length. If the shadow breaks or shows a curve or bend you will know there is a crook or bend at that point.

The skill of the beginner in using one of these presses lies in his ability to judge by eye the exact location of crook or bend and its proper location and direction or position, and to slide the barrel backward or forward on the lower fingers to the exact spot. In order to straighten the bore, turn the wheel to the required amount of pressure. This is accomplished by sudden jerks, giving the barrel a springing effect as tho sudden blows were struck with a hammer, except that these are more severe on the steel. By watching the shadows carefully it only requires a few minutes to straighten any barrel. Care must be used in this operation so that too much pressure is not placed upon any size of barrel. The only pressure required is that of the short, sharp jerks of the wheel, which is enough to bend the barrel slightly in the opposite direction—just sufficiently so that when it springs back it will return to a straight line. Too little pressure will not remove the crook permanently, and too much will place a bend in it the opposite way. If you have a press of this nature it will be well to test both methods and judge the best results between the press and the hammer and open anvil.

Reaming — Let us suppose we are completing a .25 caliber. An allowance of .012 inch is made for the reaming; therefore the drill is made to measure .238, the first roughing reamer .244, and finishing reamer .247. This now allows .003 inch for the burnishing reamers. Figure 54 shows the roughing reamer, which is made on the same principle as all the other reamers, except that it only has four flutes, and finishing and burnishing reamers have six flutes. It is now in order to complete the reamers and sweat them to the oil tube. Make the necessary fixtures for the end of the tube, like those made for the drill tube with a hose connection. Clamp the tube in the V-fixture on the cross slide of the lathe in the same manner as the barrel drill was clamped. As this is drawn through, reverse the feed and start the machine. It is not necessary to change the clamp of the tube in the V-fixture on the cross side, as this can move back to a much greater distance without undue strain upon the tube. Provisions were made in the drilling operation to extend the oil pad back far enough to catch the oil as it passes from the rear end of the barrel. After the roughing reamer is passed through, pass the finishing reamer and check the alinement. The barrel is now turned to the desired size, allowing $\frac{1}{32}$ inch for finishing; to complete this process, pass first, second, and third burnishing reamer, to bring bore to the desired size of .250. These are illustrated in Figure 54.

The oil pressure need not be as strong as it was

in the drilling operation; accordingly provisions must be made for a valve to reduce it. It is only necessary to remove the fine chips that follow the reamer. Figure 54 shows the spiral reamer, but its employment is not necessary; a straight reamer answers the same purpose except that the former eliminates much of the chatter which follows when the straight reamer is not made exactly as it should be. This point should be taken into consideration thoroughly, as the burnishing reamers will not be able to cut out some of the deep chatter marks left, and these will have a tendency to pick up metal if not entirely removed. Burnishing reamers are the only kind that will eliminate all tool marks and leave the bore a perfect mirror surface, doing away with minor abrasions that a regular cutting reamer leaves and which can be seen under the magnifying glass. As you look through the barrel, after the finishing reamer has passed, a mirror-like surface presents itself; however, if you should take that same barrel and sectionalize it, you would find deep scratches that the tool left. After passing the burnishing reamer through, observe a small section and you will see the difference in the results of these two forms of reamers. If one wants to eliminate the least possible error in the finished barrel, it is necessary to have three reamers, .001 in steps, which, after passage in order of size, will be followed by the most desirable results.

After the roughing reamer is passed through the barrel it is checked for straightness, and since the rough interior finish has been removed the shadows may be seen more distinctly. When reaming barrels it is advisable not to have any more material to be removed by the reamers than is absolutely necessary. When drilling rather hard barrel steel, frequently 0.010 inch left for a reamer to remove is hardly sufficient, but as the size of the bore increases in rifle barrels, drills must be comparatively reduced in size to allow more for the roughing reamer to remove.

The student will find various reasons for the inefficient working of a roughing, finishing, or burnishing reamer. The most common are: (a) chattering, when the flutes are not evenly stoned, milled back of center, or when they are stoned with too great a clearance; (b) chips clinging to the flutes, caused by a high revolving velocity, or the flutes being stoned out, allowing saw teeth to form on the cutting edge; (c) enlarged holes caused by the reamer cutter being oversize—often from holding the oil tube too rigidly. A floating holder should be provided which is held in the V holder, for with this it is often possible to ream a barrel on a lathe without any change. There are various methods adopted to prevent reamers from chattering; I have

found that when making these tools it is advisable to test them in a sample piece of metal and continue to stone the high point until an even full chip is noted in each flute. This edge is kept by rubbing an Arkansas stone over the flutes lengthwise before a reamer is pulled through the barrel. A free supply of oil must be continually flowing to keep the reamer well lubricated.

The surface speed for reaming should be rather slow; on a regular barrel-reaming machine, the reamer turns; but on a lathe, the barrel turns and the reamer is stationary. Instead of using an open belt with a high speed to drill this, it now requires a slow speed with the back gears in position. The feed can be made faster when used for drilling, as a barrel reamer is pulled through and used for a greater depth and has more cutting edges in contact with the barrel. For the roughing reamer you can use a feed twice as fast as that for finishing. When a good supply of lard oil is used, the burnishing

reamer should have a very slow feed as well as a slow speed. Usually three reamers are used for this operation in order to obtain the finest results. A steady flow of oil must be passing through to remove the fine chips, and before the next reamer is used the barrel should be wiped out thoroughly.

After the roughing reamer is used, the barrel is checked for straightness and then turned down within $\frac{1}{32}$ inch of the finished size, and again normalized. The barrel is again checked for straightness. If perfect, the burnishing tools are next in order and the bore is ready for the rifling operation.

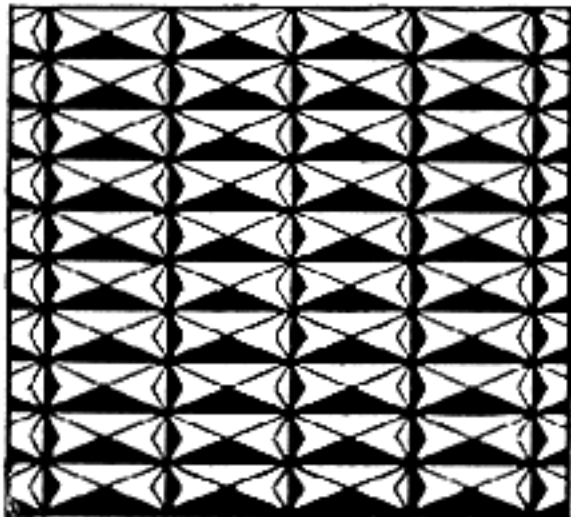
After the drills and reamers are made—and kept in order—many barrels can be turned out with them. It is a simple operation, and with this information and the tools to produce a barrel, the student will become enthusiastic over the results, especially when he has the tools working perfectly.

The following is a table of drill and reamer sizes:

CALIBER	Drill Diam- eter	Rough- ing Reamer	Finish- ing Reamer	1st Burnish- ing Reamer	2nd Burnish- ing Reamer	3rd Burnish- ing Reamer
.22	.207	.212	.2145	.2155	.2165	.2175
.25	.238	.244	.247	.248	.249	.250
6.5 mm.	.244	.250	.253	.254	.255	.2563
.270	.256	.264	.267	.268	.269	.2703
7 mm.	.262	.270	.273	.274	.275	.2766
.30	.285	.293	.297	.298	.299	.3003
.303	.285	.297	.300	.301	.302	.3033
.32	.295	.304	.308	.309	.310	.3113
.350	.332	.343	.347	.348	.349	.3504
.375 Mag.	.350	.360	.364	.365	.366	.3673
.404 Mag.	.397	.407	.411	.412	.413	.4143
.405	.388	.398	.402	.403	.404	.4053
.45	.430	.443	.447	.448	.449	.4503

CHAPTER XI

Rifling Barrels



Rifling Barrels

THE method by which rifling is placed in a gun barrel has been a source of mystery to users of rifles as well as the trained mechanic, and our best men often spend hours trying to solve the problems of the operation. Since the adoption of the breech system of loading, involving the use of brass cartridge cases and both lead and jacketed bullets, we have seen many different systems of rifling on the interiors of gun barrels. By loading the rifle from the breech instead of from the muzzle, it is possible to use a bullet of a size to fill the grooves of the bore; thus gas escapement is prevented, and as the bullet takes the rifling, accurate shooting is possible. Instead of deep grooves and a soft spherical bullet that was necessary for the old muzzle loader, we now require jacketed bullets of cupro-nickel, or a copper alloy, and a shallow groove for our modern projectiles in high-velocity arms.

The shape and depth of the grooves in our muzzle-loading rifles were of no marked importance, but in our modern barrels a bullet much larger than the grooves of the rifling causes undue pressure, particularly a jacketed bullet. Still, a lead bullet fired in the same barrel can be made slightly larger and fired independent of the rifling and depth of the groove. In our modern weapons using metal-cased bullets, shallow grooves are imperative and the nearer the rifling is made to the smooth bore the finer the results in accuracy will be.

The rifling with which the name of Medford is associated, consists of wide grooves and narrow lands, or the lands and grooves of equal width and the rifling of a uniform depth of 0.004". This system has proved best, altho there are slight modifications of the number of turns in the twist or spiral of the rifling. Mr. Medford laid the foundation for the most successful rifling, and altho others have done an enormous amount of fairly successful experimenting in later years, it was impossible to find a more perfect system than his. You can still find advocates of the oval system of rifling with which the name of Lancaster is associated—a system for large-bore rifles. Applied to modern high-power weapons, however, such a system prevents the accuracy desired and is not applicable to all barrels—that of the Newton rifle,

for instance. Altho the latter had a good action, the barrel unfortunately was very poor, for this point of rifling in design appeared to have been overlooked by the experts who decided upon the rifling to be adopted.

The Rigby method of rifling looked more like a ratchet as it was viewed through the barrel; the deeper part of the groove was on the driving side as the bullet was forced through the barrel, so that when it rotated during flight it would cause the least possible aerial friction. Therefore, our present success with rifling can be linked up with the Medford and Rigby systems, developed over a number of years. Of recent years all barrel makers of reputation, together with the arsenals of the various nations, realized the advantage of this rifling. Combining the two riflings—such as holding the square side of the Enfield and modifying the Rigby by a slight radius to the driving side of the groove—proved to be nearer the ideal rifling for extreme accuracy. The depth of rifling should not be greater than is necessary to grip the bullet and prevent it from "stripping" within the barrel. The nearer the bullet is to a perfect cylindrical form free from deep grooves produced by the rifling the less will be the resistance it offers to air.

Rifling consists of cutting away the interior of a drilled and reamed blank of steel in such a manner as to form spiral grooves upon its surface, the purpose of which is to guide the bullet down the barrel, forcing it to turn upon its own axis like a top, and at the same time impart to it a revolving motion which it will retain during its entire flight. By such means it equalizes any irregularities and lessens the tendency to depart from a straight and direct course. The rifling is done on a modern machine which pulls the rifling head through the barrel and is so arranged that any angle of pitch, turn, or shape may be given to the grooves. The remaining sections left by the grooves in the interior of the barrel are given the term "lands."

The enlargement of a rifle barrel has often been a means of using it for another caliber after it has become worn. Such an operation is possible, but the enlargement done by a manufacturer usually costs as much as a new barrel. Those, however, who wish to accomplish this with the set-up given

for the standard drilled barrels may do so with a slight alteration from the standard set-up, which will be discussed later in this chapter.

The spiral or twist in different modern calibers varies from one turn in twenty inches to one turn in eight inches. The longer the bullet in respect to its diameter the quicker must be the spiral in order to maintain a higher spinning effect, thus establishing greater stability during the flight of the bullet and keeping its point on instead of letting it turn over. This is one reason why such a fast spiral is given the 6.5 mm. barrel. The spiral in our caliber .30 Model 1903 barrel is one turn in ten inches. Different weight bullets perform with equal results, and still the higher the velocity the slower the spiral; this has been proved by experiments such as one turn in twelve inches and also one turn in fourteen inches, but the latter spiral is not so good on long-range shooting. The main object is to design a barrel with the correct rifling and the desired twist that will not allow a bullet to keyhole. Some rifling is so designed that fair accuracy is possible on short ranges, tho after that has passed there is a tendency for the bullet to keyhole because of reduced velocities. Many .22-caliber rifles come in which keyhole the bullets. After checking into the cause it is found that the barrel is so enlarged in diameter that the bullet does not take the rifling. It is much better to have a little faster spiral in a barrel than a slower one to handle various defects found in bullets. The faster the spiral and the wider the lands the greater the friction; therefore the design of faster twist requires the reduction in lands as well.

Measuring Bores — The arsenal takes the final measurement of the bore of a rifle barrel with an instrument called a "star gauge," but since this is only made to measure the bore of a .30-caliber barrel, various other means must be employed by the student. Chapter XVIII explains the common method used with a lead plug. A star-gauged barrel is simply one which has been measured by this instrument and found to come within the tolerance set, which is 0.0005 inch on a caliber .30 barrel. All National Match barrels are star-gauged, and on the muzzle is found a small stamp in the form of a star which shows that the barrel reads between the minimum of 0.3080 inch and maximum of 0.3085 inch. The correct figures are usually given on a regular star-gauge card, showing the correct figures found in every inch of the bore.

If you are making your own barrels and following the instructions given in these chapters, it will be necessary to make some simple gauges. If the barrel reamers were made to the correct sizes and

all instructions carried out precisely in their making, they should cut the exact size of any bore of barrel intended. For the satisfaction of knowing that the size is correct, a plug gauge should be made, or even two; one for the maximum diameter and one for the minimum size. With these gauges you can always check the reamers, know when they start to wear, and when new ones should be made; however, a well made burnishing reamer will last for a number of barrels and a plug gauge is only a check to prove that a perfect-sized bore is maintained.

Gauges should be made from $\frac{1}{32}$ inch Brown & Sharpe ground stock or from Disston Saw steel of the same size. Three gauges are required in 0.0005 inch sizes or constructed in 0.0002 inch for making a target barrel. A set of six gauges should be made to the latter figures as these will enable you continually to test the groove made by the cutter. An allowance of 0.0002 inch could be made for the lapping, or if the interior is to be chrome-plated, 0.0010 inch oversize must be made. When these gauges are used to measure the groove diameter, they should be kept at a knife edge so that it is possible to measure into the exact center of the groove.

To detect any tight or loose places in the grooves, and also to determine how smooth a barrel should be made, use a series of gauges with the clearance of the lands cut out on a milling machine into the cylindrical portion of the plug—on a spiral similar to that of the rifle barrel. These are made in the same size as the thin feeler gauges used to check the grooves in the end. By pushing each plug through until the maximum plug is reached—which will just push through with friction—the grooves will be proved to be of uniform size the entire length and free of tight places. If the student does not care to go to all this trouble, Chapter XVIII, which describes a more simple method, may be referred to.

There are different ways of rifling a barrel: with the standard Pratt & Whitney rifling machine or with the set-up of a lathe or of a milling machine; even a planer may be used, and the old method of using an old barrel as a guide. We shall, however, confine our explanation to the milling machine. Nearly every tool shop is equipped with a Brown & Sharpe Universal milling machine or a good Universal machine that has the different change gears for the spiral milling. It is possible to obtain a great variety of turns of spiral to the foot, or the lead in inches, and by turning to the table of "spiral milling" in the *Machinery Hand-Book* you will have a wide selection. Any combination of twist or spiral may be had for any bullet by

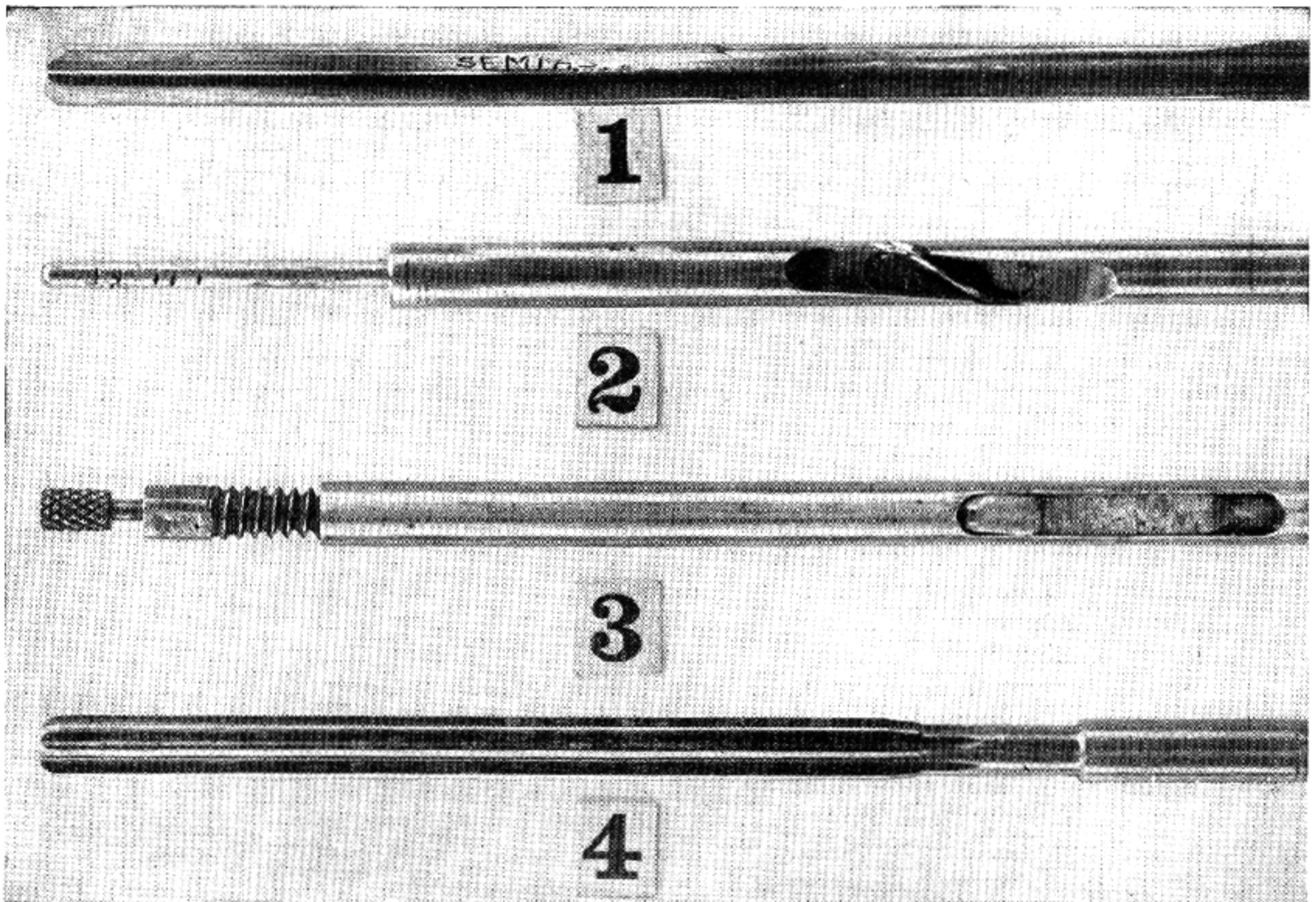


Fig. 80

Gun-barrel tools: (1) Barrel drill welded to oil tube. (2) Scrape-cutter rifling head. (3) Hook-cutter rifling head. (4) Standard barrel reamer sweated to oil tube

making the required set-up. Figure 80 shows the standard barrel tools used for caliber .30 Model 1903 barrel, and Figure 81 the barrel rough-turned and finished.

It is then necessary to make an arm to clamp on the face of the milling machine below the driving spindle to hold the rifling head. As this arm can be moved along in any position, the expense of making one should be considered incidental. Figure 82 illustrates the rifling arm in detail, and from a pattern that you have had made at a pattern

shop, the casting for it can be made; furthermore, if you have the planer which will carry this size casting you can do the work yourself and save considerable expense. This is the only fixture required on the milling for the rifling operation, and is very reasonable compared with the expense incurred in setting up a lathe for the same operation, in which case you would only have the one turn—say one in ten inches.

By using the lathe it is also necessary to make two drums; a small one fastened to the ceiling

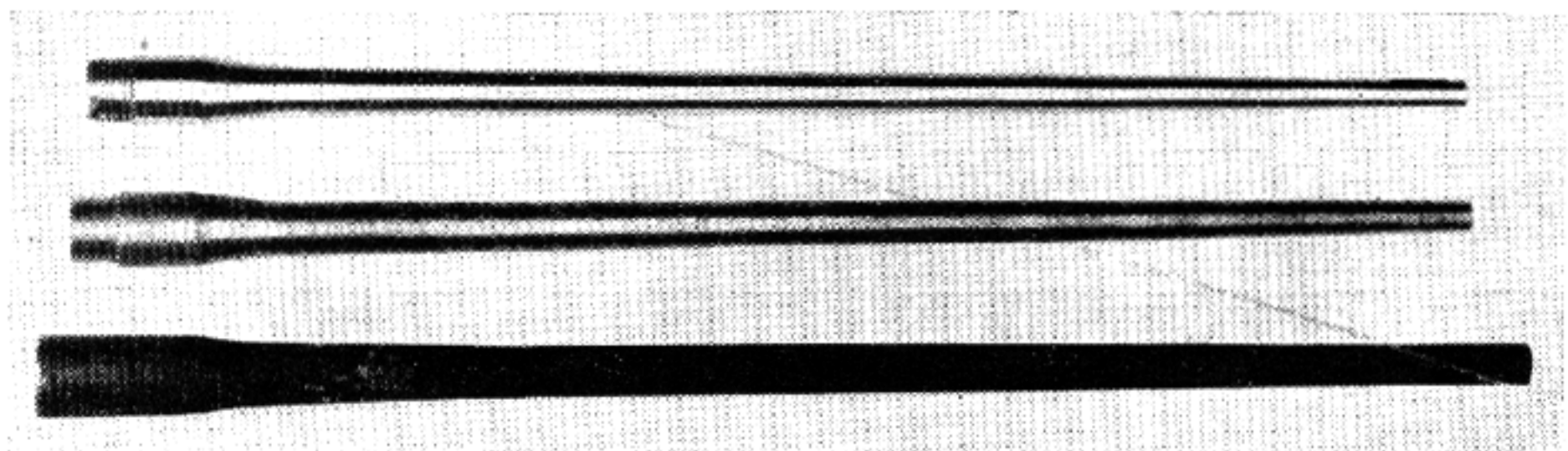


Fig. 81

Stages in the manufacture of a rifle barrel: blank, rough-turned and finished

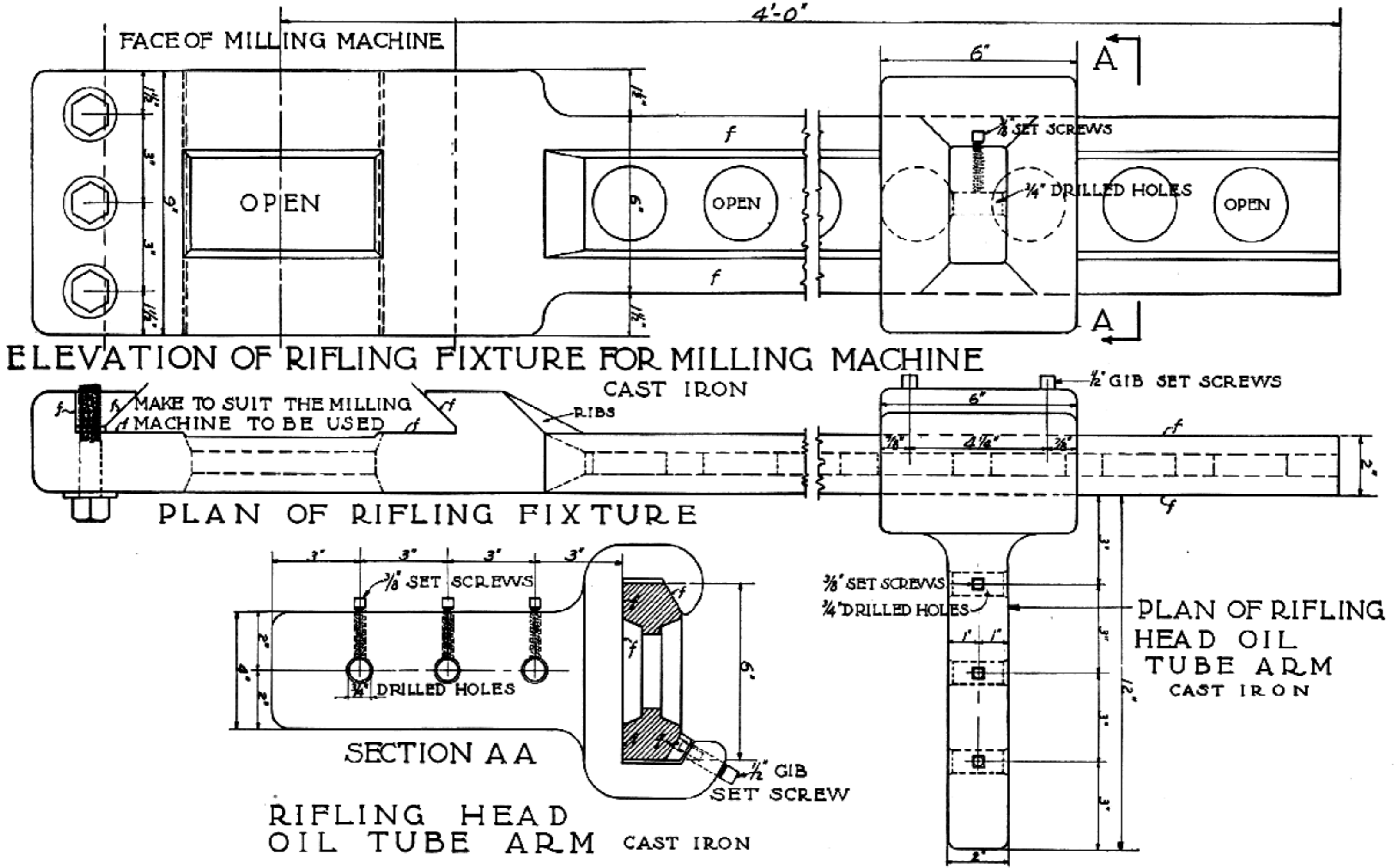


Fig. 82
 Rifling-head fixture. When milling machine is to be employed for making barrels, fixture is clamped to face of machine

and another on the floor with a belt drive connected with suitable pulleys to the rear of the machine, and then to the lathe carriage. If a change is to be made to one turn in twelve inches, we must figure on a different drum for the lower drive. An index fixture should be made to clamp in the cross slide so that we can make any number of grooves we may desire. When selecting a milling machine it is wise to choose one with a long table travel and with the rifling arm in place on the face. We have the sliding arm which can be placed in any position and at the same time give the length of travel required to work the rifling head. The travel of the table and head governs the exact location. The arm which clamps the rifling head has three positions and we can use any one of them. It is then necessary to line up the exact center of the dividing head so that the oil tube will not bind in the barrel.

When this work is ended the next requirement is a rifling head, the completion and installation of which calls for patience and skill. Figure 66 shows a detailed drawing of a .30-caliber rifling head, and Figure 65 a detailed drawing of a rifling head for a .22 caliber, one of the most difficult heads to make; difficulty is also true of the scrape-cutter heads and heads with the complete number of cutters on the head itself as illustrated in Figures 69 and 70. Other calibers are made in different proportions, but the principle of the heads is about the same. As you can see, this is rather a difficult tool to construct, particularly the hook-cutter head, as there are so many small parts that make up the head with other little kinks that are difficult to put into a drawing comprehensibly. You should have the equipment to carry out the operations properly. I would advise securing these tools from a reliable source, for much depends on a rifling head that is correctly made and conducive to efficiency. Chapter IX is devoted to the making of these tools.

After the rifling head has been chosen, provide for a suitable oil tube and hose connections and fasten them to the oil tube. It is then connected to our source of oil supply on the milling machine—the oil pump. Clean out all of the old oil that was used in any of the milling operations, and use pure lard oil as in the drilling and reaming operation. Connect a bracket from the index head to the end of the barrel, allowing enough space so that adjusting screws will touch, but no more. Since there is no automatic ratchet or cutter release as on the Pratt & Whitney rifling machine, a small hollow adjusting screw is made; then where adjustment of the screws is required in the rifling, a slight turn is made on each revolution, which will be equivalent to just a “scraping” or removal of

about .0001 inch on each pass through the grooves. This adjustment is only made once in one turn of the barrel, and this is done often enough so that the rifling head secures the correct depth of groove. Also a suitable arm should be made with a small section so it will release the rifling cutter where it passes through the barrel. If a hook cutter is used, this may be done with a small tool, but an automatic arrangement is better, the release of the cutter never being forgotten.

For example, suppose we wish to make a barrel with five grooves, a .375 caliber with one turn in fifteen inches. Right- or left-hand spiral on the milling machine is a matter of choice; however, the cutter is made so that the lands and grooves are the same width. Turn to the table of spirals in the *Machinery Hand-Book*, page 911, for a lead of one turn in fifteen inches, as given in the table. Place a 48 gear on the worm, 24 gear on stud, 24 gear on second stud, and a 32 gear on screw. This gives a lead of one turn in fifteen inches. As we wish to make five divisions we use any index plate, setting fingers at the top so that the spindle will likewise come there without chance of mistake. Eight turns of the crank are equal to one-eighth of the division. Chalk the chuck on each turn you make, so that it will come back to the same location; then double-check and be certain that you have turned the index the proper number of turns. A mistake means a broken rifling head. An oil pan to the rear of the barrel must be provided so that the oil will run back into the proper grooves on the milling-machine table, and not over the floor.

One of the simplest rifling cutters to make is the scrape-cutter rifling head illustrated in Figure 67. Such a cutter has a burnishing effect upon the groove as it removes a scraping cut in both directions. The cutter only has a direct wedge adjustment and the raise of the cutter must rely upon the wedge and spring of the cutter itself. This is the most simple to construct and at the same time the most practical for the beginner to use, as it works perfectly if everything else is equal. Keep the cutter well stoned and of the proper hardness so that it will hold its sharp burnishing edge.

With the set-up for a standard caliber, it would be more practical for the beginner to work upon sample pieces. The first ones should be short in length: they can be used for revolver barrels. From then on you will eliminate any faulty procedures through experience. The rifling of any barrel should be started from the chamber end; that is, the hook cutter should start the cut from that end; therefore, the barrel should be placed through the dividing head with the muzzle facing the arm.

Before the barrel is set in place a lathe dog is fastened to the barrel so that if it is ever found necessary to remove the barrel from the dividing head to check it before the completion of the cutting, it can be set back in the exact location. Consequently, a suitable form of stop must be devised on the back of the dividing head to be pushed out in position at the time of clamping the barrel in the chuck, and then removed at will when the barrel is removed.

Power is used to feed the rifling head through the barrel; by gearing it up to the fastest feed, a very satisfactory speed for the cutter can be maintained. After the cutter is released the reverse feed is used. You must be careful, when it requires the revolving of the barrel to the next groove, not to get confused regarding the number of turns that were made with the index crank, for a mistake here means a broken rifling head, and these are not easy tools to make.

The chips which come off a hook cutter are similar to shavings removed by a wood plane. If the chips are broken or in the form of little wires, it is a sign that the cutter is not working just right and hence must be removed and stoned, or the face ground until there is a perfectly sharp cutting edge stoned to a mirror polish with a fine Arkansas

stone. A scrape cutter must always be kept to a perfect sharp edge; the chips removed with such a tool are very fine, similar to those removed with a small scraper. A continuous flow of pure lard oil should be maintained at all times, and when the cutter emerges from the end of the barrel all chips must be removed before the return of the head. This is done with a tooth-brush, but it is well to use your fingers at times to feel the nature of the chips the cutter is producing; and at the least sign of broken chips have a fine Arkansas oilstone handy to maintain the edge. The rifling head should be clamped in the arm so that the cutter is at the top and the wedge at the bottom, as Figure 83 illustrates.

The problem was placed before me some time ago, to make $\frac{5}{32}$ -inch, $\frac{1}{8}$ -inch, $\frac{3}{32}$ -inch, $\frac{1}{16}$ -inch barrels, 34 inches in length out of $1\frac{1}{2}$ -inch diameter alloy steel; only in the above described manner was it possible to make the $\frac{1}{16}$ -inch barrel, not to mention incidentals. The average person with tool-making experience should complete the construction of a rifle barrel from the .22 caliber on up without great difficulty. Any extensive explanation of this subject would require a separate chapter.

The Rebored Barrel — The boring or removing

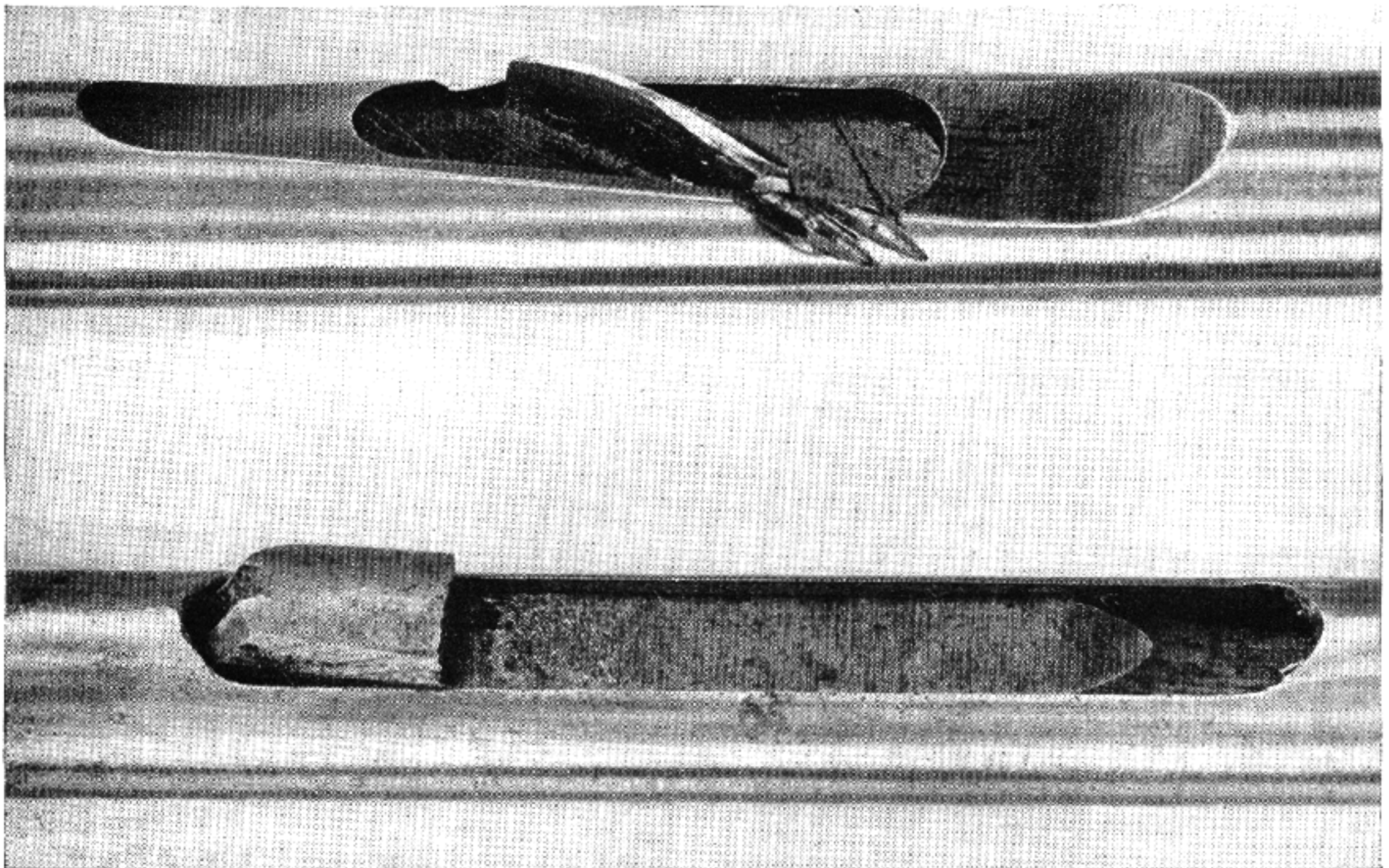


Fig. 83

Side views of scrape and hook cutters in the two standard rifling heads used at the Springfield Armory. Note the angle on the scrape cutter, which produces the best results. Correct hardening of this cutter is very important

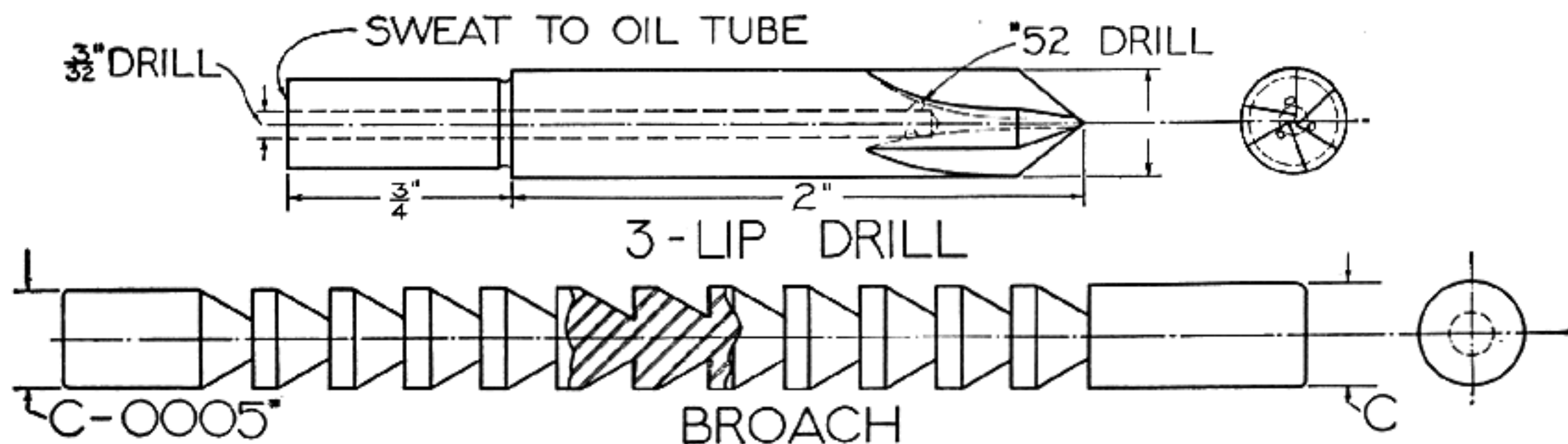


Fig. 84

Spear or three-lip barrel drill: used when rifle barrels are to be relined. **Barrel broach:** used for cleaning out lands of muzzle-loading rifles

of the old rifling from any barrel intended for a larger caliber can be done very easily by first counterboring the barrel with counterbores shown in Figure 63, or by drilling it out with a specially made three-lipped drill as Figure 84 illustrates. This drill is often referred to as a spear-shaped drill. Before it can be started into a barrel, a barrel counterbore must be used and then followed by the three-lipped drill in order to keep a perfectly straight bore throughout the drilling operation. Before any drilling takes place a bushing one inch in length made of barrel steel is sweated on the muzzle. Prior to this the muzzle is faced off square so that the bushing may find a perfect seat in the sweating operation. This end bushing is employed so that when the rifling head is passed out of the end it will not bell-mouth the muzzle. A hole is placed into the bushing slightly smaller than the bore of the barrel so that the drilling or counterboring operation will remove the inside material and the reaming operation will remove the balance of stock, and when finish-reamed the bushing will be a continuation of the bore.

After the drilling of the bore the barrel is straightened and then the reaming operation, which is the same as explained in Chapter X, takes place. The rifling of any rebored barrel is similar to the rifling of a new barrel as described in the first part of the chapter, and if those instructions are followed a perfect barrel will be produced.

The barrels which can be rebored to a larger caliber are in the following class: .22 caliber barrels on single-shot actions to be rebored to .25 caliber; .25 caliber barrels that have actions sufficiently strong to withstand the greater pressure to 7 mm.; caliber 6.5 mm. bored to 7 mm.; 7 mm. barrels to .30-30 or .30-06 caliber; .30-06 caliber on Springfield or Mauser action rebored to .35 Whelen. Even in such a list a great amount of good judgment must be used. One cannot expect to rebore a .22 caliber barrel which has been made from cold-drawn

steel and expect good results in a .25-35 W. C. F. caliber; the only possible caliber that could be used is the .25 caliber Stevens with a lead bullet. The prevailing idea among owners of .22-caliber worn barrels is to convert them into a higher velocity arm and use jacketed bullets, which cannot be done successfully. Before any barrel is changed into another caliber the interested person should study all angles of the possibility of the change.

Many barrels have telescope bases mounted on the barrel with the screw holes drilled to a greater depth than really necessary; also deep slots cut in them for sights and forearm studs to hold the forearm in place. Too much care cannot be used when drilling a barrel of this nature so that the holes do not go into the enlarged bore or even weaken the barrel to such an extent that it would be impossible to secure any accuracy.

Chambers should also be taken into consideration. The accuracy of the rebored barrel depends upon correctness of the work performed, carefulness of the workman, and tools employed for the operation.

Heat-treatment of Barrels — Inasmuch as the automobile industry calls for better and finer steels in the construction of a motor car, other branches of industry must keep pace. The rifle barrel, however, has shown little improvement in this respect, for altho parts of the gun have been heat-treated, the barrel has been altogether neglected. A rifle barrel is no more difficult to heat-treat than a driving axle of an automobile, and a heat-treatment should be given both these to increase the toughness of the steel and prolong life and accuracy. I have not discussed the matter of the heat-treated barrel very thoroughly in Chapter VIII, for much cannot be said on the subject without a series of technicalities. However, by adding together the information given throughout the various chapters, the interested individual will be provided with enough

material to make this operation a success. Of course it is essential that he have the proper equipment at his disposal. Any of the various heat-treatments applied to rifle barrels may be reduced to a combination of the following elements: (a) heating at a definite temperature for a definite length of time, (b) cooling from this temperature at some desired degree, and (c) reheating if desired. The more complex treatments consist in the duplication of one or more of these elements together with changes in various temperatures, degrees of cooling, etc. These treatments will be considered under their proper designations: normalizing, annealing, toughening, or hardening and tempering.

The size and shape of a rifle barrel must be considered, and the bottom of the furnace that is used must be true and level. This is especially important for the large and tapered shape of the barrel. Among other essential points is the fact that the heating should not be forced, as the outside and taper would then be greatly overheated. If a number of barrels are heated at a time, they should be so arranged in the furnace as to insure as even heating as possible. Instead of laying barrels on the bottom of a furnace, fire-brick supports would be much better placed about three inches apart to allow the free passage of gases underneath the barrels.

The proper heat-treatment should be determined, as in the case of normalizing above the critical range by the properties desired, and should be governed by the size of the barrels and their carbon content. For maximum softness, the barrels are allowed to cool in the furnace. In the case of the full diameter of the bar of which the barrel is made, it may be removed from the furnace and cooled in the air. On the other hand, very small barrels of high carbon content with nickel and chromium, cool rapidly enough in the air to become quite tough, altho a tempering bath of oil has the greatest advantage for correct toughness of the metal.

Pack-hardening could be given barrels with low carbon content; and barrels heated just above the critical range, if packed in various materials, could be left about two hours for the correct surface hardness both to the interior and exterior of the barrel, and portions to be left uncarbonized could be given, for protection, a plating of coppering solution. Most of the companies manufacturing special grades of steel have worked out experimentally the heat-treatment necessary to bring out the most desirable physical properties of their particular steels. Upon purchasing, directions are given concerning the heat-treatments.

These instructions are not for the man who has a small shop and only small furnace equipment for attempting to work out the correct heat-treatment of rifle barrels, but for the larger companies who can carry each operation through after the proper steels are selected. However, in such work a metallurgist will be able to determine the correct-working barrel steel, and will give barrels the proper heat-treatment, also coating their interior with a special non-rusting alloy which will make a rifle barrel nearly perfect according to our present-day standards.

Lapping — On the subject of lapping the barrel, let us assume that we have a perfect bore to deal with, that our barrel-burnishing reamers made a mirror surface, that our rifling cutter held up and made a perfect groove, but that it is necessary to finish lapping the barrel to remove the fine wire burrs that have been raised from the rifling-head cutter. These must be eliminated and the only method is by properly lapping the barrel so that it will polish to the highest degree under the abrasives used.

First cast a pure lead lap in the barrel, wrapping the two grooves with cotton string so that it will just push through. Figure 85 shows the completed lapping rod. A cord is wrapped around the rod in the cannalures and the latter carefully pushed into the barrel until the jagged tip is about $\frac{1}{4}$ inch below the muzzle. The cotton string is to prevent the melted lead from running down the bore. Clamp the barrel in a vise and heat it with a blow torch to a light straw color in order to allow the lead to flow freely; when this method is followed, a full and perfect plug will be formed. The molten lead is poured into the barrel, held vertically in the vise, and should not extend beyond the end of the muzzle.

The lead will cool immediately, and the rod should then be pushed forward just far enough so that the plug may be examined; if it has overflowed at the muzzle, it should be trimmed to muzzle length with a sharp knife. A word of caution may here be given: never remove the lap from the bore until its work is finished. Assuming that the lap is a perfect one, apply a coat of oil and withdraw the plug to the opposite end, far enough to remove the cotton string, and coat it with fine optical emery and oil. To eliminate any possibility of error in a fine barrel, the best emery to use is optical emery of about No. 320-M grit. Also coat the inside of the unoccupied bore with oil through the opposite end. A stop is provided for both muzzle and barrel, insuring against accidental pushing or pulling out of the lapping plug. For

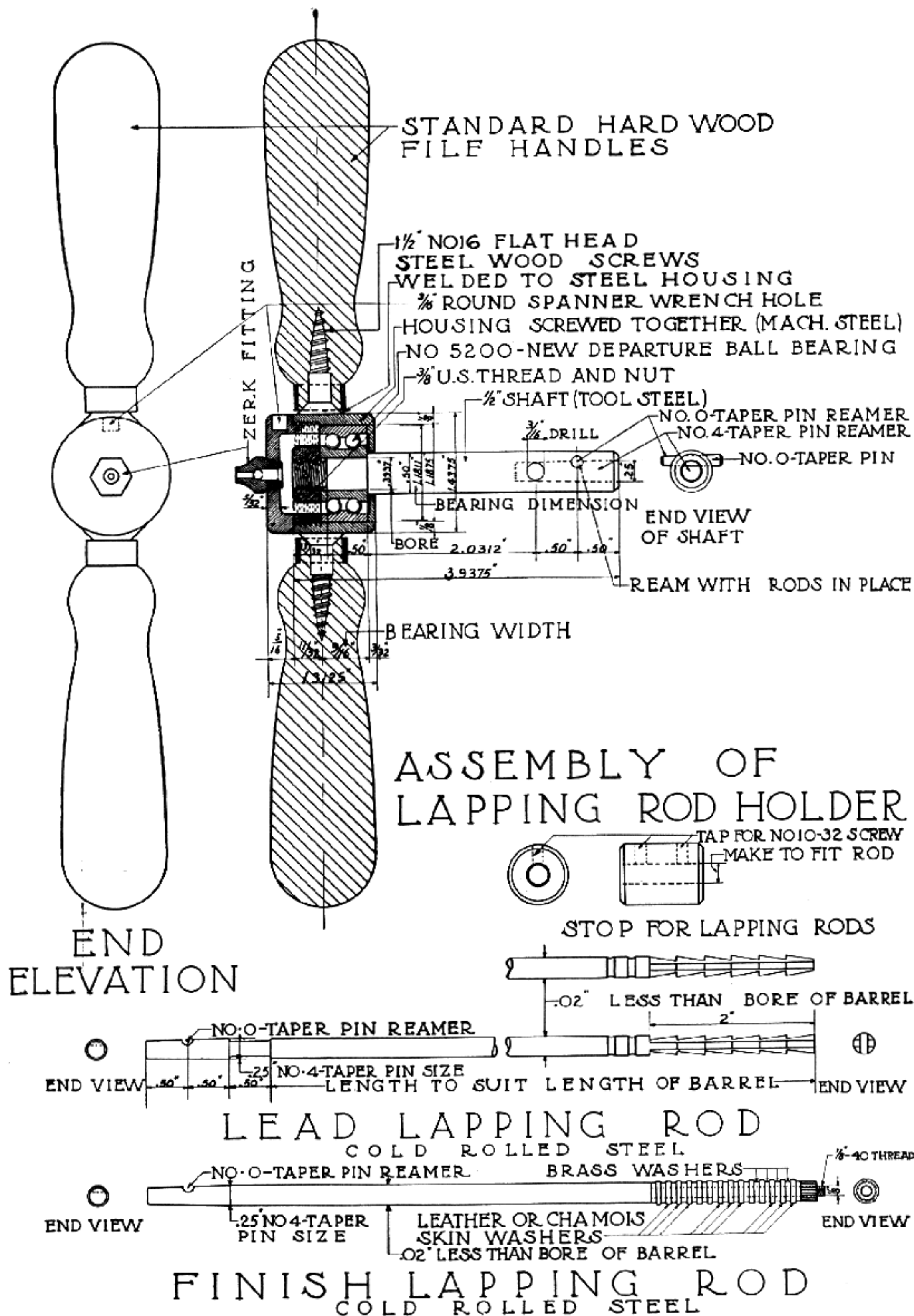


Fig. 85

Barrel lapping rod holder and rods for producing high finishes required in rifled gun barrels

five or ten minutes the plug should make its excursion from end to end of the bore, the abrasive and oil being added frequently. Now the barrel may be cleaned thoroughly with gasoline and patches, and examined.

Next, the polishing rod is inserted as illustrated in Figure 85. Such a rod is made with a series of chamois skin or thin leather discs with small brass space washers between, which may be tightened on the end by means of a nut and a pair of pliers. Turn about .001 inch to .005 inch above the groove diameter. As one portion of the nut is made the same size as the diameter of the bore, gently tap this through, allowing the land to cut its way into the chamois. Then mix olive oil and rouge and proceed further to lap the barrel for between one and two hours.

When this is completed, you have one of the finest polishes possible. Wipe out thoroughly with gasoline and apply a coat of fine gun oil. For further explanation on this subject refer to Chapter XVIII.

A great many more details could be given on the problem of rifling barrels, but it would involve a very technical explanation, and from the general outline given in this chapter the man with mechanical ability can perform the operation, as the subject is thoroughly illustrated. It will require a considerable amount of time, but in the end, if you are determined, you will win and be amply repaid by the satisfaction of having produced a barrel with a spiral in its interior surface. How it will look when viewed from the muzzle, Figure 52 will show.

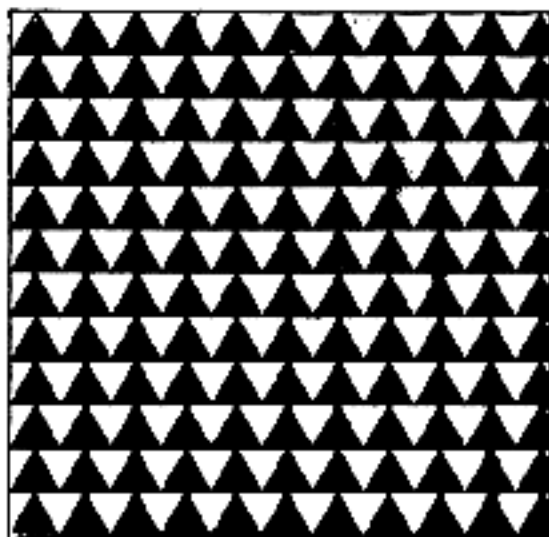


Fig. 86

Showing how rifle barrels are lapped in the large arms plants

CHAPTER XII

Barrel Turning, Chambering, and Headspacing



Barrel Turning, Chambering, and Headspacing

AFTER the rifle barrel has passed through the drilling, reaming, and rifling operations, chambering follows. When barrels and actions are fitted, the student or gunsmith should be keenly alert and know just what he is doing. Barrel chambering and the correct headspace of a cartridge are among the most essential factors in a barrel; therefore, one who undertakes the fitting and chambering must be a person with considerable mechanical ability. I am assuming that the person who can make a barrel to this point has that ability.

To begin with, no novice should attempt this work without special instruction, for he is endangering not only his own life but that of others who may be in the immediate vicinity at the time the accident occurs. I can not stress too greatly the importance of a correctly fitted cartridge case in any chamber, together with a recess in the breech of the barrel free from any marks on the surface. Chambering consists of reaming out the breech end of the barrel with a set of fluted reamers known as chambering reamers, which enlarge the barrel at the breech so that a cartridge can be employed with the correct tolerance between the barrel and the cartridge selected.

A slowly revolving lathe is employed, and as the two first reamers are used, the burnishing and throating reamers are employed when the action is screwed into place to secure the correct headspace and bullet seat. These operations are done very gradually, with the roughing and second reamers forced in by the tail-stock center. After the first reamer is used, the second one finishes the chamber, allowing enough for headspace and the burnishing of the chamber. The barrel is then threaded and fitted to the receiver, and the chamber plug is employed to hold the threads concentric with the bore and chamber. The bore and chamber must also be in perfect alinement, and for this purpose floating pilots are used on the first and second reamers which project beyond the neck diameter. Finally, the burnishing reamer is run in to the exact depth, which will show on the head-space gauges, whether used on a bolt action or a breech block upon the individual rifle. The chambering reamers are illustrated in Figure 56 and the headspace gauges in Figure 71.

The threading of a barrel is connected with two other operations, chambering and headspacing. Rifle manufacturers have used different forms of threads on their barrels and actions. The Springfield, both in the 1898 and 1903 models, uses a 10-pitch square thread; this thread is the old form and has been superseded by the acme thread, which is much stronger. The advantages of the acme are its strength and the ease with which it can be cut compared with the square thread. This is due to greater strength of the teeth in both taps and dies, as well as to the facility with which the chips free themselves. The United States standard thread is used to a great extent on all standard arms manufactured, and is the most commonly used screw thread in this country. When merely the form of thread of the United States standard is referred to, but not the number of threads per inch corresponding to a certain diameter, the abbreviation U. S. F. (United States Form) is employed. The sides of the thread form an angle of 60 degrees with each other.

The Whitworth standard thread, also known as the British standard (B. S. W.), is used principally in Great Britain on most of their firearms. The Germans use the same form of thread as the United States standard system, except that they use the metric system of measurement. The same is employed by the French arms companies as well as the Swiss.

The threading of a barrel for the receiver or action must be cut so that when the threads are completed it is possible to pull the barrel tight and in line with the index line already marked or about to be established; it is then completely set in position with a good-sized wrench. The barrel should screw upon the receiver or action with some effort of the hand, to within about $\frac{1}{4}$ inch of meeting the index line and shoulder, and then require a heavy crescent wrench to screw it solid against the shoulder. The "index lines" are the two short, almost invisible lines, one cut into the receiver on the left or bottom side of a receiver, and the other cut into the barrel, meeting in perfect alinement when the barrel is screwed completely home into the receiver. The assurance of correct headspace and security of barrel and receiver are the most im-

portant reasons for seeing that the barrel is screwed exactly to an index line. If the front and rear sight bases have been previously mounted on the barrel, they should stand truly vertical when the index lines meet.

Milling Sight Bases — If the rear sight base is integral with the barrel and also the front ramp and sling-swivel base, the barrel must be set home with a large wrench. The next stage of the operation consists of laying out for the rib, ramp, and swivel base. Coat the barrel with the coppering solution at the points where the respective laying-out lines will come. All bolt-action receivers have a flat under-surface, and where the magazine bears against this surface it is always at right angles to the line of sight; this surface is clamped against an angle plate and set upon a large surface plate. A true center must be established at the muzzle and also at the rear opening of the receiver. The most satisfactory means of locating such centers is by turning soft plugs to fit into the barrel and receiver. If a height gauge is used for laying out the lines, fine centers are not required, but if a surface gauge is used a fine center must be inserted into one end of each plug as they are turned on the lathe in order to set the scribe point in the exact center. With the receiver, this is clamped upon the angle plate, and parallels are built up under the muzzle until both center lines on the plugs coincide. A center line is scribed from the receiver forward to the length of the intended leaf-sight base. A center line is also scribed at the muzzle for the ramp and one for the swivel base. By using a height gauge all lines can be laid out for width and scribed the entire length, but with the surface gauge they must first be established with a divider from the center. Having thus made all the layout lines and finely center-punched them, the barrel may be unscrewed from the receiver and the necessary machine operations made.

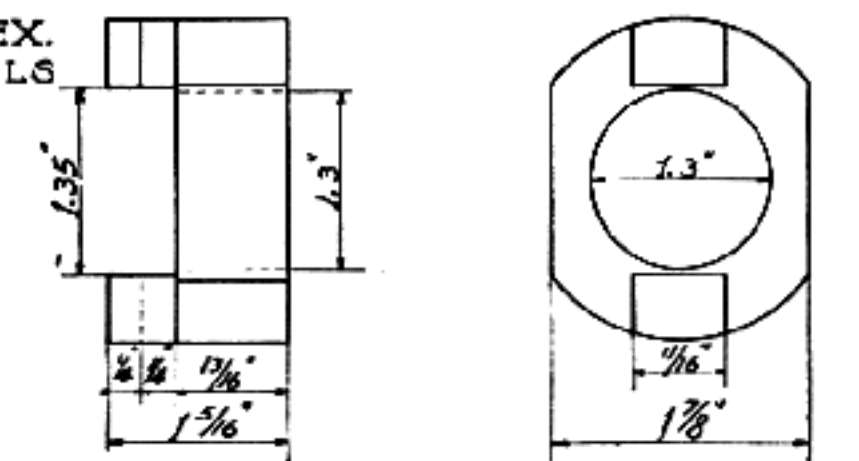
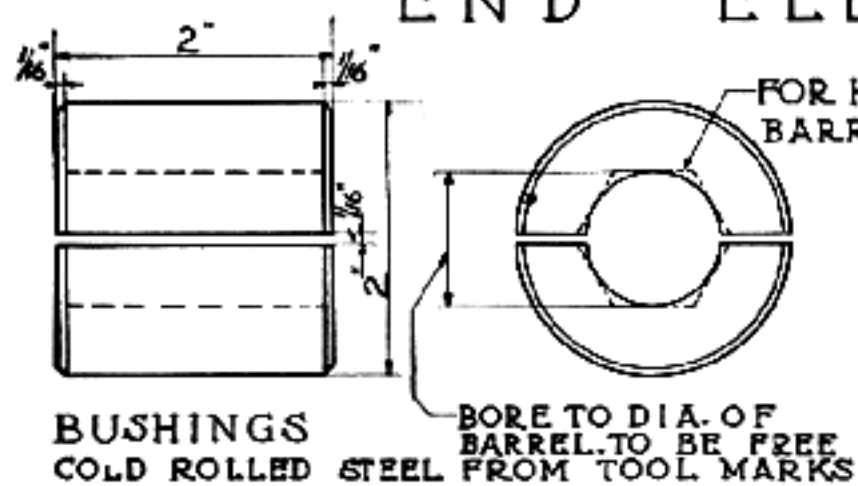
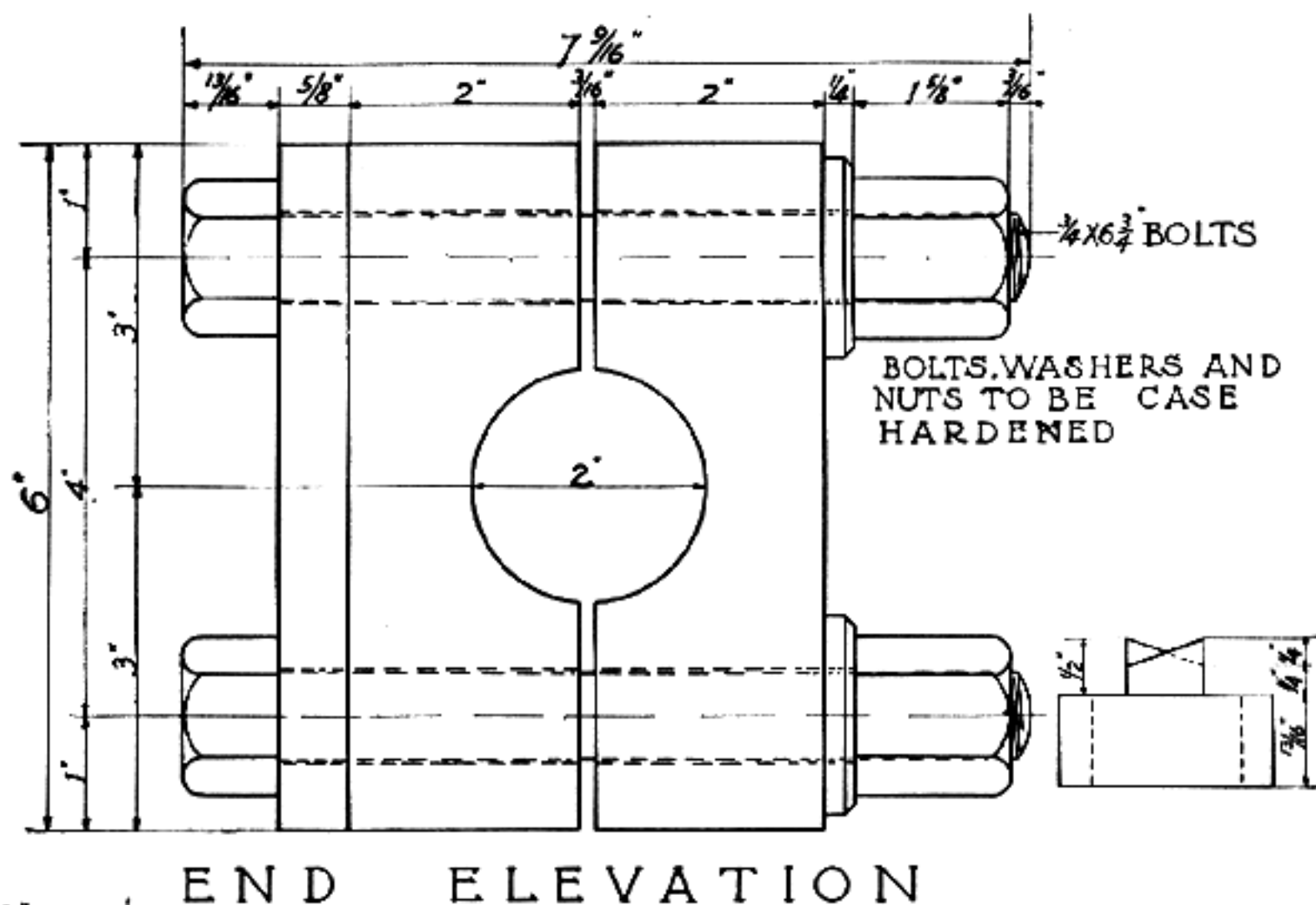
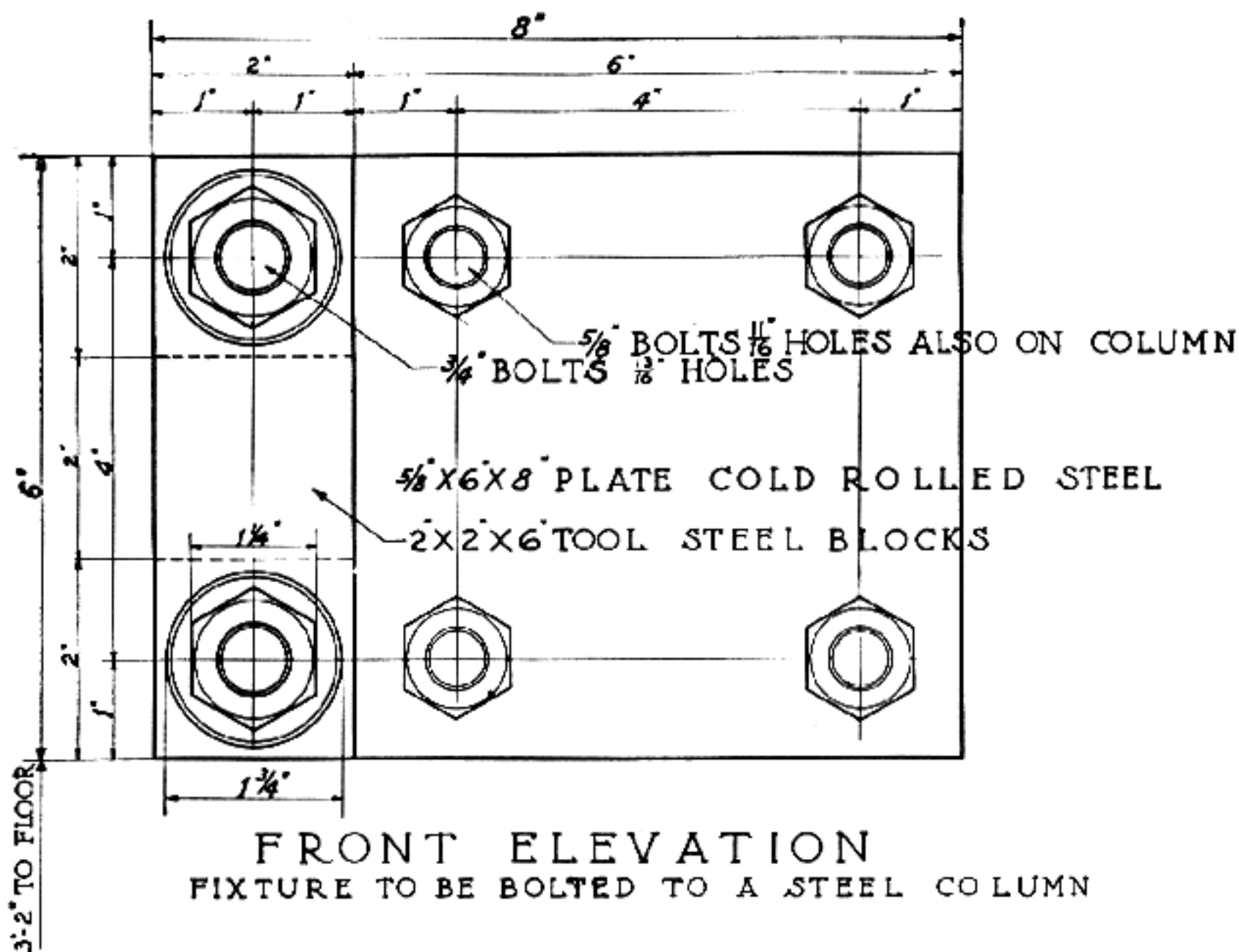
A milling machine is best employed with either a vertical head or the use of a straddle mill to cut down the sides of the rear-sight base and ramp. To make the required set-up on the milling machine, the barrel is clamped in the dividing head chuck and opposite end on the center. Barrel plugs are first inserted and a surface gauge is set to the exact center of the tail stock. After the barrel is held firmly in the chuck and center, the index crank is revolved until the center line of the barrel registers with the setting of the surface gauge, which will be at right angles to the milling cutter regardless of whether a vertical head is used with an end mill or a straddle mill. After one side of the rib is milled to the correct depth the index head is revolved 180

degrees and the opposite side is milled in similarly to the marked lines.

Having thus milled the leaf-sight rib on both sides, a six-inch straddle mill is next used. To mill the three-inch radius the correct distance ahead from the receiver to the desired depth, all the necessary measurements will be found in Figure 48. The surplus stock is milled with either an end mill or a straddle mill to a true cylindrical form by taking light cuts and setting the index crank to a number of holes on each pass of the cutter. This operation applies to the straight cylindrical portion ahead of the receiver. For the taper portion of the barrel ahead of the radius and to the end of the sight rib, the index head is set down a certain degree and the tail stock is also depressed. This angle can easily be figured out between the large and small diameter, and the index head set to the correct angle. The same operations that were employed for the straight cylindrical portions take place to mill this surplus material. With this surplus stock removed, the index head is again placed on center together with the tail stock, and two 60-degree angle cutters are used, one right- and one left-hand cutter placed together upon the arbor; thus the point of the rib is formed. After the rear end of the barrel is milled, it is reversed into the dividing head chuck and a similar operation is in order to mill the ramp. The same instructions may be followed as given for the rear-sight rib, except that there is more material to machine off than from the rear. The swivel base is milled while in place in the chuck, which is located on the under side; the same methods are employed.

After removing the barrel from the milling machine it is "struck." Chapter XV describes this procedure, and by following the instructions there, the barrel is completely finished with a high polish and screwed back again into the receiver in the same position as when it was removed. Set the surface gauge to the receiver line and then mark an index line on the barrel with a fine small chisel so that the barrel can be set up to this line at any time. With the barrel in place, the top surface of the rib is milled off either flush with the top of the receiver or a little below the top surface, according to opinion. The ramp is also milled to the correct height and the incline leading to the sight can be milled with a straight taper, or the large six-inch straddle mill may be used and a large radius milled on the face, a matter of individual taste. The sling-swivel base may be milled in any form which is most becoming to the general outlines of the barrel design.

When seating new barrels, a barrel vise should be constructed, such as shown in Figure 87, particu-



DETAIL OF FIXTURE
TO BREAK BARRELS
FROM RECEIVERS AND
HOLD TO TIGHTEN TO
RECEIVERS

Fig. 87

Barrel vise for removing and screwing barrel in actions

larly for new barrels or barrels that screw on a receiver. Bushings may be made for any type or size of barrel. The blanks are cut off to length and rough-drilled in the center so that when used for a special-sized barrel it is only necessary to bore them out and split them on the milling machine. Such bushings are made from cold-drawn steel.

The two heavy vice blocks are made of tool steel and the center bored to receive the barrel bushings. Holes for two $\frac{3}{4}$ clamping bolts are drilled, a $\frac{1}{2}$ -inch plate is made, and the two vise blocks are set on one end with two $\frac{3}{4}$ holes in line. Four holes are drilled for draw-bolts and the vise is bolted firmly to some solid upright support where no vibration is possible—a roof-supporting beam, for instance. With a barrel vise of this nature and the barrel bushings highly polished on the inside, a finely blued barrel can be removed from any receiver, no matter how tight it may be, without any danger of turning to mar the finish. There are so many different and unreliable suggestions given to remove rifle barrels from receivers that the beginner must be wary, for they come from impractical men or men who have happened to experiment with a loose barrel. These barrel vises are rather expensive to make, but once made, pay for themselves many times over.

Be extremely careful to avoid marring, crushing, bending, or springing a receiver. If it is of a shape which cannot be gripped with a large wrench, use a piece of heavy sheet tin between the jaws. A piece of $\frac{3}{4}$ -inch copper should be employed having the contour of the receiver shaped out on one side. When removing barrels from receivers always set the bolt in, but not in a locked position. This is done so that the receiver will not be crushed at that point, a frequent occurrence when the bolt is not in place, particularly if it is very difficult to break the barrel loose. Figure 87 illustrates a bushing with two prongs on it to place in the recess underneath the action of a Krag receiver. The prongs are made to the exact shape of this cut-out, and by boring out the center of the bushing to slip over the receiver the one prong engages the recess. By placing the barrel in a one-inch bushing in the vise, with this clamp in place over the receiver and the prong in the recess, the tightest Krag barrel can be broken from the action with ease.

Two wrenches may be employed for breaking barrels; the most suitable is a 14- or 16-inch crescent, and for second choice, a 24-inch monkey-wrench. Both are inexpensive wrenches, and when a barrel is set home with one of these and clamped in the vise illustrated, no one will ever remove it with some of the foolish suggestions we so often read of.

If a barrel is fitted according to instructions, there is no need of spotting in the shoulders with Prussian blue for a perfect bearing, unless barrels with two bearing surfaces, similar to those of a Mauser, are being fitted. A receiver pulled up very tightly upon a single shoulder imbeds itself into this, regardless of whether it is an even or uneven surface, for the great pressure exerted on a shoulder by the end of the irregular face of a receiver will form its own seat in the metal and make a perfect contact.

Chambering — The chambering of a rifle barrel is an operation that many students undertake; if they are going to do this work thoroughly, a complete understanding of these chapters must be had. The correct chambering of a rifle barrel depends principally upon safety. Then follows its accuracy, its length of life, and its efficiency in the free extraction of fired cartridge cases.

If the student should make some mistakes in the construction of the tools, ream out the bullet seat too far ahead, or make some other slip in workmanship, the barrel, even tho other parts are perfect, will never produce the results in accuracy expected. The most important point to remember is that it may maim or kill the person who fires it. Chambering is an operation connected with the threading of the barrel and gauging for headspace; therefore these three operations are considered together.

Let us suppose that we have the barrel completed. The next stage of the operation is to chamber it. To do this, make a complete set of chambering reamers, as described in Chapter IX, Figure 56. The field of calibers to choose from is large, but because of its popularity in this country and for sake of experiment, let us consider the .30-06 United States Government cartridge. We will use the latter set of reamers for an experimental operation on a barrel that we may have made. Our first reamer is the roughing reamer, which we place in the rear end of the barrel, or the end where the rifling head came through, as this end is always the largest. First, we make sure that our stops are set in the proper position and are certain that we have used the barrel plug which is shown in Figure 51 to turn true with the bore.

Threading and Fitting Barrels — It is often necessary to cut off one or two threads from an old barrel and rethread it for another action, which, of course, necessitates rechambering. It has been suggested to shrink a sleeve over a barrel at the chamber end; such work is satisfactory on caliber .22 rifles, but on high-velocity arms—never! Oc-

asionally a barrel can be found in the .22 caliber class on which it is necessary to turn the thread off a barrel and shrink or solder on a sleeve and then cut a new thread to fit the action selected. All such work is very simple, but when fitting a barrel to an action, the threads must be cut so that they fit very tightly, and the receiver turned on by hand with little effort.

After turning the barrel and threading, we know that it must be absolutely true with the axis of the bore. This operation may be done either by chambering or threading the barrel first. It does not matter in either case, for in using the proper set of reamers, the barrel is chucked until it runs absolutely true; and then from the barrel plug, which has been left in, the steady rest is set and reamer No. 1 is used—the roughing reamer—with stops set for the proper depth. Next is the finishing reamer No. 2; and finally reamer No. 3, which is the burnishing reamer. The burnishing reamer must be used when the barrel is screwed to the receiver to get the proper headspace of the cartridge unless it is a rimmed case. As all the rimmed cartridges have only a clearance for the neck, this form of chamber can be finished in the lathe, but all those for rimless cartridges that require headspace must be finished when the receiver and action are screwed together. Figure 71 shows two different styles of headspace gauges; one has a series of buttons which measure from the shoulder to the end of the bolt, 0.001; we always chamber to the minimum size, which is the smallest button in the set. If a tolerance is to be used, 0.004 inch is the proper space to work in. The next operation is the throating of the barrel or reaming of the bullet seat. This is determined best by inserting a cartridge in the chamber that has the proper length of bullet projection from the end of the case, so that the lands of the rifling will show plainly on the bullet. As a matter of fact, this is only used in barrels intended for target work; if the rifle is to be used for hunting purposes, reinsert the reamer and take out a little more so that you can barely see the marks on the bullet.

In the making of chambering reamers and gauges that are required for this operation a considerable amount of tool-making experience is required. A separate chapter is devoted to this subject, but a brief outline is in order here. Lengths and diameters must be held within a very close tolerance and the stoning of the reamers requires much skill to face their cutting edges properly. Always remember, when cutting the flutes on the milling machine, to set the angle cutter .010 ahead of center. This will eliminate a considerable amount of chatter, providing they are properly stoned. In stoning the

reamers, they should have just enough clearance so that they will cut freely and not have the clearance you see ground on a reamer that has been purchased, such as the standard hand reamer, machine reamer or taper-pin reamer.

The roughing reamer may be used in the drill chuck set in the tail stock of the lathe, but the second roughing and finishing reamer must be reamed out by hand. This is easily done by putting the center on the reamer, moving the carriage out of the way, and using a tap wrench. As the reamer cuts in, take up on the tail-stock center until the desired depth is reached. Always remember to use plenty of oil and withdraw the reamer to free any chips that have collected.

The first consideration to be taken up in detail is that of the chamber design—its diameter and form with reference to the cartridge to be selected. The dimension and shape of the chamber must be based on the figures and form of a loaded cartridge; therefore, figures must be taken to give the proper tolerance between cartridge and chamber which will conform to good engineering practise. No cartridges are made absolutely uniform, but they are manufactured with a maximum and minimum tolerance. However, the system of inspection at the cartridge factories is very exacting; no cartridge will be produced smaller than the minimum measurements, and for maximum sizes they are checked by a machine. The chamber must be reamed to fit and operate safely with a cartridge made either to maximum or minimum size. To do this, it is necessary that the reamers be made just large enough so that when a chamber is reamed it will work successfully and safely with a maximum case, but no larger, for in that case it will be unsafe with a minimum cartridge. This establishes the correct size and form of a chamber within very close limits.

When you start to chamber a barrel which has been drilled, reamed, and rifled, use a series of four reamers graduated in diameters, so that each succeeding one after the roughing reamer takes but a scraping cut, slowly and gradually enlarging the chamber to the desired size and shape. These are used by hand, but in large arms factories the chambering of a rifle barrel is done on a turret lathe. It is a principle of reaming that a reamer turned by hand, if not forced unduly, will ream out a hole exactly in line with the axis of the bore. To assist this and have it come in perfect alinement the first two reamers are provided with a pilot together with the throating reamer. A pilot, made of either steel—hardened and lapped—or brass, rides on top of the lands and acts as a guide in front of a reamer. The reamers are also provided with stops which are illustrated in Figure 56 together with the pilots.

The finishing or burnishing reamer is not constructed with a pilot, for this reamer removes no more than .002 inch. The bullet seat is that portion of the chamber ahead of the mouth of the case into which the bullet rest projects from the case. It should be cut with the throating reamer just so the bullet will rest upon the lands. The best accuracy is obtained when the bullet is assembled into the case and there is a portion of the cylindrical maximum diameter of the bullet projecting beyond the mouth of the case and fitting with almost a push fit into the cylindrical portion of the bullet seat. Then the bullet seat straightens the bullet so that its axis is in line with the axis of the bore, and when the movement of the bullet takes place it glides straight forward into the bore, and the rifling is cut into its cylindrical surface without any "jump" which may tend to deform it.

That portion of the chamber corresponding to the neck of the case should be slightly longer than measurements taken. An allowance of 0.030 inch is sufficient at the top of the 45-degree angle; this allowance in the chamber ahead of the mouth of the case is for expansion and the 45-degree angle is made so that small brass rings will not be cut off the mouth of the case. Cases lengthen considerably when fired, particularly those which have been reloaded a number of times, and allowance in the chamber must be made at that point, or it will actually crimp in the case, just as a reloading die does, and result in inaccurate shooting.

Headspace — After placing so much stress upon the foregoing operations a complete explanation must be given of the very important subject—"headspace." It is obvious to all users of firearms that the chamber must hold the cartridge back against the face of the bolt, thus supporting the cartridge and primer firmly against the bolt's face when the explosion takes place. Figure 71 illustrates two standard headspace gauges together with a chamber showing a headspace gauge in place. When a rimmed cartridge is used, the headspace is the distance the rim of the case extends from the face of the barrel to the face of the bolt and also the distance from the shoulder to the face of the bolt; the latter distance, however, must be a clearance, which can be in most cases between 0.010 and 0.015 inch. Headspace is usually taken care of by the recess in the end of the bolt, except in the case of rimmed cartridges used in single-shot rifles, and the use of center-fire cartridges. The counterbored recess must be deep enough so that a rimmed case can be inserted in the chamber and the breech block closed. No tolerance should be allowed; this distance of headspace is cut carefully and gradually

with the counterbore after the barrel and breech block have been assembled to the action with constant trying of a headspace gauge or a cartridge known to have a maximum thickness of the head. The headspace between the face of the barrel and the counterbored face of the bolt in high velocity arms has been provided for by the makers of the actions. The headspacing of such chambers is only a matter of finding the proper clearance between the shoulder and face of the bolt; this is usually done with loaded ammunition until it will just go in the chamber without any indications of a bearing upon their shoulder. The finishing reamer is run in until the bolt will barely close without undue effort on the bolt handle. The reamer is placed in the chamber again and enough metal removed to allow sufficient clearance to take care of all maximum cartridges. The exact sizes of the finishing reamer assures that the shoulder and neck of the chamber will be at the correct distance ahead of the removed seat and that all portions of the chamber will have the correct diameters. (Refer to Figure 88.)

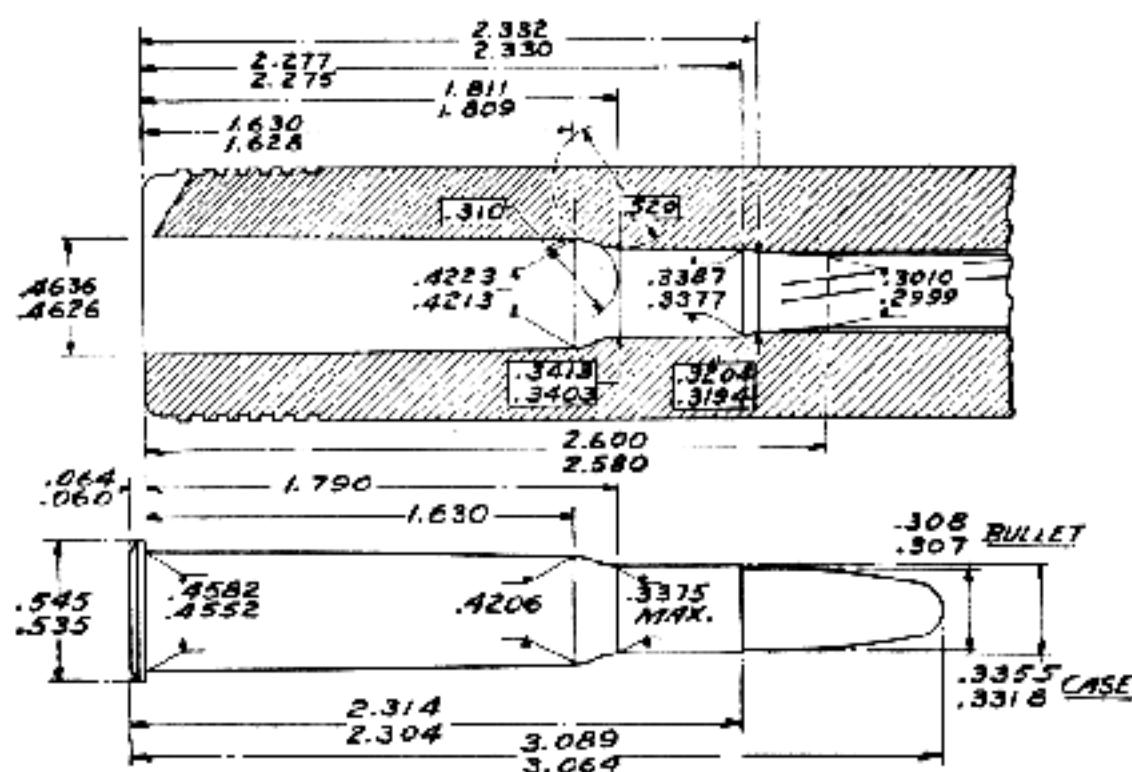


Fig. 88
Caliber .30 Model 1898 rifle chamber and caliber .30
Model 1898 cartridge

When headspacing a chamber for a rimless cartridge, greater care and forethought must be used; this operation is more important because as a rule a rimless rifle cartridge is employed with a much higher breech pressure than that of a rimmed cartridge. On a rimless case the distance between the shoulder on the chamber, just in the rear of the neck, holds the head of the cartridge back tight against the head of the locked bolt and supports the case when the explosion occurs, at the same time holding the primer in its pocket. A simple definition of headspace is: the distance between the angle on the shoulder of the case against the angle on the shoulder in the chamber to the face of the bolt. In the construction of either style headspace gauge, shown in Figure 71, for a rimless case, a selection is

made of the finest type of gauge which can be used for this operation. If it is not possible to construct these gauges, minimum length cartridges must be selected. If a number of barrels are to be made, a headspace gauge of the micrometer type which will give the correct figures for a minimum headspace to all chambers should be secured or made for this purpose. The button type of gauge is the standard inspection gauge used at the Frankford Arsenal. This gauge is more difficult to make than the micrometer type, but the advantage of the solid buttons is that they are positive, whereas the fine-pitch screw in the micrometer gauge can become worn and even sprung when too great a pressure is exerted upon the bolt in the act of closing. For this reason great care must be given to a micrometer gauge, and only the hardest pressure placed upon it when it is at its minimum setting, which is together. A master should be provided with each gauge for checking purposes; this is also illustrated in Figure 71. Without such a gauge it is difficult to check the gauges and cartridges when a doubtful situation arises.

The minimum headspace for the caliber .30 Model 1903 rifle is known as the 0.045-inch button or the 0.044 button, to be used for a very tight headspace. The 0.049-inch button is the maximum; however, on the micrometer at the minimum point it would be 1.944, or when the zero lines coincide each graduation on the thimble and barrel represents 0.001 inch, which is the same as a standard micrometer. In the use of either gauge, the length is from a point figured from the top of the angle to the face of the bolt. The bolts of all rifles using rimless cases, military or sporting, should just close on a minimum gauge. To determine a minimum length of cartridge for and of the chambers illustrated in Figures 57 and 58, a master gauge must first be made with a finished chamber reamer, allowing enough length for the end to be faced off after a minimum cartridge has been found. Select a number of cartridges of the one intended, place them in the gauge, and measure down to the head with a depth micrometer. Select the minimum cartridge which measures the deepest down from the face, then face the gauge off the top to 0.004 inch above the minimum size found. This gauge will be a maximum length of cartridge and should be marked accordingly. If there is to be a standard and a number of check-ups to be made from such a master, it is always best to harden it and grind the face to the proper length.

After the master is completed, a headspace gauge of either type shown in Figure 71 is made. With such precautions a headspace is assuredly correct for any cartridge selected. If the student only has

one barrel to fit he may be able to accomplish the desired results with the use of loaded cartridges as gauges. Secure a number of cartridges of the different manufacturers of the caliber desired. Select from these lots, by given trials in a new rifle of the standard make, two cartridges which appear to be the shortest and longest. It will be impossible to determine or measure their length from shoulder to head, but you should be able to tell by the way they feel and act when they go in the standard rifle and the bolt closes on them. Use one of these for the "Go" gauge and the other for the "No Go" gauge.

Student gunsmiths, and in fact all riflemen, should treat the ready threaded and chambered barrel with suspicion, especially if it comes from unknown sources. Those coming from standard arms plants are usually interchangeable, except when fitted to an action which has had some set-back. This condition is revealed by an examination of the bolt-lug seat in the receiver after the barrel is removed. If it shows a very large indentation, a new receiver should be purchased, for it will become worse as time goes on until headspace is so great that ruptured cases will be the result.

It is also extremely important that only a bolt intended for a rifle be used in that arm. Considerable trouble and some very serious accidents have occurred because of changing bolts. For example, the bolts for most high-velocity bolt-action rifles and also many .22-caliber bolt-action rifles will seem to the inexperienced person to exchange very nicely. The bolt of any rifle will fit into any other rifle of that particular make; thus the beginner is under the impression that everything is all right. But the use of that bolt in just the wrong rifle will give poor accuracy (particularly in .22-caliber rifles) or it may cause the cartridge case to separate in two, about $\frac{1}{2}$ inch in front of the head, leaving the forward portion of the case wedged in the chamber. Or, if the case should be a little overloaded and have a soft head from too much annealing in the furnace at the cartridge plant, the head of the shell may give way, permitting gas to escape to the rear, completely demolishing the receiver and perhaps seriously injuring the user. The possibility of such an accident is sufficient reason why one should use every precaution for the sake of safety alone. Modern military or bolt-action receivers made by private companies have their actions made from properly heat-treated alloy steel, are designed to stand a breech pressure of 52,000 pounds per square inch, and will withstand an accidental pressure up to 100,000 pounds per square inch, provided the cartridge case will hold and the headspace is at its minimum length. It is very seldom that a cartridge case is found with a soft head in the

product of our standard cartridge manufacturers.

While the danger of excessive headspace has been emphasized, I do not wish the reader to suppose that a great number of rifles are unsafe. Headspace is very important from the standpoint of safety, but the test is very simple, taking not more than a minute to perform if one has the proper gauges. Our large arms plants and also many of the smaller reliable firms turn out barrels which are properly headspaced; such arms are absolutely safe if used with any standard cartridge of the proper caliber made by any of our large cartridge companies or by the government arsenals; or with hand-loaded ammunition recommended by the powder companies or handbooks upon that subject.

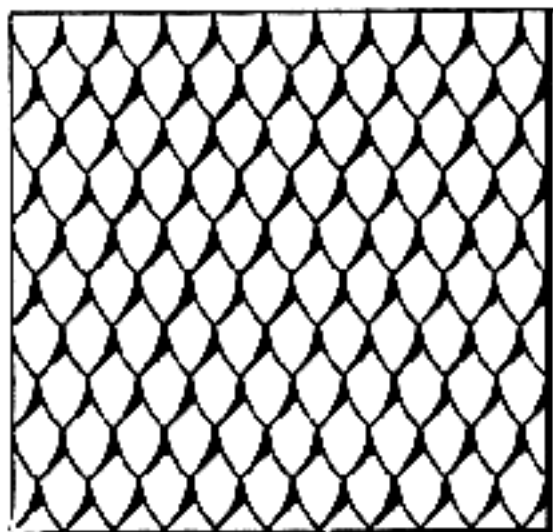
We must speak of short headspace because that also is likely to occur, altho it is not accompanied by such grave consequences as excessive headspace. If we have too short a headspace, then the breech block or bolt will fail to close down on the cartridge. It may close down on cartridges of one make but not on those of another. The chamber is just too short; consequently a finished chamber reamer must be run in a little deeper, or a shorter bolt be selected. At times the user of a rifle, if he is using hand-loaded ammunition, may experience trouble due to the stretching of fired cases. The fired cartridge cases one loads may have stretched too long for that chamber—often the case in lever-action arms. These actions do not have the bolts locked at the front, and since they are made of heat-

treated alloy steel, have considerable spring or give to them; cartridge cases fired in them lengthen so greatly that they cannot be resized to fit again easily into the chamber in which they have been fired.

I have probably not explained some of these subjects in a manner which can be understood by a person who is just beginning such work, but the trained mechanic will be quick to comprehend the meaning and will proceed to carry out the work in a highly technical manner, thus opening up new fields of experimental work never before dreamed of by him. If you are to construct a rifle of your own, carrying out ideas in good engineering practise, I feel confident that there will be very little trouble experienced in the construction of the barrels and the necessary tool layouts. The drawings are as complete as it was possible to make them and will enable you to figure out designs of tools which would require months of hard work on the drafting board. Do not try to change some of these until you understand the subject thoroughly. You may have excellent views, of course; if so, continue to experiment, or get some one with the necessary experience to create experimental designs. From these, greater results may be developed, and the knowledge gained will not be thrown to the four winds; it will help you understand the proper designs of barrels and cartridges, a branch of knowledge that leads into the study of ballistics and is not acquired through book learning alone.

CHAPTER XIII

The .22 Caliber Hornet: Design and Conversion



The .22-Caliber Hornet: Design and Conversion

THE design and construction of any rifle calls for certain basic principles, particularly in the American small arms; but ever since the old Winchester .22 W. C. F., or Winchester single-shot cartridge was given a 45-grain jacketed bullet and rechristened the "Hornet" every kind of old action has been resurrected to be converted into a .22-caliber Hornet rifle. All principles of design have been laid aside and the student of gunology has at last brought out his own basic principles reaching far beyond any gun designer's sense of responsibility. The amateur gunsmith has dug out of the past some very interesting old actions to be converted to take the popular cartridge for small game such as woodchuck, crow, squirrel, etc., and even for target shooting.

There are a number of old single-shot actions capable of handling this cartridge, and then again there are certain safety factors that must be taken into consideration in conversion. Some of the old single-shot rifle action frames, made only of cast iron, are not safe to use with the high pressure developed by a Hornet cartridge, for the reason that cast iron only has a tensile strength of a little better than 16,000 pounds per square inch; therefore, actions made from cold-drawn steel must be case-hardened and given the required strength of better than 60,000 pounds per square inch. In the selection of old actions we have the single-shot Winchester, Stevens 44½ action, Farquahrson, Remington, Winchester, Martini, Ballard, Hepburn, and certain Swiss and German actions. Of the single-shot actions, in my opinion, we have two of the best in the Winchester single-shot and the Farquahrson actions made by Westley Richards. The old Winchester was the type of action originally made for this cartridge, with ammunition popular at that time, such as the .32-40, .38-55, .40-90, etc.

The conversion and building up of one of these Hornet rifles becomes as interesting as the remodeling of a military rifle, except that barrels must be provided which are more expensive than might be anticipated. When a .22-caliber Springfield barrel, however, can be purchased and fitted to the action by the student and then chambered also by himself, the expense is brought down to a minimum. If a new barrel is necessary it is much more reasonable

to send the action to the Niedner Rifle Corporation of Dowagiac, Michigan, and have them fit and chamber it, than to try to do it yourself. You may do the other necessary work, such as making the new stock and forearm and sights.

In order to explain methods of converting various actions into a Hornet rifle I must vary my points of interest to parts of the actions, barrels, sights, etc.

Barrel — Only one standard barrel steel is suitable for this rifle, and that is ordnance steel as used in the Springfield .22-caliber barrels and also in the products of the Winchester Repeating Arms Company and the Niedner Rifle Corporation. Extensive tests have proved that it is one of the best steels for high-power rifle barrels or even the .22-caliber long rifle cartridge. It is almost exclusively used by the British rifle makers for all their rifle barrels and for many other purposes. This type of steel is a little more difficult to machine than the common cold-drawn or higher carbon steels, and a slight change in tools is often required, with stoning or grinding to complete the operation. It has a very high tensile strength, excellent wearing qualities, and more resistance to corrosion than the ordinary low-carbon steel used in most of the cheaper arms. From an entirely practical point of view it has been demonstrated by government tests that nickel and ordnance steels are the best to use in the manufacture of any type of rifle barrel, tho most riflemen are not aware of their remarkable qualities. The more experienced riflemen having rifles made from these steels have noticed this established fact long ago; it has manifested itself by less wear and a brighter appearance of the interior after long and hard use. Barrels made from carbon steel have not shown such satisfactory results, even tho they were given less use.

So many enthusiastic owners of .22-caliber long or long rifles who are planning or desiring the change to the Hornet cartridge often overlook the steel the barrel is composed of, and the twist of rifling. This is a vital point, and all owners should understand that not every .22-caliber rifle or barrel can be made to use this cartridge. The interior measurements of a .22-caliber long rifle cartridge are given in Chapter IX.

The old .22-caliber W. C. F. barrels were mostly hexagonal in form and between 26 and 30 inches in length. They were mostly made of cold-drawn steel, but since the original bullet was only made of lead they were perfectly satisfactory, for they were a straight taper from breech to muzzle in the hexagon form. Today, however, we must consider the outside dimensions and weight of a round barrel to form graceful outlines from the action to the muzzle; a Hornet barrel should have a certain weight to bring the rifle in better balance, especially when using one of the single-shot actions. One point which need not be taken into consideration is the minimum thickness of barrel to insure against rupture, bulging, or bursting, for in using a Hornet cartridge, just as long as the breech is of sufficient thickness and of the proper steel, there is no danger.

Since all things are equal, no doubt the heavier the barrel, the greater will be the accuracy. Length of barrel must be considered for proper handling and sight radius. There are many factors which should be well weighed in the final decision.

In the design of a Hornet barrel, particularly one that is made specially, we must consider the ultimate weight of the rifle and its correct balance. In a hunting rifle we desire a barrel in this class either light or heavy; in the latter we must select one which is not extreme, as on a modern free rifle in the target class, but one that is consistent with

good holding and well in balance when a telescope is used. Figure 89 illustrates a barrel fitted to a Farquahrson action by Westley Richards. The barrel measures 1.15 inches at the breech, 0.680 inch at the muzzle, and the length is 26 inches. The taper is continuous from the muzzle within 1½ inches of the breech; this small straight portion was left for the mounting of a telescope block. The taper is so gradual that the front block was only $\frac{3}{32}$ inch higher than the rear when placed 7.2 inches between centers. On this particular rifle a Fecker telescope was used, which was the only sight provided for, as it was to be used solely for ground-hog shooting. The barrel weight and proportions of the stock made a fine combination heavy rifle of the extreme limit in the heavyweight class. Still, we may desire as light a weight as is consistent with accuracy. Figure 97, Volume I, illustrates a Hornet rifle made on the Farquahrson by Westley Richards; it is a fine example of the gunmaker's art and has perfect balance of barrel and stock. The barrel length and diameter of this rifle are: diameter at breech 1.1 inches, at muzzle .56 inch, and length 25 inches, with a gradual taper from muzzle to breech. The stock and forearm are made from French walnut with graceful outlines and perfect fitting of the metal parts.

Generally speaking, the only alternative the amateur has in constructing his ideal Hornet rifle is to secure a .22-caliber Springfield barrel and fit

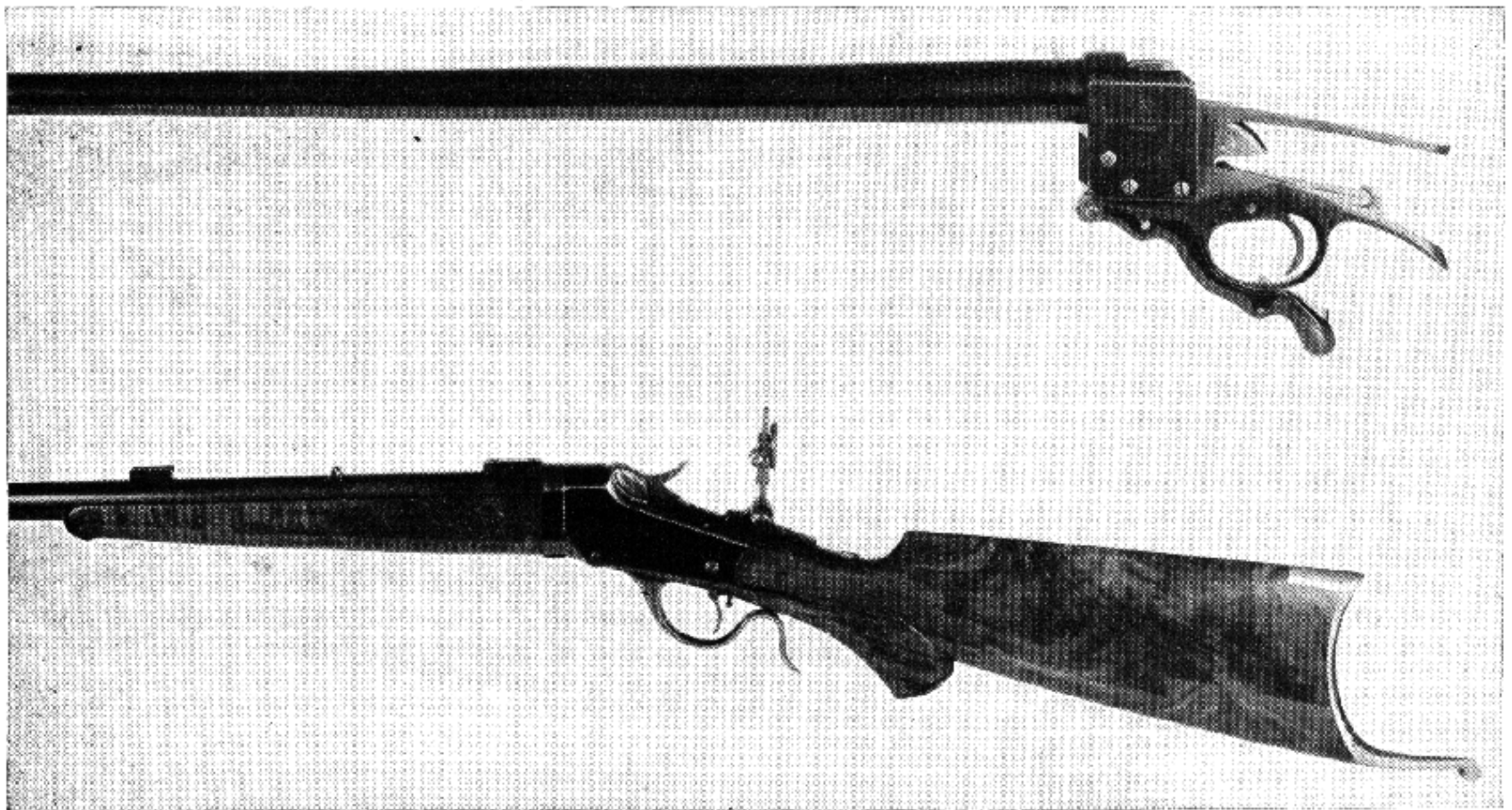


Fig. 89

Top: Caliber .22 "Hornet" barrel on Farquahrson action made by Westley Richards. Bottom: Special barrel made on single-shot Winchester action for "Hornet" cartridge

it to any of the actions named in the first part of the chapter. The Stevens actions are the smallest; therefore it is advisable to turn down the breech slightly smaller than the action in order to fit the new forearm. If Springfield barrels are fitted to these smaller actions they usually make the ideal light hunting rifle. Considering that a Springfield .22-caliber barrel is used, it will prove more than expected, owing to its remarkable accuracy. It is not advisable to reduce the weight unless a lighter rifle is desired, and then only to turn off some of the surplus metal at the breech to bring out better lines. The muzzle may be reduced only to the extent where it is possible to fit a neat and satisfactory ramp. A barrel for a cartridge like the .22 Hornet can, of course, be made much lighter; but then a single-shot action in the Stevens, Winchester, Martini, Ballard, etc., will carry all the weight necessary to make up the difference in weight of action; on the other hand, on a Springfield M-1 rifle with a standard sporting stock, the barrel can be reduced considerably to bring the weight of rifle between 7 and 7½ pounds.

Alteration on Tangs—When remodeling any of the single-shot actions or the straight-grip receiver with the under tang separate, it is possible to bend these into a very neat curve so that a full pistol stock may be fitted. This cannot be done on the Stevens action as most of the parts are of malleable iron. The bending of the tang on some actions requires the making of a new spring; still, some can be bent without a new spring as on some of the single-shot Winchester actions. When first studying the tang to bend these for forming a pistol grip it seems rather a difficult operation, but it is only one of the ordinary problems the gunsmith faces during the course of a day's work. To begin with, the action should be completely stripped of all screws, pins, springs, etc.; in fact, every movable part should be removed. Having completed this, assemble the under tang again and lay the action on a piece of sheet tin or brass and with a sharp scriber draw a complete outline of the top and bottom tang on the metal. Then on the same sheet tin or brass, lay out the exact curve you wish the new pistol grip to have, so as to show the new position of the curve on the lower tang. Since the lower tang is removable on the Stevens and Winchester actions, this is now removed and the bending operation takes place. Refer to Chapter XXIV, Volume I.

The student often makes the mistake of bending the upper tang. The upper tang should never be bent but left straight, only the lower one being curved to form the pistol grip. If the upper tang

of the action is bent, it only tends to reduce the size of the grip, and the comb must stand up out of all proportion above the handhold or grip. As a matter of fact, the high comb usually wished on the new stock is going to protrude too much to look graceful in the harmonious blending of outlines.

Before any bending operations take place, steel screws must be fitted into all tapped holes. The object of fitting these blind screws into the tapped holes is that when the bending takes place they may not be bent out of shape. The usual trouble experienced is that the holes close in because the metal is weakest at these points. Having thus prepared the lower tang for the bending operation, male and female forms should be made from a piece of cold-drawn steel small enough so they can be used in the bench vise. A hack-saw and a file are the only tools necessary to make these forms. After they are completed, heat the tang to a cherry-red and pull the two forms between the two blocks. A little beeswax placed on the face of the vise jaws, with the forms pulled up against this, will usually hold them in place until the operation is finished.

If the student is skilful at the forge or anvil, the lower tang may be heated to a cherry-red and bent by carefully hammering over an anvil horn. All tangs can easily be bent cold after once being annealed in the form first described, but it is better to heat them to relieve any strain and obviate the danger of forming surface cracks.

If the student does not care to go to the trouble of making the male and female forms, three round copper rods may be used in the vise. Cut three pieces ½ inch in diameter and 3 inches long and make a right-angle bend on each rod about in the center so they will hang over the vise jaws—two are placed on the back jaw and one on the front. Insert the tang between the three rods so that the single rod is on the side where the curve is to be formed. Gradually tighten the vise, making a slight bend. Loosen the vise and move the tang in a different position on the single rod to increase the bend, and again tighten the vise. Continue with different positions until the desired curve is formed. The tang will be marred very little by this operation, and the little dents that do occur in the metal may be removed by filing and polishing. Care should be taken not to form too sharp a bend near any of the screw holes, even tho they are plugged with steel screws. A perfect curve is the object. Continue to test the curve on the lay-out on the metal until one that is most effective is found.

If the lower tang is integral with the action a different method of bending must be used. Clamp the flat side of the action very solidly in the vise between two copper vise jaws. Two wrenches

should be made from $\frac{3}{8} \times \frac{3}{4}$ inch cold-drawn steel. Slots are cut out on the end just the width of the tang; these should be about 14 inches in length so that the proper leverage may be applied in order to bend the tang to the desired form. One wrench is used to hold the tang and placed in such a position that it will not start the bend close to the action but near the end. Heat the tang with a gasoline blow torch to a cherry-red and hold with one wrench while you bend with the other.

The alterations of most under tangs on single-shot actions require the making of new screws, particularly those which go through from the upper tang and screw into the lower; but when the bend is turned down to such an extent that a full-length screw cannot be used it may be advisable to use wood screws in both the upper and lower tangs. On some of the Winchester single-shot actions the tang is long enough so that the bend only comes up to the long rear screw hole. The bending of most tangs with the exception of the single-shot Winchester action requires the making of new main springs as well as screws. Chapter XXI gives the information for making springs, and this must be studied before any of the alterations take place.

The bending of a tang also requires alteration of the under lever on most single-shot actions. The lever is made of a heavy piece of metal and may be heated in the forge and bent to any shape by carefully hammering on the anvil or over a form, unless it is made of malleable iron. After a lever has been straightened out a good many assemblings may have to be performed before it comes into the proper position against the bent under tang. Be very careful to hold the bend of the trigger guard and the bend of the under tang so it can be formed from there back to any shape which will be most suitable for the owner. It is often advisable to weld a suitable extension to the end of lever for the purpose of operating it freely. On most of the levers a round knob is formed which is not only a means of showing artistic taste in the forging operation but will give the fingers a better grip in the act of closing or opening the action. The bending of any under lever requires the same general outlines scribed upon a piece of sheet metal as explained in the bending of the under tang. These bends must be laid out prior to the alteration, and even then a considerable amount of fitting is necessary. What little changes are required, however, can usually be done cold in the vise, as the metal is well annealed after a number of heatings in the forge.

Bushing Breech Blocks — Altering a single-shot rifle from a rim-fire to a center-fire means changing

the breech block and inserting a new firing pin. The only practical and safe way to do this is to anneal the block, counterbore into the old hole, and fit a standard shotgun or double rifle firing-pin bushing. The usual size to make these bushings is $\frac{1}{2}$ inch diameter at the head with a $\frac{3}{8}$ -inch tapped hole, using a fine thread such as 32, 36, or 40 threads per inch. After the plug is made and fitted into place the center is located in the following manner: A length of drill rod is selected which fits the bore perfectly, and on one end a center is turned; this is hardened and tempered and inserted into the muzzle. Before any indentation is placed upon the firing-pin bushing, care must be taken that the breech block is fitted into its proper position. If this has been done a slight tap of the hammer on the opposite end will place the true center in the bushing. Since nearly all single-shot firing pins are on an angle in the blocks, the setting up and drilling of the new firing-pin hole must be done on the same angle in the drill-press vise. First, a $\frac{1}{16}$ center drill is used and then followed with a No. 44 drill, piercing through the plug into the firing-pin opening. After the firing-pin hole has been drilled, two small holes are drilled into the plug on a center line with the firing-pin hole close to the outside edges. A special wrench is made to fit into these holes to remove the plug. The rear is reamed out with a firing-pin reamer within $\frac{3}{32}$ inch of the face. The firing-pin hole is now eccentric with the rear hole. Consequently there are only two things to do: either make an eccentric firing pin or bore the hole to the true center established in the firing-pin plug. The boring of the true center through the block means an elaborate set-up on the lathe; therefore, it will be much more economical to make the eccentric firing pin.

Firing Pins — Figure 129, Volume I, illustrates the correct point or end to be made on any center firing pin. Always remember that the correct projection of firing pins is 0.065 inch maximum and 0.055 inch minimum; this is the distance a firing pin should show from the face of the block or bolt. The importance of the correct form of firing pin as well as the proper steel to use cannot be overestimated; also correct heat-treatment of the steel. The best steel to use for firing pins is a high-grade chisel steel, which should be hardened in oil and the temper drawn in an oil bath heated to 625 degrees Fahrenheit and left in this bath for one hour. Naturally, this is a lot of trouble for one firing pin, but when rifles are to be used against dangerous game the effort is not too great; even if it took one hundred hours it would be well worth the time spent if a human life were at stake. The same

painstaking care should be used if it is only a firing pin for a single short Hornet rifle to be used in the field on woodchuck.

Flats or notches required on the side of a pin should be filed by hand. The most convenient way to do this is to hold the finished pin in a drill chuck held in the vise. This avoids marring the pin in the vise jaws if the copper jaws will not hold it in the correct position for filing.

A great many accidents may be attributed to faulty firing pins. Too much care cannot be exercised in the proper development of any firing pin and its correct profile, particularly at the point the illustration shows. The large diameter of the pin should fit the hole in the block easily, yet without too much clearance. The fitting of the striking end into the hole should also be a free but perfect fit, and lastly the pin should be made of good tool steel, highly polished, then hardened and the temper drawn to a point that will obviate the possibility of breakage. Be positive that the check screw or pin is in the best condition. The student may be entrusted with the making of any firing pin if he will follow the above instructions; after he has acquired reasonable proficiency with tools he will find that a firing pin is an easy part to make. It should be remembered, however, that firing pins when not made correctly have been the cause of robbing many of eyesight, and when that is destroyed it can never be replaced.

Extractors — When breeching up new barrels against the breech block on any of the single-shot actions there should be a perfect fit between the barrel and block, so that when the under lever is worked there will be no appreciable effort to drop the block. These instructions apply to any cartridge; therefore when the extractor slot is cut out and the old or new extractor fitted into the proper position it should be flush with the face of the barrel.

The old extractor may be used when fitting a Hornet barrel if the previous barrel or caliber has been a .22 rim-fire, but if it was a larger caliber it is necessary to make and fit a new extractor. It is a much better plan to secure a new factory-made extractor whenever possible, particularly if the action should be a Stevens or Winchester; but if it is an obsolete arm it is necessary to make one. The best steel of which to make a new extractor is cold-drawn or machinery steel case-hardened to a considerable depth. Tool steel will not stand the pressure of extractors, even tho the proper heat-treatments have been given; whereas the mild steels with the case-hardened surface and the soft core will stand the greatest strain.

Make the length of the extraction end slightly longer, so that when the reamers are placed into the chamber a perfect radius will be formed. The extractor should be in place when the rough and finish reaming operation takes place, and also the counterbored sections for the head, so that the cartridge head enters to the proper depth for correct head space. After fitting the new extractor it is case-hardened as described in Chapter XVI, except that it is left a little longer in the cyanid bath than the usual run of work.

Many of the old single-shot actions were made to be unscrewed from the receiver or the take-down principle applied. The barrel screwed into the frame and was held in alinement by means of a set-screw under the forward end of the receiver. When fitting a Hornet barrel this principle must be dispensed with and the barrel tightened into the receiver with a large wrench so that a perfect joint may be formed between the barrel and action. The set-screw is then placed back into the action only for appearance or removed altogether and a blind screw fitted.

After the student has all the work completed on the barrel and action, the next question is the finish of the weapon. The barrel will naturally require a blue finish, but the action, particularly the single-shot variety of Stevens, Ballard, Winchester, etc., look much better when case-hardened by the pack-hardening method described in Chapter XIX, Volume I, or Chapter VII in the volume you are now reading. The smaller actions, such as the Stevens, may be given the cyanid treatment. Parts which require considerable hardness to resist wear, such as the blocks, hammers, pins, etc., and which are well protected and subject to little danger of breakage from strain or percussion, may be left a little longer in the cyanid bath to obtain a deeper surface to the exterior, particularly on low-carbon steel. The heat-treatment for colors on bolt-action arms when converted to the Hornet rifle should never be attempted by the beginner. Such work requires experience in the working of metal, and the best results will be obtained by bluing the parts. Failure, due to lack of the required knowledge of the contents of steel, would lead to disaster. There have been too many mistakes made already to warrant any person taking chances in the heat-treatment of alloy steel used in nearly all bolt-action receivers.

The demand for a suitable small cartridge with a high velocity has been the source of a great many trials and experiments until this .22 W.C.F. cartridge was brought to light again. Many have found the .22-long rifle cartridge lacking in many respects; and the same is true of other cartridges in this class, such as the .22 W.R.F., known as the .22

Special. The .22 Hornet, with the same weight of bullet except with a jacket of gilding metal, brought the velocity up over double that secured in the rim-fire ammunition. High velocity was the thing wanted, and it was made possible by such men as Colonel Whelen, Captain G. L. Wotkyns, Captain G. A. Woody, and Mr. A. Woodward of the Springfield Armory. I may have neglected to write upon some of the most interesting results in the performance of the Hornet cartridge and rifle, but these men have gone into the subject extensively.

I know that a number of men will never be satisfied with the velocity the cartridge is now giving, and that experiments will be made to secure a much higher velocity; but then a new case must be designed, and when that is done it will require a banded cartridge similar to the Magnum cases used in such ammunition as the .375 Magnum class. It is well for the man who has such ideas to carry these out to satisfy a certain fancy, but as it often happens, men with these ideas are not in any financial position to bring them to light, and those who are will have the work performed by others, or are quite satisfied to purchase an arm in a standard caliber such as in the Hornet class. I shall now present Captain Woody's explanation of the chambering of the .22-caliber Hornet with drawings of his own design for the necessary reamers to perform the operation. With such a good explanation of this operation, any other caliber can also be done, provided the necessary reamers are constructed for the particular cartridge selected.

Chambering the .22-Caliber Hornet

By CAPTAIN G. A. WOODY

There are several rifles suitable for modification to take the recently resurrected .22 W.C.F., or, as it is commonly known, the .22 "Hornet." Because of the fairly high pressure obtained in this load, care should be exercised in selecting a rifle suitable for it, and should there be any doubt in one's mind regarding the strength of the breech and chamber walls, he should consult one who knows the strength of various guns, particularly the ones from which the selection is being made. As noted above, the chamber walls are mentioned. Barrels of mild non-heat-treated steel are often put on more or less cheap rifles. Some of these rifles have breech strength sufficient to hold the Hornet, yet a chamber made in the mild steel barrel will very probably enlarge, due to cold-working the metal. In enlarging, there is very little danger of a rupture, as the metal is in reality being set up in such a condition to withstand tremendous pressure. Yet the enlarging of the chamber is detrimental to

accuracy obtainable with this cartridge. Further consideration should be given the barrel since the fairly high velocity and jacketed bullets will eventually, and no doubt very soon, wear out where a heat-treated barrel might last for thousands of rounds.

Another consideration is the action. This cartridge is very accurate, its accuracy at 200 meters equaling that obtained with the finest heavy barrels firing the most accurate caliber .30 ammunition. Obviously, in order to take advantage of this extreme accuracy it is necessary that the action selected have a mechanism which can be tuned up to a nice sensitive trigger pull, and so maintained. It is useless to select a rifle, however good the barrel and breech action is, if the trigger pull is not first-class.

Having mentioned above the selection of a breech action, there remains the selection of a breech bolt or block with a sufficiently small firing-pin hole to prevent extension of the primer through the firing-pin hole. A great many rifles suitable to take the .22 W.C.F. or Hornet have relatively large firing-pin holes. It has been found that for the Hornet the holes should not be larger than .070 inch, and .060 is preferable. Pins as small as .050 inch have given excellent results. No doubt larger holes would give good results, yet there is always that danger of blown primers; this reaches extreme danger in hammer-actuated mechanisms where the end of the firing pin is dangerously near the shooter's eye. A great many rifles suitable for modification to the Hornet are rim-fire and it is necessary either to purchase a center-fire block, or bolt or plug the off-center hole and drill a center-fire pin hole. There are various means of filling in these holes. Some resort to welding and some plug them. In all cases the hole should be well closed with metal capable of being subjected to the pressure exerted by the rim of the primer cap. This pressure is usually very high and has been known to set back bushing plugs incorrectly seated.

In selecting a breech block or bolt, a determination should be made of the steel used. That is, one should know whether it is a case-hardened job or high-carbon heat-treated, or nickel steel. All case-hardened breech blocks and bolts require annealing before machining, whereas many of the high-carbon or nickel-steel bolts and blocks can be machined without being annealed. This is particularly true of nickel steel. However, should it be necessary to anneal the high-carbon or nickel-steel bolts or block, material of practically the same nature as the part to be plugged should be selected, out of which the plugs or bushings are to be made; because when these parts are again hardened and drawn together with the bushings or plugs they

will all have practically the same hardness. On the other hand, should such parts be machinable without annealing, the material used to plug or bush should be hard, such as high-carbon drill rod, since it, in its unhardened state, is sufficiently hard to withstand severe punishment. If possible, it is often wise, after machining plugs of this material to size, to give them a slight hardness before they are inserted in place. This is particularly so of firing-pin bushings, since the sharp edges of the hole will always break down under primer-cap pressure if left in an unhardened state.

In the case of pack-hardened or case-hardened block and bolts, it is always necessary that the part be annealed before machining. This annealing is best accomplished by bringing the part up to a cherry-red heat and allowing it to cool in a box of powdered asbestos. Cooling in the air will often produce hard spots. The selection of material used for plugs or bushings for this work should be confined entirely to low-carbon steel—a steel that will not harden in water. This is necessary since the part which has previously been annealed will have to be subsequently hardened by quenching in water. High-carbon steel would be too brittle under this quench. It will be found that these soft steel pieces will require some case-hardening; this is best done when the bolt or block is being rehardened by spreading on the bushing, when hot, a small piece of sodium-cyanid. It is not wise to resort to pack-hardening unless the bushing or plug is relatively heavy, as this treatment gives a deep case which will often render the part too hard throughout, giving it the same effect as if high-carbon steel had been used as material for the bushing. Annealing and rehardening of block and bolts should not be done by other than competent mechanics who understand the resulting stresses and strength required.

In the selection of any rifle for modification, care must be exercised to see that the extractor is capable of handling the cartridge to be used. Some rifles have extractors which handle the .22 rim-fire, yet cannot by any ingenuity be modified to handle a cartridge the size of the Hornet. The barrel should have a bore diameter of approximately .2180 to .2185 inch and groove diameter of .2230 to .2235 inch. However, it is claimed by some that .2175-inch bore and .222-inch groove is satisfactory. To get real accuracy, it is doubtful that the groove diameter should be much smaller than the bullet. With bullets running from .223 to .2235 inch, and some .224 inch, it is recommended that a barrel be selected that will have a groove diameter not less than .223 inch, especially when the lands have a large percentage of surface in relation to the grooves.

One of the most popular rifles capable of being

modified to take the Hornet—and beyond doubt the most satisfactory—is the caliber .22 Springfield, M/1. The barrel, while designed entirely to handle the caliber .22-long rifle cartridge, handles the Hornet bullet of sizes from .223 to .224 inch.

Obviously, one of the first considerations in chambering a rifle is to provide a reamer. The reamer should be of a size that will accommodate any cartridge you intend to use in the rifle. This should not be taken to imply that it should be capable of accommodating any make of ammunition. There are some commercial firms who are so thoughtless as to make ammunition of any and all sizes. There are, on the other hand, some companies who have tried to standardize their ammunition and a rifle handling one make will handle the other make just as well. In selecting the types of ammunition from which to obtain the reamer dimensions it is well to select a few cartridges from makers who are more or less standard. Measure the salient features, such as the neck diameter, the diameter at the shoulder, the diameter at the base, the angles of the shoulder and the various lengths. These dimensions should be listed. From these dimensions select the dimensions you want to apply to your reamer. Be sure that in no dimension selected will there be interference with any cartridge you have selected. And bear in mind that you are probably in possession of some minimum cartridges. It is desirable that you obtain from the manufacturer the dimensions of the cartridge, but this is not always possible, so you have to take what you can get.

A chamber reamer should ream your barrel to take the cartridge you are to use plus a slight clearance. For a cartridge of small caliber this clearance should not be more than .001 at the base and about .002 to .003 inch at the shoulder and neck. Never have the neck too tight. It does no good and often a lot of harm. A good cartridge has its bullet and body loaded in line and it should be fired this way. The recess for the neck should extend about 0.010 inch to .020 inch beyond the mouth of the case. With these clearances given your selected dimensions, you can determine your reamer dimensions. The usual way to make a reamer is to select a piece of good tool steel of a diameter large enough to make a reamer with a pilot about one inch long and with a means provided to hold it. This is best accomplished by selecting a suitable thread to which you can attach a driving rod. Center both ends with a small center drill. Rough down to the dimensions plus about 0.015 to 0.020 inch, or more if the reamer is long, for grinding. Flute in the usual manner and do not be misled into using an odd number of flutes to

prevent chattering. This can only be had by using unevenly spaced flutes. Evenly spaced flutes allow quick and accurate measurement and a reamer so fluted will not chatter if the proper speed is used. In fluting, use good judgment to assure that your reamer, after grinding, will have good substantial flutes, yet sufficient chip room.

A reamer should be hardened, drawn, and ground in the usual manner. Leave it plenty hard and be careful with it. Grind to the dimensions you have selected. Back off slightly but not too much. Just assure yourself that your edges will cut and not drag. The pilot should fit the bore diameter snugly but should not be tight enough to bind.

In chambering a rifle with a reamer which you are not sure of, it is wise to get an old barrel first and chamber it. Adjust your breech in order to fire a shell in the chamber. You can learn a lot from the fired case and correct your reamer accordingly.

The above preliminaries to chambering a Hornet rifle, while condensed, are considered essential to doing a good job. As stated above, the Springfield M/1 caliber .22 is considered one of the most popular and easily converted rifles. The bolt is removed and disassembled. Take the bolt head and remove the extractor and ejector. The ejector is removed by knocking out the small pin from the top. If the bolt head is nickel steel, it will have "N.C." stamped on the under side of the ejector stops and can be machined without annealing. If of carbon it will be very hard and require annealing. This is done in the usual way to allow free machining. The first operation is to plug the firing-pin hole. This hole has a 60-degree bevel in the rear end. A rod should be selected of a diameter which will just about fill the largest diameter of this beveled hole. If the bolt head is carbon, this rod should be of a low-grade carbon steel. If the bolt is nickel, it should be of high carbon. Do not make a mistake here, since the carbon bolt head will subsequently be hardened without annealing whereas the nickel-steel head will not be hardened and the high-carbon rod is necessary to give the plug the maximum strength. One of the easiest methods of plugging is to tap out the firing-pin hole into which is screwed tightly a threaded end of the rod which has previously been shouldered back on a 60-degree included angle bevel. With a scratch awl, mark through the ejector slot, a line on the rod just about .010 inch above flush with the bottom of the large hole in the head. Remove the rod and with a small cutting-off tool ground slightly to an advance toward the bevel of the rod, turn the rod just at the line on the rod to a diameter just under the diameter of the turned and threaded end. This will allow you to screw the rod again in the head, the last

pressure twisting it off smoothly at the cut you have previously made. Before screwing in the rod for the final operation, the hole at the front end of the bolt should be counterbored with a diameter of about .120 to .125 inch to a depth of about .080 inch. Into this counterbore you can upset the end of the plug by hanging the bolt head over a hardened rod which just enters the small hole in the interior. To do this operation properly, the threads should be removed from the end of the plug, which will be in the .080-inch-deep counterbore. Be sure that you have left sufficient metal on the end of the plug to upset into the counterbore.

Having completed the plug, the next operation is to recess the end of the bolt for the cartridge head. Chuck up the bolt head to run central and with a well ground tool slightly counterbore the head to a depth of not over .100 inch below the original face and to a diameter of the cartridge head plus about .015 inch. This recess is necessary in order that the lip of the extractor will not be cut too thin for the thick head of the Hornet case, yet you should not go so deep as to weaken the extractor-retaining recess in the head of the bolt. Leaving the bolt still chucked up, the next operation is to bore a hole in the center. This hole should be about .050 in diameter and through the ends to the head interior. Now remove the head, and with a flat reamer shaped with a bevel, ream the hole to about .060.

The bolt head is now complete except for hardening. If of carbon, it should be heated to a good red and smeared over at the forward end with sodium cyanid, or if possible, pack-hardened. Usually if you have not cut through the case when recessing for the cartridge head the cyanid will be satisfactory. This, however, gives only a superficial case.

The striker should be removed and annealed. Leave the pin in but cut it off flush with the end. Select a drill about .10 inch and drill into the end of the striker while it is chucked up to run absolutely central. Into this hole, which should be about 1/2 inch deep, drive a piece of drill rod. Cut the rod off, about 1/2 inch extending, and turn it down to fit the hole in the bolt head, leaving a good substantial point at the place it joins the striker. The extreme point should be reduced to just fit the .060 hole in the head, and when the striker is dropped into the bolt head it should bottom. Assemble the bolt, and with the cocking piece down in the cocking angle, the pin should be reduced to give a pin protrusion of about .050 inch or even less. Remove the striker and round off the point to a perfect hemisphere. You can now harden the striker and pin together and draw to a blue. Never have it too hard.

The extractor lip should be cut down and beveled just so as to grasp a shell; and the ejector, which, like the extractor, can be filed without annealing, needs to be cut back until it comes flush with the cartridge head. The bolt head, extractor, ejector, and striker are now completed.

The driving rod you have selected to drive the reamer should be turned to fit in the handle of your bolt. This supports the reamer. A flexible joint, somewhere near the point it is attached to the reamer, is very desirable. However, if it screws to the reamer and makes a straight assembly, it will be satisfactory without the joint. To recess the end of the barrel it has been found very convenient to have a counterbore with a pilot which fits the .22-long rifle chamber, and which cuts a recess the diameter of the Hornet head, plus about .010 to .015 inch. The counterbore should fit the driving rod, and a disc the thickness and diameter of a maximum cartridge head should be used to determine with the bolt the headspace you want. The bolt should close snugly against the disc or headspace gauge.

Having determined the proper headspace, proceed with the reaming. Always ream slowly, use plenty of lard oil, and keep the reamer clean. Do not allow the reamer pilot to disturb the surface of the lands adjacent to the bullet seat. This seat, which, of course, is made by a cutting edge just in front of the neck, should be carefully made. It is essential that the bullet shall rest concentrically with the bore and in perfect position to start forward without lateral movement. Herein lies one of the greatest secrets of Hornet accuracy. Carry the chamber forward gently, trying several cartridges until you can close the bolt. Do not make the mistake of carrying it too far forward as a result of hanging up on the head. You will often hear that a rimmed case does not require a close fit at the shoulder, yet best results have been obtained where this fit was snug and the case was not allowed to expand more than absolutely necessary. The mouth of the chamber should have the corner broken down slightly to prevent the case scraping.

You can now try your rifle after having thoroughly removed all chips. Examine the fired case. If there is a tendency to stick, the place will show up on the case and you can lap the chamber out with a stick which just fits snugly at the point you want enlarged or smoothed. It is an excellent idea to lap the entire chamber, but do not disturb the bullet seat. The bullet should just begin to engrave when the bolt is closed. If it is a little too tight you can run your reamer in slightly or you can adjust the reamer to lengthen the seat and not change the chamber. Always be sure to re-

move all the lapping material before firing the gun.

If you intend to chamber several jobs, make up a roughing reamer; an excellent idea here is to have the size of the roughing reamer just the size

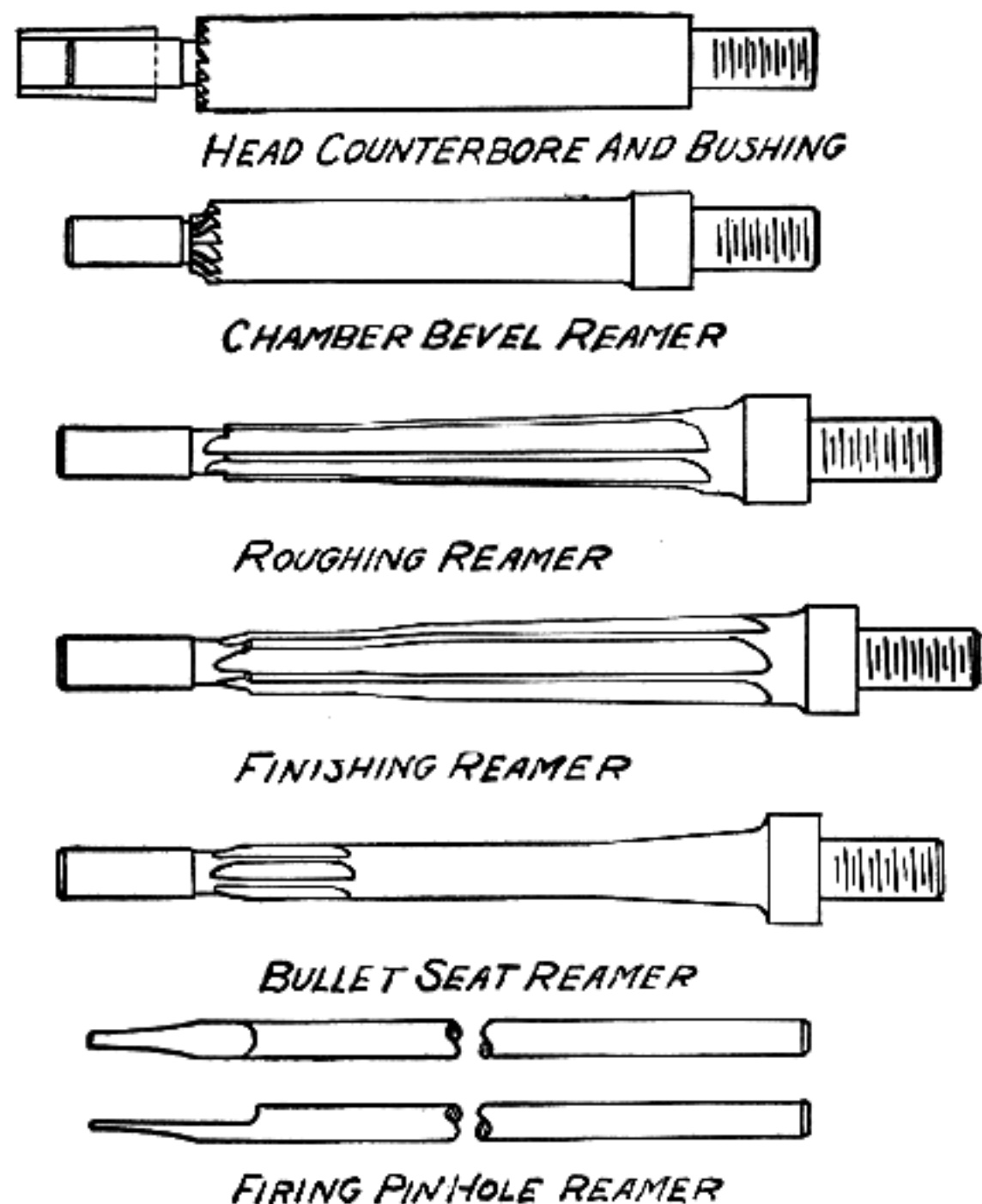


Fig. 90
Caliber .22 "Hornet" chambering reamers, etc.

required to make a resizing die. Your regular reamer will have to cut very slightly and will remain to size a long time.

Figure 90 shows the essential tools required to make a good Hornet job. Figure 91 shows the

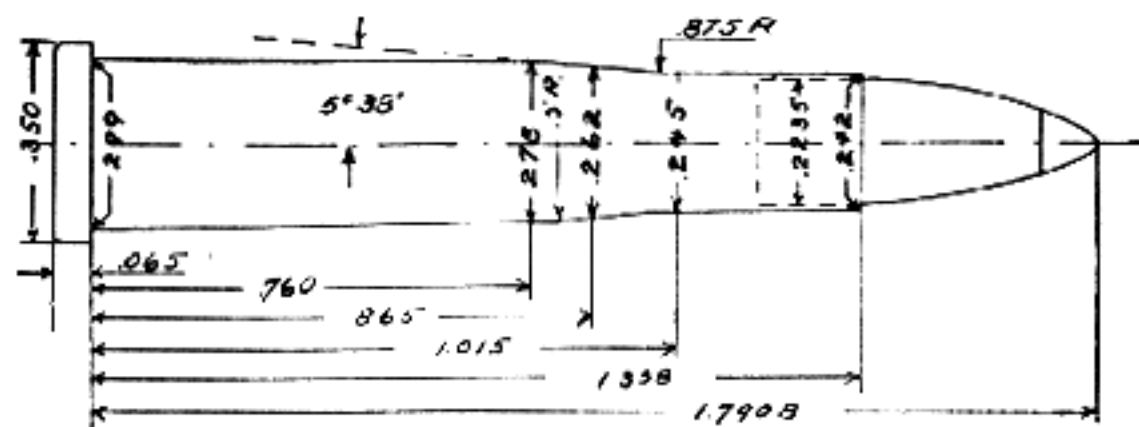


Fig. 91
Caliber .22 "Hornet" maximum case measurements

cartridge dimensions which will give excellent results.

After you have given your chambering and other alterations your best attention and have obtained by your efforts an excellent job, it will amount to nothing unless you stock properly. The stock of a Springfield rifle is so designed as to bring out the

best shooting results obtainable, but some miserable failures can result if the bedding is not right.

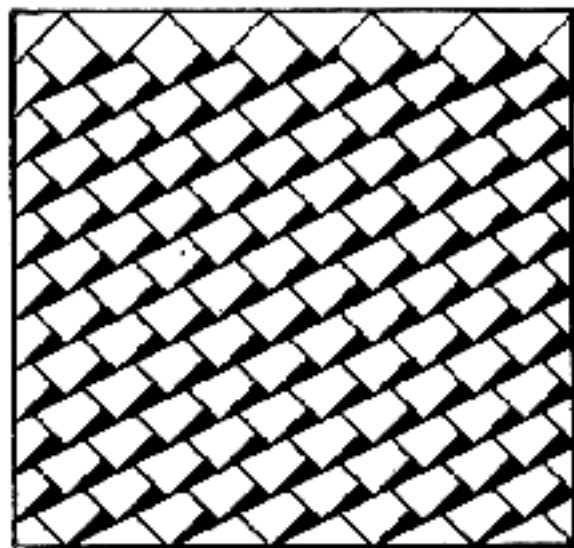
When a barrel and receiver assembly is dropped into a stock it should come to rest on three points. These points are the inside tip of the forearm, the recoil lug, and the rear tang. The bed of the receiver should not come in contact with its seat until the front guard screw is drawn down. With this screw drawn down, there will be considerable pressure between the barrel and the tip of the forearm. When the rear guard screw is drawn down this pressure will be relieved due to the rear tang sinking into the stock before contact is made with the metal bushing surrounding the screw. This pressure, however, should not be decreased to a point lower than about three to five pounds. The barrel should not touch its bed except at the tip of the forearm. Before the front guard screw is drawn down there should be about .015 clearance between the bed of the receiver and its bed in the stock. This clearance varies with stocks of various wood densities. When the front screw is drawn down there should be considerable squeezing of the wood before the front guard tang comes in contact with

the receiver. This and the squeezing the stock is given, are absolutely essential to good stocking. Obviously, it is necessary that the barrel fit straight in its bed and not hug either the right or left.

Wood seldom remains in the shape it was cut. It changes shape as it takes on or lets off moisture. Even well oiled stocks will change shape; as a matter of fact, the addition of oil relieves strains, and if these strains are present when the stock is made it will go out of shape when the oil is added—not much, but to an amount dependent on the strain present. Hence it is almost impossible to machine a stock and have it just fit a barrel and receiver. It is often necessary, therefore, to bolster up certain portions of the stock that are low and to cut down high spots. Often the part under the receiver rear tang needs a pad to give it the proper squeeze, and this holds true for the portion under the guard front tang. Sometimes the barrel needs a thin bolster. For this nothing is better than a good piece of cardboard or paper shellacked in place. Never be content with the bedding of a stock because a reputable stock maker made it. When you have it, it may not be as it was when he finished it.

CHAPTER XIV

Relining of Rifle Barrels



Relining of Rifle Barrels

THERE are a large number of fine old .22-caliber rifle barrels on single-shot actions that have been shot out and rusted because of neglect. On many of these arms the exterior and the other parts are in perfect condition. The construction of a new barrel made to the outside exact duplicate of the old barrel, particularly on the outside diameter, would cost at least four times what the barrel could be relined for.

Naturally we must draw a dividing line at the relining of some of the cheap factory-made arms such as the Winchester Model 06 and 90. New barrels can be purchased for these arms for much less than a barrel liner would cost.

When even the small shop intends to set up for such an operation it would be well to use a lathe for the drilling and reaming operation, as described in Chapter X; that chapter contains the complete details for drilling and reaming a rifle barrel, and those instructions may also be applied to the enlargement of the interior for the rifle tube to be explained in detail later. The operation of relining an old barrel is very simple when the proper materials are procured. There are as many worn pistol barrels as there are rifle barrels, and the same instructions may be applied to both.

The British gunmakers are the pioneers in this particular line of work, and it has not reached its full popularity over here as it has in England.

The prevailing impression is that only .22-caliber barrels can be relined, but since this operation has become so successful in that caliber, other calibers have been taken into consideration such as the .22 Hornet, .22 W.R.F., .25 Stevens rim-fire, .25-20 W.C.F., .32-20, .38-40, etc. It will be noticed when studying any of the ballistic tables that all the larger cartridges have comparatively low breech pressures as well as a low velocity. The only reason why a tube cannot be applied for the higher-velocity cartridge is that the liners would have to assume the proportions of a new barrel in order to withstand the higher breech pressure established. Nevertheless liners could be made for some of these high-pressure cartridges (or as they say in southern Ohio, "high-voltage cartridges"), but it would be necessary to shrink a collar on the barrel at the chamber.

All tubes are obtained from the tube mill in two outside diameters which are $\frac{3}{8}$ and $\frac{1}{2}$ inch and have a small hole which is concentric with the outside. The hole is a true diameter from end to end. The making of such tubes involves considerable expense, but the assistance of metallurgical chemists with their elaborate laboratory equipment has been a great aid in producing a consistently high quality of even mixture of the alloys throughout the entire length of each tube. The first process which a rifling tube is subjected to is the straightening operation, and then comes a complete inspection. It is placed upon a standard barrel-drilling machine and a high-speed spear drill is slowly traversed through the interior while a constant supply of lard oil is used to cut and wash the chips away from the point of the drill. Figure 84 illustrates this drill.

This operation is called the rough-boring or drilling operation and is followed by reaming. After drilling, the tubes are again inspected—and straightened if necessary. At this stage they are slipped into tubular containers which clamp the tube in several places along its entire length with a hold firm enough to prevent it from revolving, yet without marking or denting it.

A 12-inch hardened and tempered bit is electrically welded to a long piece of tool steel similar to the ones illustrated in Figure 55 for the boring of shotgun barrels. The bit is packed with a strip of soft wood which is now used in the tube, and one of the cutting edges on the bit is forced into contact with the inside of the tube. Very fine shavings or chips are removed, so fine that when mixed with lard oil they feel like graphite grease. As the pressure from the wood strips decreases, thin strips of paper are skilfully inserted between the wood and the tool until the desired size of bore is obtained and the entire length is parallel. The tubes then go to the straightening press or anvil, where great precision is required. They are bored to within 0.0005 inch of the size the tube is to have when finished.

Before being placed on the rifling machine each tube is inspected for marks left by the reamers, or any other defects; also for straightness and concentricity. The reamed tubes that fail to pass be-

cause of interior blemishes are reworked and given whatever attention is needed to save them. Those which pass the final inspection and are considered to be in the highest state of perfection are rifled on a semi-automatic machine. The rifling head is of a novel design and cuts all grooves at once. The tool is similar to that shown in Figure 69. Absolute uniformity of rifling is obtained by revolving the dividing head and holding the tube in position in a chuck. After so many strokes of the rifling cutter, each tooth on the eight, six, or four-groove cutter takes a predetermined number of strokes along every groove in the interior, and the construction of these heads makes it impossible to cut one groove deeper or wider than another.

The liners have now reached the lapping stage of the operation, and again they are inserted in a holder like that described for the boring and reaming operations. They are lapped with a short lead lap which is automatically upset into the grooves at each end of the machine's stroke and has the effect of beautifully polishing the bottom of the grooves without removing the corners of the lands. The emery paste is fed into one end; consequently this end is a trifle deeper in the grooves and is therefore stamped for the chamber end of the barrel.

As soon as sufficient time has elapsed to remove all tool marks left by the rifling cutter in the interior of the liner, the tube is removed and placed into another special holder on another type of machine having a 6-inch length of lead lap that is cast into each tube on a long straight wire. This wire is stretched between holders on the lapping machine. A carrier on which the tube holder is fixed takes the tube backward and forward along this wire with the cast lap in place. This solid lapping operation, peculiarly enough, does not abrade the grooves as much as the bore, and therefore as it leaves the machine the liner is practically parallel, altho the grooves are about 0.0002 inch deeper at the stamped end than at the other, which is used for the chamber as heretofore stated.

After final inspection these liners are ready to be inserted into barrels. A large stock of liners is always available, and naturally a selection can be made according to whether the rifle is for a common sporting arm or a high-grade target arm.

The actual operation of inserting the liner into a barrel is undertaken as follows. All movable parts are stripped from the barrel while it is held vertically by a special attachment on a vertical drilling machine. A pilot counterbore is first inserted at the chamber end in order to have the drill make a perfect start—also to avoid trouble with the other operations, including that of drilling with the spear-pointed drill as illustrated in Figure 84.

The reaming operation is now carried out on a standard barrel reaming machine which resembles a long-lathe bed with a head stock and universal carrier to take any shape or size of barrel. The head stock is adapted to hold the high-speed reamer with a continuous flow of oil as the reamer is pulled through the bore.

The drill follows the original bore of the barrel and is made to cut a hole about 0.005 inch under the diameter desired. The barrel is then reamed out in a manner similar to that adopted for the tubes to give a clean internal surface to the barrel and at the same time a perfectly straight bore; if not quite straight, it is then straightened, tho this is rarely found necessary.

Taper reamers with pilots to fit the bore interior of the barrel for the purpose of driving the brass bushings when completed will be explained later. After selecting the liner, a barrel is placed on the soldering stand. Gas jets play along the entire length of the barrel, which is clamped down with spring clamps into two grooves cut in the stand. The inside of the barrel is tinned the entire length with a turning tool, or with a stiff wire brush suitably saturated with solder known as tinner's solder and containing 50% lead and 50% tin. The liner is then tinned externally after the end has been plugged with suitable wooden plugs of hard wood turned to the correct diameter and inserted in the heated tube.

Applying No-ko-rode soldering salts as a flux will make the solder run freely. Work the tube in and out of the barrel or until it is seen that the liner has a clean and bright tinned surface. When it is properly soldered into place, allow 1½ inches to extend from each end of the barrel. At this stage of the operation a split taper brass bushing, which is tinned inside and out, is slipped over at both ends and gently tapped into the tapered counterbored hole at the ends. When the ends of the tubes are cut off flush with the barrel, they give a complete finish to the ends, and also possess the advantage of centering the liner in the event the barrel-bore diameter has been drilled oversize in the operation.

During the time the soldered barrel is cooling off, it is placed in an upright position on one end; when completely cool it is suspended by a wire and struck with a small hammer. If it does not have any "ring" it is reheated, and upon the removal of the liner it will show that it is badly soldered in places. If well soldered it is placed in a boiling soda bath to remove all traces of the No-ko-rode soldering salts, which have bad corrosive effects upon both ends of the barrel or where it may have touched on the outside of the bluing. After this last-named operation the protruding ends are cut

off the liner. The breech end is filed or machined to conform to the original contour and the barrel is refitted into its action.

Before the liner was placed in the barrel, the action may have been very close between the block and the barrel and the face of the block worn very badly. Relining will restore the tightness between the new tube and breech block because the liner can be left standing out a slight amount, which is necessary to prevent bulged rims with the rim-fire cartridges or blown-out primers with center-fire cases. The liner is now ready for the finishing operation.

Final Finishing of Lined Barrels — These instructions should be followed very carefully if the finest results are to be obtained with any high-class rifled and lapped tube. Superior craftsmanship on the interior of a liner will show to advantage. The most correct process of finishing is necessary to obtain the finest accuracy. By fine accuracy is meant the consistent grouping into the $1\frac{1}{4}$ -inch circle at 100 yards.

We shall assume that the liner has been firmly soft-soldered into the barrel and that it has a ring like a bell when struck with the hammer. The tube should then be made flush at the breech and a perfect fit made between the barrel and breech block. The extractor is then let in perfectly and should be held between the breech block without any lost motion. The chamber is now reamed out; this operation is extremely important, as I have pointed out in Chapter XII. After years of many trials we have adopted the chamber size that not only suits nearly every long rifle cartridge successfully but prevents gases from getting back along the case while giving perfect extraction. Figure 58 illustrates these chambers, and when the reamers are made to form them, no rings or blemishes should be seen. Gauges should be at hand to work to if many barrels are to be chambered in the course of time.

In spite of cutting the throat or head with the most accurate throating reamer, it can easily be seen that the rifling has slight flashes or turnovers, commonly called burrs, caused by the reamer cutting the lead into the rifling. These cannot be removed or corrected by a lapping operation because the lap only touches this place by accident; and to remove these burrs thoroughly with a lap would enlarge the throat beyond the limits of good chambering practise. We therefore first attack such burrs with a stiff bronze-bristle brush. After a few pulls back and forth, the most obstinate (which at the worst are only 0.0015 inch thick) disappear.

The greatest attention should be directed to the throating of a .22-caliber chamber; this should

never be too deep, but in all processes of this operation the length of the chamber and lead should be perfectly regulated, so that when the breech block or bolt is closed, the bullet is slightly pressing into the lands.

A bullet should now be pushed through the barrel from the breech, and after forcing it into the rifling it should run perfectly smooth the entire length of barrel as far as the muzzle. This part calls for the closest attention, and if there is the least doubt about the chamber, first cut the tube off within one inch of the muzzle of the barrel so that in case of accident it can be pushed back to form another chamber.

Take a 50-degree angle countersink fitted with a 0.2173 pilot, and after being assured that the pilot fits correctly in the bore and will turn free, slightly countersink the end, again using the bronze-bristle brush to clear any burrs thrown up by the angle cutter. The barrel at the end should appear dead sharp as you look into the bore at the muzzle.

Assuming that the bullet is still in the tube, push it right through the end and make sure that no check can be felt as it emerges. In any condition it cannot be expected to slide through as well as it should; therefore a lap about 3 inches long at least should be cast and No. 320-M optical emery mixed with olive oil used; the high spots must be lapped inside at the point discovered and lapped out. Provided this is done carefully without enlarging the bore above 0.2180 inch or without deepening the grooves above 0.2235 inch, the rifle should group perfectly.

It should be noted that when the bore is bell-mouthed at the muzzle to the extent of 0.001 inch over the size that prevails through the entire length of the barrel, the rifle will never group consistently but will throw one or two wild shots in every group of ten. You will often find that a liner placed in a barrel will equal the finest matched barrels produced anywhere in the world. The information given here will be valuable to the small-bore rifleman; these suggestions, if applied, will solve many difficulties. It is still hardly realized that after a .22-caliber rifle has been made to group accurately, it is almost a crime to clean or in any way touch the muzzle end with a cleaning rod or pull-through. All cleaning should be done from the breech end whenever possible.

The possibilities of relining rifle barrels include not only the single-shot action but bolt-action rifles as well. There are many obsolete arms in the hands of riflemen throughout the United States, such as the Krag, Enfield, Russian Nagent, etc. Take the Krag for instance; there are many of these actions in the hands of riflemen, and their barrels

can be relined to take such popular cartridges as the .22 W.C.F. or Hornet, .25-20 W.C.F., .22 Savage high-power, .22 Baby Niedner, .25-caliber Roberts, .25-35 Winchester, 6.5 mm. rimmed head, etc. Various changes can be made in this action, such as removing the magazine and setting a plate over the opening where the cover has been removed, cutting out the center of the bolt channel and setting in one of the Savage or Winchester magazines, which would make the rifle a five-shot magazine rifle.

Many owners of Krag rifles object to the projecting magazine on the right side as it often interferes with carrying the rifle in the field, but by using the popular cartridges recommended, together with the changes, a very fine arm can be built up. Other rifles, such as the Winchester Model 95, Russian, Steyr, Lebel, etc., have the disadvantage of a projecting magazine, but often these disadvantages are compensated for by certain other good features as on the Krag. This last is the only magazine that cartridges can be dropped into, and if any one has gone through the experience of trying, with frozen hands, to place ammunition down into a magazine like that of a Model-95 Winchester, his prejudice against the box magazine of the Krag will soon vanish. If you find the magazine an objection, however, by all means remove it, as Figure 92 illustrates. I do not approve of this idea when using standard ammunition for the rifle, but for any other cartridge, when it is possible to install a new magazine and use any of the cartridges named, the removal of the magazine should take place and a neatly blued plate be fitted over the opening. When relining a barrel for the cartridges named, it becomes necessary to alter the extractor in some instances, particularly on such a small cartridge as the Hornet. The old extractor

can easily be used, and the only work necessary is to build up on the end with a welding operation to increase the length, and alter it for the new cartridge used; then reharden and temper it to the color which will give the end the required strength for extraction.

The relining of a Krag barrel for the Hornet cartridge is very reasonable. The selection of any other method suggested, even tho only used for a single-shot arm, will not be advantageous until the time comes when a magazine feed can be provided. The Springfield M/1903 and the Enfield M/1907 could also be altered for any of the cartridges named; but to reduce expenses, the Krag offers the greatest possibilities even tho it will be found necessary to use it as a single-shot arm.

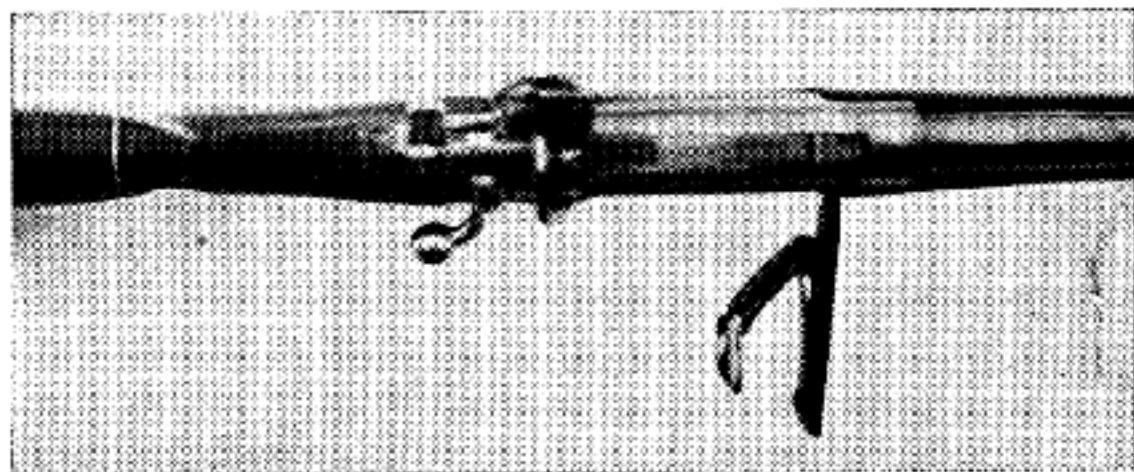


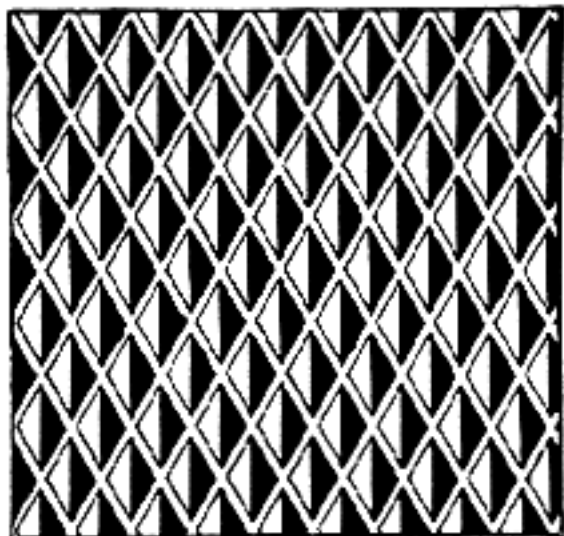
Fig. 92A
Magazine removed from a Krag rifle. Hinged cover in the opened position



Fig. 92B
Closed position, showing the flush outlines along the action

CHAPTER XV

Striking Barrels and Polishing Gun Parts



Striking Barrels and Polishing Gun Parts

AS HAND polishing performed by direct labor on gun parts is a long and tedious operation, we must devise means to accomplish these same results by power, using suitable polishing and buffing wheels in such a manner that very little finishing will be required by hand.

The terms "polishing" and "buffing" are often used interchangeably, altho the special process of obtaining a very fine surface having a "grainless finish" is commonly known as buffing. Soft wheels are used to obtain this buffed or grainless surface. They are sometimes made of felt to which a very fine polishing material is applied, but usually they are formed of layers of cotton cloth and are known as muslin wheels. These cloth layers, the edges of which form the periphery of the wheel, are bound together and held on the machine or grinder spindle by a collar and nut. Some cloth or muslin wheels are sewn in a spiral, from the center to the outer edge; they are used to secure the required polish and buffed surface of the part. The sewn wheels are known as the "hard wheels," whereas the unsewn are the ones producing the high buffed finish. These cloth wheels have soft, yielding surfaces into which the work can be pressed so that every curve and corner of an irregularly shaped part may be polished. There are also wheels made of sheepskin, chamois, canton flannel, and paper.

The above methods are used when power is available to eliminate most of the hard labor connected with hand work. Having in mind the amateur's problems, I shall apply the hand operations as well, so that a clear understanding can be had of both methods. In the course of your work, power will eventually be used, even tho you attach a polishing or buffing wheel to a cheap motor; then this information will be of value to you.

The gunmaker usually makes most of his polishing wheels; something has been said of this process in Chapters I and II, Volume I. There are so many varieties and shapes that it would be difficult to name them all, but the principal kinds are of canvas, walrus, felt, rubber, leather, wood, and linen. The wheels mostly used by the trade are made from walrus and turned out to different forms and sizes to suit all conditions. They have emery or other

abrasives glued to the surface and are employed extensively for finishing and polishing flat and rounded surfaces. The flat wheels are used when good edges must be maintained. There are wheels made of discs of sheepskin, either loose or held together. The loose wheels are used to polish uneven surfaces, and are usually mounted on small polishing spindles. The canvas wheels are made from canvas belting, and the emery paste or other abrasive is applied from the stick. Rubber wheels can be made from 1, 2, 4, 6, or 8 inch diameter round rubber, such as is used for pressure pads on punch presses. These have about the proper elastic properties, when covered with fine abrasives, to produce a very even and true finish. When the final buffing takes place, the part has a high luster. When the wooden wheels are used, they are usually turned very small, felt-glued, and used more to polish small springs having radii which would be difficult to get to in any other manner. These are coated with glue and a very fine abrasive is used.

When remodeling a rifle, as well as making a new one, the exterior metal parts must be finished to a high, bright polish prior to being blued or treated with any other form of finish desired. The final appearance of the arm depends mainly upon the high polish secured. This degree of polish is accomplished by a number of operations, such as striking, emery cloth preparation, rough polishing, medium and final buffing.

Striking — This term is often used in connection with shotgun barrel work and the finishing of rifle barrels. The term is the result of hand-filing a barrel (whether rifle or shotgun) lengthwise, holding the file while performing the operation in a horizontal position or at right angles. In the larger shops, barrel striking is in a separate division of the plant, and particular men perform this one operation. To prepare a rough-turned barrel, a series of striking files, made specially by the file makers for this class of work, are used. You can make your own striking files from new "vixen" files by forging the ends so that suitable handles may be used. These files are made up in various lengths, widths and forms to work out the rough metal and solder when ribs are sweated between the barrels

on shotguns. A considerable amount of practise is required before such files can be used successfully. They are drawn lengthwise of the barrel when the finishing takes place.

A mill file between 10 and 12 inches long is held at right angles to smooth out the high spots left by the striking files. When using the striking files, make a barrel holder from a piece of brass, one for each of the different types of barrels you may have to do, such as the Springfield, Mauser, Enfield, or Winchester M/54. Figure 93 shows one together with a holder for shotgun barrels. The amateur

the final high finishes required before the bluing of the parts can be done. If this is the case, you must do all this work by hand with a draw-file and emery cloth of different grades, adding the final high polish with French paper and crocus cloth. Such hand work requires time and patience to produce the same results that can be obtained by mechanical means. On the other hand, the beginner with a lathe can turn down the barrel on these same arms to any required weight and contour; the tool marks left by the lathe tool should be rough-filed or stricken out with a tool, as Figure 93 shows, and

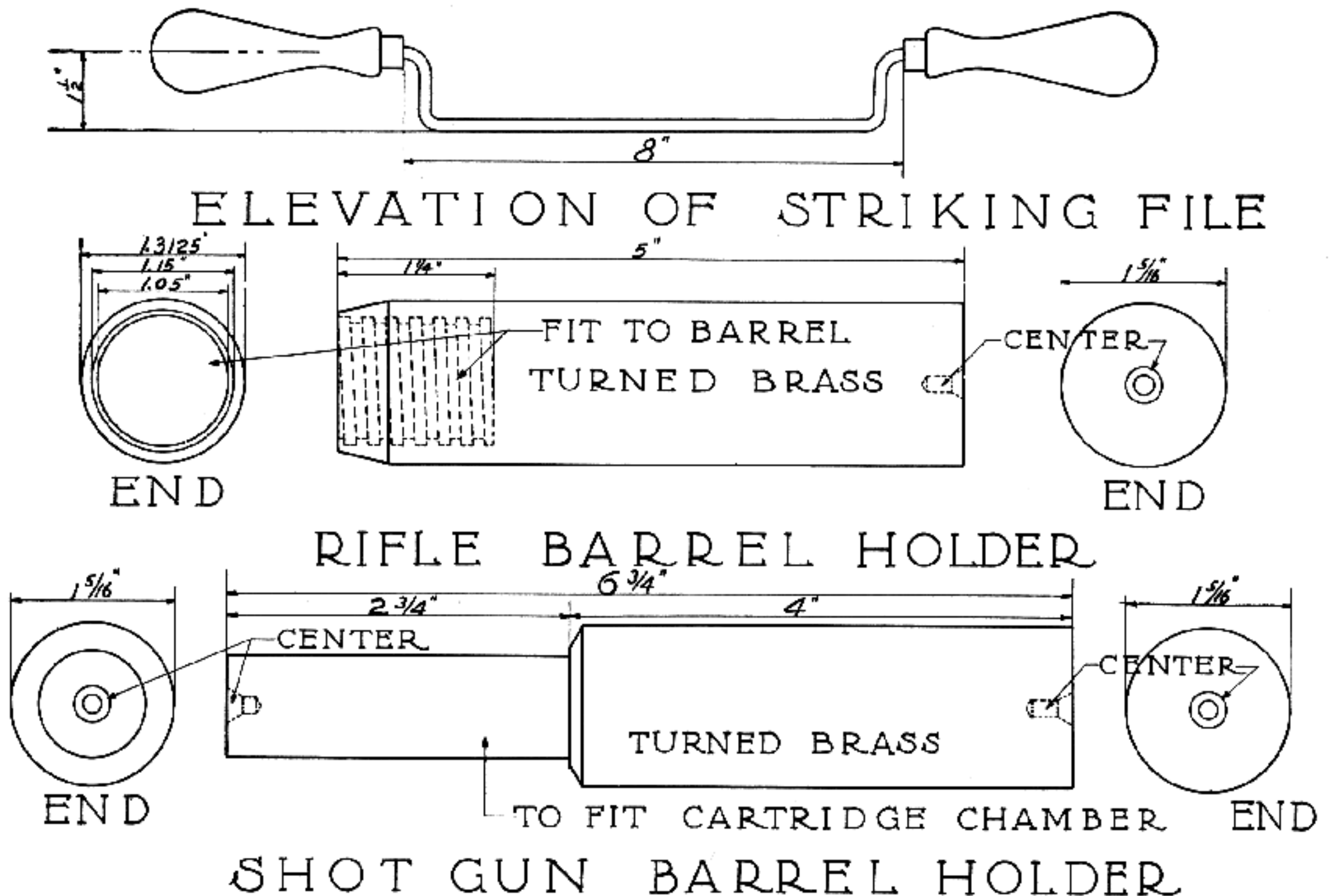


Fig. 93

Rifle and shotgun barrel holder. This is clamped in bench vise while striking or polishing takes place

may only have one or two barrels to polish; therefore, such holders as these will not be necessary, nor will the striking files be an essential addition to your tools, for they are of material benefit only when you are turning out a number of barrels in the course of a year. It would then pay you either to purchase a set of these files or make them yourself, if you have a milling machine to cut the teeth in the files similar to the vixen type previously described.

In this chapter I shall mainly keep in mind the student who is just starting to remodel a rifle, say a Springfield, Krag, or Enfield, without any equipment such as a lathe or polishing wheels to give

the barrels finished with emery cloth placed in a wooden holder, as Figure 94 illustrates. Of course, it is also necessary for the man without power equipment to make one of these, provided he will have other barrels to polish in the future; still this can be dispensed with and the emery and crocus cloth can be held on the file and used in the same manner, as tho you were draw-filing the parts in a lengthwise direction.

Assuming that you have turned down a barrel and wish to carry out the striking operations upon this part, you will have gained the experience that will enable you to judge the requirements of the necessary tools involved before using the 12-inch

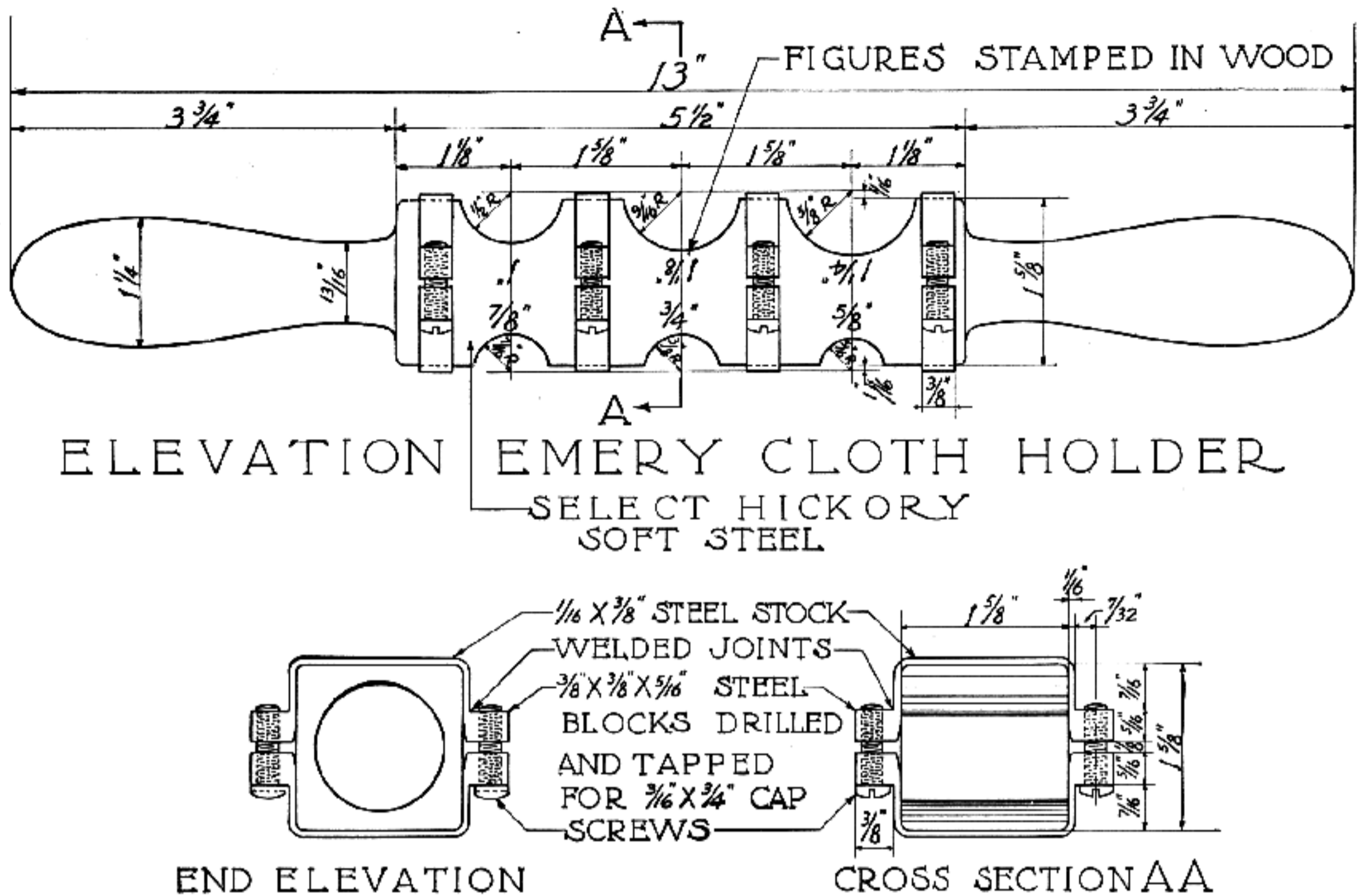


Fig. 94
Wooden holder for emery cloth when draw-polishing gun barrels

file to perform the final draw-filing. Purchase the vixen files (this type of file is used on aluminum and soft metals) in the narrow widths. Offset the tang and forge the end, and also offset this so that you can get a file handle on both ends. On the end you have forged, file and sharpen the teeth again before hardening the file. When all this is done, harden and draw both tangs to a blue up to the teeth on both ends, and insert file handles. You have a perfectly flat surface on the file thus made, but by ordering these from the file manufacturer you would specify a slight concave surface. With a file with a flat, you are obliged to use care not to produce flats on the work.

With the barrel fastened in the vise between lead jaws in the brass holder and the muzzle resting on a gun brace, you are ready to perform the so-called striking operation on a gun barrel. Stand at right angles to the barrel with the file resting lengthwise to the muzzle, and with even straight strokes begin to remove the rough tool marks made by the lathe tool. Do not continue in the same spot on the strokes, but always shift the striking file toward you or away, until it is necessary to turn the barrel a slight amount in the vise so that the rough surface is again in a convenient place to work. When a striking file is cutting perfectly, the chips which

come off the metal should be in a curled form and as fine as steel wool, or straight and in the form of short wires, tho fine. With such results you know the file is at its height of efficiency. If the chips are only coming off in the form of dust, however, the teeth must be stoned or the barrel will have a wavy appearance when polished. Not only can you see these waves as you look along the barrel, but their feel will remind you of a wash-board.

When you come to the radius of the barrel near the chamber end, you will find that the straight striking file is useless: therefore, it will be necessary to make a file with a marked convex surface to enable you to finish the radius at that point. This is made in the same manner as the straight file with the offset tangs, except that it must be bent in the form of a bow to pass over this radius and at the same time remove the metal as you did on the straight cylindrical part of the barrel. These two striking files will last for years if the proper care is given them. When you have found the performance of such files greater than your expectations, you will continue to make them in a variety of shapes and forms, until you have a striking file for every kind of barrel you may wish to make or refinish.

It is better to make short striking files rather

than the longer ones, for better work can be accomplished with them. When the brass barrel holders are made for the vise, you then have the entire barrel length available to work on. As you become accustomed to the use of such files, you will be able to use a long one and even stroke the full length of barrel, maintaining a constant and even pressure to remove the chips in fine curled wires. It is not necessary to use as much bearing pressure as you would on a regular file. A little practise will determine the required effort and effect. Excessive pressure only makes flat spots, sometimes $\frac{1}{16}$ inch or more wide, and these are difficult to remove in the draw-filing operation. When you have had the required practise in this work, you will apply the proper pressure; the cuts will have scarcely any width and the barrel will have its true cylindrical surface.

When all the high spots have been removed, you have completely "struck" a turned barrel. If you do not have a lathe to turn a satisfactory taper and the necessary radius on the Springfield barrel, where the rear sight base has been removed, you must "strike" this barrel until the contour and taper is pleasing in appearance its entire length. With the striking files, remove a considerable amount of metal at the rear end of the barrel where the base was removed, using as much pressure on the striking files as required; this may be easily accomplished after the necessary practise is obtained. The old name for these vixen files was Dutch planers, and you will find that they were well named after you become accustomed to their use and see the amount of metal they remove on work of this nature. The same methods apply to any barrel, regardless of whether it is a rifle or shotgun barrel, for removing dents and deep scratches which require complete refinishing before bluing. This is especially necessary on military arms when the barrels have been covered with wood, for it was not originally necessary to finish such barrels underneath the hand guards; therefore, it is essential to strike or draw-file them now to make a fine-appearing sporting arm.

On all Springfield military barrels it is necessary to fill in the spline cut on the upper right-hand side, which is half a radius left when the sight base is removed. This is a pin which is placed half-way in the barrel and sight base for an anchor, so that the base cannot turn on the barrel. The cross-pin slot can be left in; this does not show, as it is directly on the bottom of the barrel. Drill the top spline cut with a series of four holes, using a No. 29 drill. Only drill deep enough so that it will be possible to catch three or four threads, tap these out with an 8 x 36 tap; then apply a screw of the same

tap size, cut it off about $\frac{1}{16}$ inch above the barrel, and so on until the four screws are in place. Thenpeen these over flush with the barrel, and after it is filed and polished it will not be apparent that it was filled in.

Draw-filing — The file needed for this operation is either a wide 10- or 12-inch mill file. These are made by such firms as Disston or Nickelson in this country, and by the British or Swiss abroad. A wide file is the most essential kind, as it follows a straight, well-directed movement of the arms upon the cylindrical surface of the barrel; therefore it removes the light spots left by the striking files. It is well to keep the file chalked on both sides, and as often as you knock the file free of chips, again go over the surface with chalk. Applying chalk to the surface of a file prevents the steel from clogging in the teeth; when bunched-up metal is deposited in the cuts, it causes deep scratches on the surface which are difficult to remove and are not discovered until the final finishing takes place with the emery cloth.

A file card should always be handy for removing metal deposits in the teeth. A file card is made by inserting short stiff wire into leather, and tacking it to thin pieces of hard wood with a handle formed on one end for convenience. A similar card is used in textile mills to pick wool apart, except that those used in machine shops have short stiff wires projecting through the leather, whereas the mill cards have longer wires.

The barrel is either clamped between felt jaws in the vise or held in the brass barrel holder with the vise swung at the most convenient angle—about 45 degrees—so that the barrel will be in front of you. The striking files were used in the manner of a wood plane, but now the file is held in both hands in a horizontal position or at right angles. Each stroke is taken the full length of the barrel, maintaining a very slight pressure on the file. It is not necessary to bear down much, for a new file which has only been used for draw-filing will remove enough metal almost by its own weight to complete the most satisfactory job. A little practise will teach you the right pressure. Excessive pressure, just as in the striking operation, will result in flat spaces, which must be avoided. Each stroke of a file will remove a certain amount of metal, and when applied in the proper manner will reduce a surface in a surprizingly short time without any exertion. You will notice many men who habitually use a file with a disgusted countenance, making the operation anything but a pleasure. When you learn the art of draw-filing, particularly on a rifle barrel, you can scarcely notice any flat surfaces,

and what there are may be easily removed with the emery cloth or in the polishing or buffing operation.

Draw-finishing With Emery Cloth — This work is very similar to draw-filing, except that you will use emery or carborundum cloth in the medium and fine grades, which will be in grit sizes: No. 1/2, 1/0, 2/0, and 3/0 beginning with No. 1/0, and finishing with No. 3/0. Figure 94 illustrates an emery-cloth holder which can be made up and will make the operation a pleasure. This is made with four semicircular notches and a clamp to hold the emery cloth in position on any of the four sides. With the wing nuts for easy removal of the clamps, the emery cloth may be changed to any circle; or by making two sets of clamps, emery cloth can be inserted in all four circles.

If you so desire you may at first take a piece of No. 1/0 emery cloth, 1 inch wide by 12 inches long, and cross-polish the barrel. Such a performance with the emery cloth will show the small "flats" left by the file. As you grasp the two ends, work it rapidly up and down from one end of the barrel to the other. Turn the barrel one-quarter turn in the vise and repeat the operation until it is cross-polished completely. Then use the hand polisher lengthwise of the barrel as you did the draw-file. Different grades of fine emery cloth are used in this hand polishing up to crocus cloth. Draw-polish with emery and crocus to a degree which will completely eliminate all scratches. Now, insert a piece of thin felt, similar to that used with the rottenstone rubber in Chapter XII, Volume I. The felt is clamped in the largest semicircle in the holder, and then optical emery and powdered rouge are mixed in equal proportions—or any other polishing compound of a similar nature—with sweet oil added until a heavy paste is formed. The paste is then applied to the felt, and a complete draw-polishing is again done until a high and bright luster is produced.

In use of the draw-polisher on tapered barrels, the largest circles must be used to clamp either the emery cloth or felt. After having once begun to polish, do not lift the polisher from the work, but continue with even strokes the full length of the barrel—particularly when using the felt pad with polishing paste.

To use the draw-polisher which Figure 94 illustrates, grasp the handles in both hands and use it as you did the draw-file, but always continue the strokes the full length. Never lift it off the work, for if you do there will be small scratches left; this does not matter with the roughing operation, but on the complete finishing, every care must be used. Try to finish the part with a high luster.

After a piece of steel is polished with a polishing paste to which oil has been added, a greater amount of cleansing is necessary because the oil penetrates into the pores of the steel. This has been thoroughly explained in Chapter XVI, and the student is now again urged to use special precaution on this point.

Emery cloth which has been worn should always be saved, particularly the finer grades, for these pieces contain enough abrasive to give steel parts a very good polish. Such emery cloth can be used with the draw-polisher when oil is applied to the cloth. Do not apply the oil until it runs off the steel, but use just enough so that the parts will have a very good film all over. Continue to draw-polish with worn emery cloth until you have a high luster; this can easily be detected by wiping a small spot on the steel surface and observing the appearance of the metal. When the steel is polished to your satisfaction, use the worn pieces of crocus cloth in the same manner and you will have a finish equal to that of any buffing operation. Of course, such operations require time and patience, but the beginner can accomplish all of these operations without power equipment, not only on barrels, but on actions, receivers, guards, floor plates, trigger guards, revolvers, pistols, and all small parts on either rifles or shotguns; on these, similar methods, as outlined in regard to barrels, should be applied. Revolvers, automatic pistols, and rifle receivers require various methods to get into the odd cuts, radii and corners, and also into the interior of actions or any places where it is impossible to use ordinary means.

Power Polishing — There are many varieties of polishing wheels. The type used depends upon the class of work. A wheel which I commonly use for flat work is the rubber wheel previously described. Different grades of emery are glued to the surfaces—Nos. 90, 100, 120—the grade depending upon the finish desired. These wheels are excellent for producing results on all classes of flat work, and because of their flexible nature I have found them superior to the walrus wheels. If one of the large rubber companies would develop polishing wheels of this type—not only the flat cylindrical wheels in different diameters, but smaller wheels with various semicircles or radii—they would have a large sale when their advantage over the walrus and leather wheels became known. By moulding these in a die, a fine corrugated surface would be possible in the rubber to hold the emery and glue in place. These wheels are used mostly for roughing special shapes, and when the finer abrasives are used very good finishes are produced. The solid canvas



Fig. 95

Polishing surface of barrel to remove tool marks, as done in the large arms plants. The polishing wheels revolve at a moderate speed. This operation is known as "spinning"

wheels such as those made from canvas belts also give good results when fine emery is glued to the surface.

Polishing operations are usually known as "roughing," "dry-finishing," "finishing," or "oiling." The abrasive numbers used for most gun parts and for roughing ordinarily range from 80 to 100; for dry-finishing, from 90 to 120; and for finishing from 120 to 150 and also 150 to XF. For roughing and dry-finishing the polishing wheels are used dry. For finishing, oil, beeswax, and tallow are used on the wheel to produce the finish. Dry emery is seldom used by the gunmaker, as all abrasives are glued to the surface of the wheels; but in finishing, when a paste is used made from beeswax or tallow, it is first applied and then the wheel is put into operation.

Walrus wheels are used when a high polish is desired; however, they are expensive and it is much better to buy a piece of hide and make your own wheels. These are the only wheels that can be used on gun work requiring special forms. Felt wheels

are made from Spanish and Mexican felt and are also used extensively for finishing.

Grain Numbers of Emery — The numbers commonly used in designating the different grains of emery, carborundum and other abrasives are: 10, 12, 14, 16, 18, 20, 24, 30, 36, 40, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, and 200, ranging from coarse to fine. The numbers represent the number of meshes per linear inch in the grading sieve. An abrasive finer than 200 is known as "flour" and the degree of fineness is designated by the letters EF, F, FF, FFF, FFFF, and PCF, or SF, ranging from coarse to fine. From the foregoing classifications the student will be able to form a general idea of what he will require for any of the polishing operations mentioned in this chapter.

Buffing and Polishing Compositions — These compositions are in the form of a stick or cake of compressed tallow or other heavy grease containing some polishing material, such as tripoli, crocus, rouge, flour emery, Turkish emery, Vienna lime, etc. When Turkish emery is used, and rapid, sharp and even cutting is required, the grit numbers used are 120, 140, 150, 180, and 200.

When gluing emery to the polishing wheels, heat the glue, thin it to the consistency of a light oil, and apply it to the surface of the wheel. After clamping a round piece of steel in the vise, the wheel can be placed upon this, and the emery sprinkled upon it; a large-sized pan should be underneath to catch the surplus emery. When the surface is completely covered, remove the wheel and roll it on a clean smooth board so that the emery will be well rolled into the glue upon the surface. A very effective method is to take three sewn-muslin wheels and remove the two outer circles of stitches. Then coat the outer surface and the spaces between the layers of cloth with coarser emery and apply the glue, sprinkling the emery in the same manner as described but working it well into the layers of cloth where the glue has run. Such wheels are used on actions and receivers where odd forms are hard to get into with other wheels in the roughing operation.

When making walrus wheels, it is better to make a number of different sizes and shapes. These should be made in different diameters and sizes for use on a small electric motor. One of these motors may be purchased for about \$8 with the tapered spindles for attaching the wheels. The taper is threaded up to the shoulder, and when the polishing wheels are attached to the spindles they always run true. A dental polishing motor can be converted into a buffing and polishing motor for small

parts. One side of the electric grinder can take different-sized wheels, and it is surprising to see the number of different wheels you will use on such a motor to solve all the polishing and buffing problems, from using the wooden disc with sandpaper on the face for sanding, to the sheepskin wheels for fine buffing.

The muslin wheels are used more than any other. Those of an 8-inch diameter are best for all gun parts, from roughing operations with emery and glue applied to the surface, to the fine buffing with rouge worked in from the stick, or when powdered rouge and oil are mixed as a paste. The cloth wheels are the only ones that can be purchased at a reasonable price. They are used so extensively because of their soft yielding surface, into which the work can be pressed so that the curves and corners of actions or any other irregular-shaped parts can be buffed or polished. In the use of these wheels as buffs, with rouge or tripoli, a very highly polished surface is the result. There are many varieties of wheels on the market, but it will be best for the beginner to use the wheels and methods I have outlined rather than to experiment upon wheels which may never prove satisfactory for his needs.

If you should purchase one of the small utility polishing motors, turn up a number of tapered hard wooden plugs, as for polishing small radii and curves where it is impossible to polish in any other way. One end is bored out on a taper to fit the tapered spindle and the other end is turned to a pointed taper to take the abrasive material. The tapered end is covered with fine felt which is glued on; rouge or fine optical emery paste is used to buff and polish in small corners, such as on springs, sears, triggers, etc. Larger wooden spindles are made and covered with felt to polish and buff the inside of trigger guards. You will find in time that you have a great variety of these on hand for all small parts.

When emery alone is glued to the taper, score the surface of the wood with the scoring tool, lengthwise, so that the glue and emery will have a corrugated surface to adhere to.

Problems of Polishing—When you first begin to use buffing wheels you will find that you have done a number of wrong things such as trying to polish out deep scratches by buffing, when you should have used a polishing operation with fine emery glued to the proper form of wheel and then completed the final buffing with rouge or tripoli worked into the correct wheels. You will find that each particular job presents its own problem but after you become accustomed to each one you can

always apply the same rules as to other parts similar in nature.

When refinishing a rifle, first remove everything from the arm—even the barrel from the receiver if you have the proper means. Begin with the barrel, as this is the largest metal part, and if it is a military arm, leave the front-sight base attached and polish this together with the barrel. Of course, if you have a barrel band it will be necessary to remove this and polish it separately. When setting it back in place, make special pins with rounded heads instead of the flush pins; for after these are removed it is difficult to place them back in position, especially on the Springfield M/1903. When leaf-sight bases or ramps are soldered to a barrel the surplus solder may be removed with a circular wire wheel on the motor. It will only be necessary to buy a small one for this operation. If you do not have electrical connections or a motor, coarse emery cloth will answer the purpose.

A fine circular wire wheel is also a valuable addition to the polishing and buffing department. You not only use such a wheel for the removal of rust for the bluing operations, but it can be used for a number of operations; the polishing of nickel-plated revolvers, the complete removal of rust from metal parts, and a number of operations such as on receivers before polishing takes place to remove the old bluing, etc.

Barrels and parts should be completely polished before any additions are soldered on, such as ramps, sling-swivel bases, sight bases, etc. After soldering, remove the solder left on the barrel or parts, as previously described, and then complete the buffing operation. Be sure to see that no solder remains on the parts. This will be easily detected by the colors of the two different metals: One will be dull and the other bright. This may go unnoticed at times, but if you are a very keen observer you will correct such faults before the bluing is attempted. To remove solder along the edges of ramps, sight bases, etc., make a three-cornered scraper from an old three-square file, by grinding down the point; or you can also make a flat scraper from an old hack-saw blade or a flat file ground in the form of a scraper.

Receivers of rifles are naturally the most difficult parts to polish because of the various curves. Muslin wheels with fine emery glued to the layers of cloth generally solve those problems and the same kind of wheels can be used for the buffing operations as described. When hand work is necessary on such parts, emery cloth is the only solution and is used in different ways, such as folding the cloth around different shapes of files to get into the corners. Pieces of hard wood in various forms,

with the emery cloth glued on, and sticks with thin felt cemented on and rouge paste, will also serve.

Guards must be polished inside the curve with fine emery cloth placed on a half-round or round file of wood shaped to fit the curves, with the felt and paste. Flat surfaces are the most convenient to polish, for flat files and emery cloth can be used altogether in a lengthwise direction. Automatic pistols and revolvers are among the most difficult to polish by hand, for you run into the same difficulties as on receivers; but when care and patience are exercised on the easy parts or flat sections, you will find that in the course of time satisfactory results are produced. The greatest difficulty is to hold revolver parts securely, especially the small parts of thin plates, etc. Therefore, you must not only provide suitable clamping fixtures for the vise, but make special ones from wood as well.

The most essential thing to remember when polishing any of these arms is always to polish in the direction of the profile cuts. When refinishing an arm, polish the inside working parts as well. Bring them to a high luster, but be very careful not to round the edges of any of the mechanism. The inside working parts are rarely finished as we see them on Smith & Wesson revolvers; a favorable impression is received when a revolver or any arm is opened and all the working parts have a bright and polished surface. I believe that in time the public will demand all this much-needed improvement. When polishing any parts such as these, work in one direction, for cross-polishing only tends to dull the surface. This rule naturally applies to all polishing operations.

Polishing Bolts — When polishing these with power and the circular buffing or polishing wheels, the problem is very simple; but by hand it is rather a difficult one, especially on the Springfield or Enfield, which have been Parkerized, causing a rough finish. Remove the extractor and extractor collar and polish them separately. Clamp the bolt in the most convenient way in the vise, using either felt or lead jaws. Coarse emery cloth may be used, such as No. 0 or $\frac{1}{2}$, until the old finish is completely removed. At first you must do some cross-polishing around the bolt handle and knob with abrasive cloth cut in strips of $\frac{1}{2}$ inch or wider, then completely cross-polish with fine emery cloth and oil. When finishing these parts it is much better to use the worn cloth and oil, as it gives a far better finish than the new emery cloth and oil. To polish in the corners fold the cloth around a file or a wooden stick. When the roughing operation is completed, the bolt proper must be draw-polished lengthwise with oiled emery cloth, which will bring

out a highly polished surface. When all this is completed, finish to a high luster with strips of felt soaked in rouge paste or optical emery and rouge mixed into a paste. A much higher luster may be obtained by using a dry piece of felt and rouge powder; this is the so-called dry-finish. When finishing a bolt with the polishing and buffing wheels, it is only a matter of obtaining a very fine surface with the muslin wheels, using emery paste, and for the roughing-down operation rouge or tripoli.

Be very careful not to polish down or remove any metal, particularly around the lugs where the extractor works in, or you will be unable to eject the shells. Another place requiring care is at the rear of the bolt lugs. It is much better to avoid using any abrasive here whatever, for you might remove too much metal, causing an excess amount of head space or rounding the lugs so that only the center has a bearing. This will cause the bolt to set back into the metal and cause excess head space and difficulty in opening the bolt upon extraction.

Polishing Shotgun Barrels and Parts — The student will run into greater difficulties in the refinishing of shotgun barrels, for on some of the old barrels Damascus and laminated steel has been used. When such barrels are draw-filed, polished, and buffed to a high luster, they must be "eaten up" again—a process described in Chapter XVI. The plain steel barrels such as the Whitworth, Krupp, or standard fluid steel, are finished the same as the regular rifle barrels, except that here is a greater amount of work to perform, due to the upper and lower ribs of double barrels and ventilated ribs on single trap guns.

When working on double guns make special wooden sticks to polish in the sharp corners of the ribs. Be careful not to reduce any of the matted surface on the top rib. Shotgun barrels may be given much better treatment by hand than with power buffing or polishing, when a matted rib is on such a gun; but if it is just a plain rib, the power can be used to advantage, provided you are able to keep sharp edges on the ribs and lugs. The amateur will show better judgment if he will finish the barrels by hand rather than to trust to power finishing.

Shotgun actions are usually engraved and case-hardened, except the cheaper ones; these do not have any engraving, but are generally hardened by the case-hardening method for colors. It will be much better to leave these alone except when you anneal them to rework the action and fore-end arm completely; this will be taken up further on. Nearly all the finishing is done by hand, for a power

polisher or buffing operation would remove the sharp corners.

There is a considerable amount of refinishing to do on any shotgun if it is not of the best grade. When any action is taken apart, examine all the working parts regardless of make or kind. You will find that the sears, tumblers, springs, triggers, etc., can be greatly improved upon and all these parts given a high luster such as we find on the best British guns. Examine the Westley Richards detachable locks; you will find that the finish is very like that on the inside of a watch. The same effect may be produced by the method known as damaskeening—described in Chapter XXII, Volume I.

Of course, the amateur will not be able at first to measure up to the British standard, but he can obtain finishes which will be a credit to his ability. The sears are usually a neglected part on American shotguns. The engaging points which fit into the notches should not be touched unless you wish to reduce or add to the trigger pull; if this is the case, they must be worked over with a fine oilstone. The sears must be polished with the small tapered spindle polisher if you have a small motor. If it is to be done, use fine emery cloth and small files to hold the cloth, or other means that will produce a high finish. Triggers may be polished on the tapered wooden polishers, and for the flat sides glue fine French or Turkish paper to the small wooden disc set on the small polishing motor. The tumblers may also be polished in this manner, as the fast-revolving disc with the fine emery paper attached removes but a slight amount of metal and gives a flat surface a very high luster. Flat parts may be polished with the wooden disc; it is surprising to see how complete a finish this method produces. The pressure that will give the most satisfactory and accurate results, when flat surfaces are held against a disc, depends upon how you hold the part and the nature of the work.

Small parts, such as screws, pins, special small parts, etc., should have special holders to fasten them so that a satisfactory job may be done. It is difficult to hold a flat piece against a disc polisher, and the only method which can be used to polish a screw is to make a holder as illustrated in Figure 14. Set the head into the counterbored part slightly above the surface and clamp the wing nuts; then hold the fixture against the disc very lightly, and produce a flat, polished surface on the head. By trying to hold the screw in a holder with the head projecting over the holder, you have a surface which is off on an angle. On most screws the heads are more or less marred, and this is usually because of the efforts of some one trying to remove them

with poor screw-drivers not fitting the slots; badly marred heads must be reworked and repolished by the method outlined. Rounded screw heads must be polished either in a lathe or a drill press, first filing them to remove the burrs left by the screw-drivers, then holding the fine emery cloth or paper on your finger-tip until the head has a finely finished surface.

Vise Clamping—When parts are clamped in the vise for polishing, great care and judgment must be used, because of the nature of some parts. One essential point is to protect all parts from the vise jaws; this is just as important as using forethought when clamping parts that are thin and liable to spring and be ruined, between padded vise jaws. Lead jaws are one of the most useful accessories for a vise and an essential part of a gunmaker's equipment. Next come the felt jaws, altho these are made more for softer material such as wood and blued parts, which are easily marred if clamped in any other manner. Sheet brass and copper follow for some of the larger metal parts. Leather can be glued to wooden barrel staves or thin gumwood and used as vise jaws. The main thing is always to keep in mind the proper clamping methods when polishing any metal parts in a vise, and to provide material and means most suitable for the work you are doing. Always look ahead to see that you are using the correct locations on the parts so that you will not spring or damage them. There is usually a way out when mistakes are made on wood work, but when you spring or crack a receiver you can only purchase a new one.

The polishing and buffing of steel parts requires considerable experience before you reach the point where you are capable of producing a fine and even-grained finish on them.

I have not touched upon the subject of a buff finish on nickel-plated parts, or the finish given to chrome-plated work, or even the brass you find on antique arms; as so little of this work is done, I did not deem it necessary. Your problem is to secure a luster upon steel parts of the more modern arms, and if all instructions are followed out you will undoubtedly be pleased with the results of your hours of labor. Then, if you have completed the interior of the firearm equally well, you will be proud to say it was through your own efforts that it appears as it does.

Here are a few rules which should be remembered when polishing by power or by hand:

1. Polishing wheels should be kept in perfect balance and running true at all times. A wheel out of balance wastes time and will not do good work.
2. When using a file as a holder for emery cloth,

care should be taken to wrap the cloth around the file two to four times, so that the file teeth will not break through and cause deep scratches. That is the reason wooden holders are best.

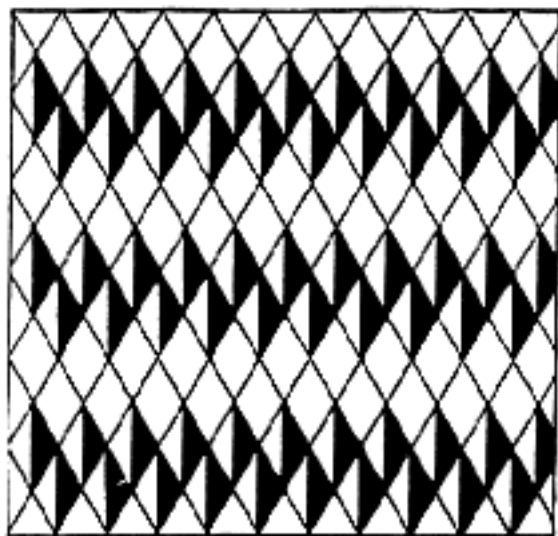
3. When choosing wheels for either polishing or buffing, select them for the particular work you are about to accomplish. As in grinding, only the

wheels best adapted for that purpose should be used.

4. Scratches will magnify greatly through the bluing—those who place a "Pittsburgh finish" on a firearm will be surprized to see how the bluing will show this finish up. A luster free of scratch produces the best bluing on any metal.

CHAPTER XVI

The Art of Bluing and Browning



The Art of Bluing and Browning

THE primary object of bluing and browning is to dull the bright color of the barrel and other metal parts exposed to the sight of game. It does not entirely prevent the metal from rusting, but rust will not attack the steel thus treated so readily as if left in a bright condition. A well blued or browned rifle or shotgun is as pleasing to the eye as a well-groomed person. When a weapon so treated is displayed to a group of men and commented upon, a question arises in the minds of the more curious as to just how the lustrous blue-black finish is obtained.

The first consideration in browning or bluing is an analysis of the metal and of the heat treatment to which it was subjected. You would not expect the same result on a hardened piece of steel as on a soft piece, even tho these were fastened together and one solution used for both. It is necessary to mix the solution for more strength when bluing or browning a hardened piece of metal. One will find the low-carbon steels easiest to blue or brown with any of the solutions used for this purpose; the high-carbon steels, together with the alloy steels, come next. The case-hardened or heat-treated alloy steels are the most difficult, but become fairly simple when the right solutions are learned.

There are various methods of bluing and browning, such as the several acid processes, bluing with the potassium nitrate bath, bluing by charcoal and charcoal gases, pack-hardening with charred bone and other animal substances in cast-iron boxes, and the cyanid bath. The latter subjects will be treated in separate chapters. The beginner, making a thorough and individual study of this subject, will find that a fundamental knowledge of chemistry is very useful in working out many of these problems.

The word "browning" is the original British term for the process of producing color on steel or iron with acid. "Bluing" is more universally used and is technically correct. One very seldom sees nowadays a really brown finish on a firearm unless it is an antique. However, the British still use the term browning even tho the metal is blued. In this chapter I have described both processes so that the student may use either, according to his fancy.

Another process is Parkerizing. This is the method in which the service Springfields are finished; it is efficient and highly rust-resisting. Parkerizing, briefly described, consists of sand-blasting and boiling all parts to be finished in a solution of "Parko Powder" composed of specially prepared powdered iron and phosphoric acid. In the process minute particles of this powder are deposited on the metal and dissolved. The result is a dull non-reflecting finish, which, while less attractive than bluing, is far more practical from a military standpoint. It is possible, however, by buffing the parts with various oils, to produce a soft gloss that is more attractive. This method is far too cumbersome and expensive for the beginner, who only has a small amount of bluing to do from time to time.

The large arms plants have a separate department set aside for this work. When using the rusting process for bluing they have cabinets so arranged that the air is kept at an even temperature and is saturated with humidity. Special processes allied to the Parker method are also used.

If the methods outlined are followed carefully, you will be able to secure results similar to those of factories with modern equipment. They should be economical, enabling you also to use them with equal efficiency in both summer and winter.

In purchasing a supply of chemicals, I would suggest that you choose for each method those which answer your purpose most satisfactorily. Have a wholesale drug house or your local druggist supply your needs. If, however, you wish to experiment with more than a few of the formulæ, you will find the following list of chemicals very helpful. They form the principal bases of all.

Aqua regia	Binoxalate of potassium
Verdigris	Potassium nitrate
Sulfate of zinc	Bismuth oxychlorid
Vinegar	Tincture of ferric chlorid
Salt	Hydrochloric acid
Sal ammoniac	Nitric acid
Gallic acid	Alcohol—pure grain spirits
Corrosive sublimate	Cupric chlorid
Ferric chlorid	Sweet spirits of niter
Copper sulfate	Ferric chlorid
Distilled water	Caustic soda "cleaning"
Sodium nitrate	Lime "cleaning"
Nickel carbonate	Benzine "cleaning"
Sulfur	Black oxid of manganese
Ferrous chlorid	Ferrous sulfate

With the above it is necessary to have a scaled measuring glass, glass funnel, glass mixing receptacle, glass mixing rod, and blue or brown bottles. A complete equipment should include three galvanized tanks, one three-burner gas stove, or a specially-built gas arrangement to take as many as three tanks. A small motor that will carry a fine steel wire circular wheel at least 7 inches in diameter should be nearby. The galvanized tanks should be made 5 inches wide and 5 inches high, the length being governed by the longest barrel or part which is to be blued—42 to 44 inches is very convenient. Mark the tanks Nos. 1, 2, 3; tank No. 1 to be used for the caustic soda solution, tank No. 2 for the lime, and tank No. 3 for hot water and bluing the work with the quick-method process, for boiling the barrels, and as a means for securing the required humidity to rust parts. On each end of all three tanks have good-sized handles for moving off the gas stove and in cleaning. On tank No. 3 have a lid, cone-shaped, with a rod fastened in the center on the under side the full length, so that the hooks can be fastened to it and to the work. On the lid have also four pieces of flat stock fastened one on each corner, projecting from 10 to 15 inches from the bottom of the lid so that when this is placed over the tank there will be an opening of 12 inches between the lid and top of tank. The object of this hood is to get the required humidity from the steam that comes off the water, rising to the cone-shaped lid where the work is fastened. The water only needs to be heated to generate enough steam to saturate the air with moisture. By all means avoid having too much of the latter, or it will condense on the work. After a few parts are blued in this manner, one can easily regulate the required humidity to secure proper results.

Before any barrel, either old or new, can be blued, it must be highly polished and absolutely free from oil or grease. It is advisable to wear clean cotton gloves throughout the operation to prevent the hands from touching any part of the work, for as we know, the skin contains oils and acids which react chemically.

If the work upon which you are engaged is a rifle or shotgun barrel, grease or oil the inside well and make suitable wooden plugs of hard maple. The plugs should be at least 1 inch in diameter and long enough to act as a handle. Turn these to a shoulder, six-thousandths of an inch larger than the groove or bore diameter. Remember to allow for these plugs when constructing the tanks.

If a plug is for the muzzle of a barrel, turn it to the required groove diameter, 2 inches long. Grease well and drive in, allowing over $\frac{1}{2}$ inch between the muzzle and shoulder of the plug so that the

muzzle can be blued as well as the rest of the barrel. The one for the chamber should be turned the same form as the chamber, allowing oversize to drive in place. Both should project enough to form handles. When such precautions are used, there is no possibility of the acid reaching the inside, to ruin rifling or chamber.

When the barrel is thus prepared, saturate a clean cotton rag with benzine and wash the work to remove all oil or grease before placing in the tank of caustic soda. In tank No. 1, place 3 inches or more of water. Let this come to a boil, and add a sufficient amount of lye or caustic soda in the water to form a very strong solution. Place the work in the solution and allow to boil for ten minutes, removing all grease and oil. Remove and rinse with hot water. In order to handle work conveniently, make two hooks from $\frac{1}{8}$ -inch cold-drawn steel. When thus prepared the metal is free to take the solution evenly. These solutions may be used again at some future time, so it would be well to make flat lids for the tanks to protect the solutions from dust and evaporation.

Before using tank No. 3, wash it well, first with caustic soda and then with some of the lime solution from tank No. 2 to remove all traces of grease and oil. After rinsing well and filling with clean water, it is in readiness for the bluing operation.

Before beginning there are a few cardinal things to be remembered. As mentioned earlier in this chapter, all steels are not alike; we refer to them by different nomenclature. There is low-carbon steel, which includes cold-drawn and machinery steel; there is high-carbon steel, also called tool steel. The alloy steels contain nickel, vanadium, chromium, manganese, and tungsten. When varied steels are treated, the formulæ must be changed by adding to or diluting the solution for oxidizing.

Low-carbon steels are simplest to blue when heat-treated by pack-hardening or the cyanid bath.

If the acids are unsatisfactory on the cold metal when applying any of the solutions in the so-called ten-day processes, which are described later, heat the parts in water or in tank No. 3 to about 160 degrees. If they are still unsatisfactory, increase the copper sulfate, or add such acids as hydrochloric and nitric. This problem is very simple for a chemist to solve when the bases of the formulæ are worked out, but with the average man, patience is required to accomplish such results. I have endeavored to compound these formulæ precisely, so that no trouble will be experienced when using them if all directions are followed carefully. In my own experience it took a number of years of painstaking work to perfect them. Many a problem encountered by the beginner can be solved merely

by adding to the solution a grain of common sense.

BLUING SOLUTIONS

Formula No. 1 — Quick Method or Hot-solution Process —

1st	750 gr. (avoir.)	corrosive sublimate
	1000 "	potassium chlorate
	1200 "	potassium nitrate
	300 "	ferric chlorid
	150 "	cupric chlorid
	300 "	sodium nitrate
2nd	1700 cc.	distilled water
3rd	175 cc.	sweet spirits niter

Weigh out the first six chemicals, placing them in a glass receptacle or glass jug. Heat the 1700 cc. of distilled water to 130 degrees Fahrenheit. Pour into the glass receptacle and keep agitating until all chemicals are completely dissolved. Let cool. After ten hours, add 175 cc. sweet spirits niter. Place in blue or brown bottles. Shake well before pouring into bottles and let stand twenty-four hours before using. Label bottles POISON.

Directions for Use—This is one of the finest formulae for quick-method bluing. It only requires one hour to complete a rifle and will produce a fine blue finish if directions are carefully followed. It can be used for almost any steel. Naturally, variations will take place when it is used on heat-treated parts.

After the work is prepared, place 3 inches of water in tank No. 3, rain or distilled water preferred. Rain water should be secured if at all possible. The chemically treated water encountered in all cities has various deleterious effects on the bluing operation and at times the finish will be streaked with gray.

Secure a heavy eight-ounce bottle with a large opening at the mouth and attach a wire around the top. Fasten it in one corner of tank No. 3. Locate it at the most convenient end to work from and let the bottle rest on the bottom of the tank. Pour four ounces of the above solution in the bottle, allowing the work and solution to boil together. Be sure that no water enters the solution while the operation is in process. Make a swab of 1-inch gauze bandage on a clean maple dowel or stick, slitting the end with a hack-saw to anchor the swab.

Have two wooden blocks made with notches cut out in the center so that the wooden barrel plugs may rest in these cut-outs while applying the solution or carding off the rust. If you do not happen to have, for the next step, a motor with a circular wire wheel attached, use No. 2/0 or 3/0 steel wool

or a fine carding brush for light burnishing. If steel wool is used, bunch and hold it so that only one part is used throughout the operation.

Place the metal parts to be blued in boiling hot water. Let remain between three and five minutes. Remove and apply a coat of the solution. Use even strokes lengthwise of the work. Let the heat of the barrel or parts completely dry the solution and place back in the boiling water. Let boil between two and five minutes. Remove and card off the rust and apply another coat of the solution. (To "card off" is to remove rust by means of wire browning brushes, steel wool or a circular wire wheel.) Repeat the operation between six and eight times. Each operation deposits a coat of stain or blue, and after the sixth or eighth application a very heavy coat is built up. After carding the last time give the work a coat of light gun oil—raw linseed oil—while still warm, to terminate further action of the solution.

Throughout this operation work very rapidly, both in applying the solution and carding off the rust, for the solution will take effect much better on heated steel. If too much time is lost when using the circular wire wheel on the motor, place back in the boiling water a few minutes before applying another coat. When using either steel wool or the carding brush, apply it gently and with light pressure. The same caution should be observed when working with the circular wire wheel. Remove the parts from the water with the two hooks made from $\frac{1}{8}$ cold-drawn steel; each small part should have a wire attached so that it may be lifted from the water conveniently.

The secret of bluing small parts is to coat the surface as soon as the water dries off and place at once back in the solution. After removing the rust, place the part back in the boiling water, remove, and apply a coat of the solution, meanwhile keeping the swab in the solution until the very instant of applying.

When the several applications have built up a blue-black color, as dark as it will apparently become, rub it well with No. 3/0 steel wool and then with a clean cotton cloth. Use the fine steel wool and card on the matted surface. If the work is engraved, brush over very lightly, as this operation burnishes the surface and a velvet finish is secured. Oil as directed previously. Wipe off in a few minutes and rub beeswax and turpentine into the parts; rub until all traces of the oil are removed. This will produce a beautiful finish. (See formula No. 5, Chapter XII, Volume I.) Remove barrel plugs, wipe out the bore, and apply gun oil. The parts are now ready to assemble.

When this solution is used on parts where gold

inlay has been used, you will find that the gold has turned white, a change due to the action of mercury in the corrosive sublimate. To restore the bright gold appearance, dip a toothpick in raw nitric acid and rub over the gold. Care must be taken that none of the acid touches the parts already blued.

Variations for Formulas—When dealing with heat-treated or case-hardened parts such as Krag, Springfield and 45-70 Model 1873 receivers and lock plates, or shotgun actions which have been case-hardened, polish brightly and remove all traces of oil or grease by thoroughly cleaning with alcohol. Make a small swab from gauze bandage on a hardwood stick. Then rub over the hardened parts with nitric acid. When the surface of the metal shows a black appearance, wash in hot water before placing in tank No. 3 for the coats of quick-method bluing solution. In this instance the action of the acid on the surface of the steel is necessary to make it chemically receptive for the solution.

For some Stainless Steel it is necessary to mix a coppering solution as follows:

240 cc. distilled water
Add all copper sulfate it will dissolve
Then add 2 cc. sulfuric acid

Test by applying to a piece of steel, and if necessary, add a few more drops of acid. The surface should show a light copper coating. Wash parts in alcohol to remove all traces of grease or oil, and apply solution with a swab. Then apply a coat of nitric acid as given for hardened parts. Rinse well in hot water after the desired results are obtained, and proceed with the quick method of bluing. You will find that to blue these steels is rather a difficult operation; it will be necessary to lay on more applications than for the alloy or cold-drawn steels.

There are other slight variations of formula, but you have the base of one of the best. It is suited for all purposes where a quick process is required. Of course, the evaporation of the sweet spirits of niter takes place very rapidly when the operation requires too much time. When half finished, if the time required is more than anticipated, add a small amount of sweet spirits of niter to the solution left in the bottle. If you wish a deep black color, add more sodium nitrate to the ready-mixed solution.

Formula No. 2—Simple Quick Method or Hot-solution Process—

800 gr. (avoir.) corrosive sublimate
1200 " potassium chlorate
1400 " potassium nitrate
960 cc. distilled water
120 cc. sweet spirits niter

Weigh out the first three chemicals, placing them

in a glass jug or other receptacle. Heat the 960 cc. of distilled water to 130 degrees Fahrenheit. Pour this into the glass receptacle and keep agitating until all chemicals are completely dissolved. Let cool. After ten hours, add the 120 cc. sweet spirits niter. Place in blue or brown bottles. Shake well before pouring into bottles. Let stand twenty-four hours before using. Label bottles POISON.

The same methods as those given in Formula No. 1 are used throughout the operation. These chemicals can be secured in any part of the world where you can find a drug store. The last-mentioned formula contains the base of all the quick-method bluing solutions placed on the market in recent years; they sell for \$1.50 to \$2.50 per 4-oz. bottle. Many gunsmiths and amateurs have used it and in most cases very successfully. If any difficulties have been encountered, they have been due to not recognizing the varieties of steel, negligence in freeing the parts from grease or oil, and a number of causes which seem trivial to the beginner, but which are nevertheless of great importance. If you meet with disappointment, try again, keeping in mind all the elementary instruction that I have attempted to bring to notice.

Formula No. 3—Simple Quick Method or Hot-solution Process—

600 gr. (avoir.) corrosive sublimate
1000 " potassium chlorate
800 " sodium nitrate
800 " potassium nitrate
960 cc. distilled water
120 cc. sweet spirits niter

Mix the same as in Formulas 1 and 2. The sodium nitrate has been increased to produce a deeper black, and is similar to Formula No. 2. Both formulas are good for the student to practise with.

Formula No. 4—Ten-day Rusting Process of Bluing—

1900 cc. distilled water
180 cc. tincture ferric chlorid
180 cc. sweet spirits niter
30 cc. nitric acid
800 gr. (avoir.) corrosive sublimate
400 " copper sulfate

Mix in order given and place in blue or brown bottles. Let stand for three days before using so that the chemicals will amalgamate.

Directions for Use—This formula is a ten-day rusting process. Prepare work by polishing, removing oil and grease as directed in the first part of the chapter. After boiling, remove and let cool slightly, and apply a coat of the solution with a

clean swab. Place the cover or lid on tank No. 3 in position. Fasten work to the rod in center of the top. Have the water warm enough so that the proper humidity will saturate the air under the cover and the work. Do not allow moisture to collect on the work, forming drops of water. If it is not possible to collect the required moisture, place a cloth around the tank and lid so that no humidity can escape. Let stand between eight and ten hours. Card off the rust with a circular wire wheel or No. 2/0 steel wool. Boil for about five minutes. Remove and let cool. I find it desirable but not necessary to do this, for each boiling neutralizes all chemical action of the previous application of the acid and gives the new coating of the solution a better foundation to build upon. Repeat this operation between ten and twelve days, twice each day.

Fine results are secured by applying Formula No. 2 first. Then give the work a three-day treatment, except to remove the rust more often as you have a body built up, making the rusting process take better effect. This method not only shortens the process, but you secure a wearing surface as tho the ten-day process were used.

Formula No. 5 — Rusting Process of Bluing —

960 cc. distilled water
90 cc. tincture of ferric chlorid
15 cc. nitric acid
220 gr. corrosive sublimate (avoir.)
110 " copper sulfate

Mix in order given and place in blue or brown bottles. Let stand for three days before using so the chemicals will amalgamate. Same instructions to be followed as in Formula No. 4.

Formula No. 6 — Rusting Process of Bluing —

300 cc. nitric acid
240 cc. hydrochloric acid

Mix the acids in a glazed stone jar out of doors. Add 600 grains of machinery steel chips which are free from oil or grease, or 600 grains of iron nails which have not been galvanized. Let stand until acid has completely dissolved the chips or nails. Then add to this mixture three quarts of distilled water. Place in brown or blue bottles and let stand three days before using.

Directions for Use—Clean the barrel or parts as previously described for quick-method process. After the final boiling, wash in clean water, dry and cool. Apply solution with clean swab. Place barrel in position on hooks in tank No. 3 as explained in Formula No. 4, or in a damp place for twelve hours. When a heavy coat of rust has formed, card

this off on circular wire wheel or with steel wool. Boil in hot water for about five minutes. Let dry and cool and re-coat with the solution. Repeat this operation every twelve hours for ten days. After final carding, boil. Let dry and oil. When cool, apply beeswax and turpentine as explained in Formula No. 1. This solution works out best on cold-drawn steel, and the result will be a beautiful blue which will wear for years. This is one of the old formulas and when a barrel is completed with this finish it always commands admiration.

The following combined formulæ on the quick-method and rusting process of bluing are given for broader choice and for experimentation. The first six are the most reliable; however, the student should have others at his command to acquire the experience and perfection necessary to satisfactory development. As mentioned earlier in the chapter, if you have had a course in chemistry you will find this knowledge, even tho fragmentary, to be very useful. Combinations are possible, as for instance to compound the quick-method with the rusting process, as the chemicals I have listed are of such a nature as to impart color to metal when properly used. Those who wish to make a more exhaustive study of the subject may proceed from where I have left off.

Formula No. 7 — Rusting Process of Bluing —

90 cc.	alcohol
90 cc.	tincture of ferric chlorid
1300 gr. (avoir.)	corrosive sublimate
90 cc.	sweet spirits niter
45 cc.	nitric acid
800 gr. (avoir.)	copper sulfate
2000 cc. (2 liters)	warm distilled water

Mix in order given. Place in blue or brown bottles. Let stand three days before using.

Directions for Use—Apply solution with swab. After allowing to dry for twenty-four hours, remove loose rust with card or fine steel wool. The second coat is given in the same manner, after which the work is boiled in water and dried quickly. Boiled linseed oil, beeswax, and turpentine are applied to achieve a glossy surface and act as a rust preventive—1 part linseed oil, 1 part beeswax, 1 part turpentine. (See Formula No. 5, Chapter XII, Volume I.)

Formula No. 8—A permanent and beautiful blue-black color may be obtained by using just enough water to dissolve two ounces of copper sulfate and then adding enough ammonia to neutralize and make it slightly alkaline. Test with litmus paper. The work must be heated before immersion. This was tried when I was at the Arsenal, but the

work was never carried far enough to see what results could be obtained on small parts.

Formula No. 9 — Rusting Process of Bluing —

135 cc.	alcohol
45 cc.	tincture ferric chlorid
660 gr. (avoir.)	corrosive sublimate
45 cc.	sweet spirits niter
450 gr.	copper sulfate
20 cc.	nitric acid
1000 cc.	distilled water

Mix in order given, and warm distilled water to 130 degrees Fahrenheit. Add copper sulfate and corrosive sublimate. Dissolve these solids and add liquids in order given.

Three treatments will produce very satisfactory results with this formula, carrying through the same routine given for other formulæ.

Formula No. 10 — Quick Method or Hot-solution Process —

50 gr. (avoir.)	corrosive sublimate
1800 "	ferric chlorid
470 "	ferrous chlorid
3 cc.	hydrochloric acid
1000 cc. (1 liter)	distilled water

Heat water to 130 degrees Fahrenheit, and dissolve all chemicals. Let stand for twenty-four hours before using.

Clean work as before and use the same treatment as given in Formula No. 1, but boil the parts for twenty minutes after each removal of rust. The treatment only requires three repetitions. This formula produces a very fine deep black.

Formula No. 11 — Quick Method or Hot-solution Process —

55 gr. (avoir.)	bismuth oxychlorid
112 "	corrosive sublimate
55 "	cupric chlorid
4 cc.	hydrochloric acid
15 cc.	alcohol
150 cc.	distilled water

Mix in order given. Treatment as described in Formula No. 10. Produces a very deep durable black on soft, hard, case-hardened and tempered steels alike.

Formula No. 12 — Quick Method or Hot-solution Process —

45 gr. (avoir.)	bismuth oxychlorid
10 cc.	hydrochloric acid
15 cc.	alcohol
100 cc.	distilled water

Mix in order given. Treatment same as No. 10.

Formula No. 13 — Quick Method or Hot-solution Process —

35 gr. (avoir.)	copper sulfate
110 "	ferrous sulfate crystals
25 cc.	ferric chlorid sol. 28%
1 cc.	hydrochloric acid
100 cc.	distilled water

Mix in order given. Treatment same as No. 10.

BROWNING SOLUTIONS

Next in order are the browning solutions, which give a butternut brown stain to steel parts, particularly to softer steels such as the cold-drawn and machinery varieties. We cannot help but admire the old method of browning such as is seen on well preserved shotguns with Damascus barrels.

When browning a rifle or shotgun, humidity of surrounding air will have an important influence on the action of the browning mixture, as is the case with the bluing solution. It is also important—and not hard—to determine the moment when the proper drying stage has arrived for the removal of rust. When applying the card or steel wool, if thoroughly dry, the rust will be eliminated quickly; if not dry, the rust will adhere firmly, and the surface of the barrel will look streaky. Some mixtures will dry in twelve hours or even less, but twenty-four hours will insure perfect dryness. Whenever you find a well-built-up coat of rust on the barrels, remove them from under the hood in tank No. 3 and allow them to dry away from their humid bath. A trial or two and you will sense the correct time during drying (which also means cooling) when the rust should be removed.

Browning or rust may be obtained very rapidly and well, by enclosing the barrels in a cabinet and subjecting them to the vapor of hydrochloric acid. The same results may be obtained by moistening the surface with diluted hydrochloric or nitric acid. There is another material sometimes used—chlorid of antimony. In using this substance, a uniformly smooth mixture is rubbed in with olive oil. This is spread upon the barrel, which is slightly heated, and then exposed to the air until the required degree of browning takes place. The operation of the antimony is quickened by superimposing upon it a thin coating of nitric acid.

The browning of barrels will take the student back to the days when Damascus barrels were considered the last word in metal staining. Today we still admire those fine old barrels with the beautiful twisted effect of the steels; the beginner will probably wish to secure the same effect. The characteristic bright wavy appearance of Belgian Damascus barrels is procured by direct chemical

action—a process termed “pickling.” It results through dissolution of the softer metals as against the harder used in constructing the barrel. The preparation recommended is one pound copper sulfate dissolved in one gallon of distilled water at the boiling point. Continue to boil until the quantity is reduced about one-fourth. Then let it cool. Pour out into a lead vessel. Plug the barrels securely at both ends so that the liquid cannot penetrate into the interior. When the barrels are immersed in the solution it will act upon the metal in fifteen or twenty minutes. Remove and wash with water. If not satisfactory, immerse again until the operation is complete. Pour boiling water over them and scratch well with a steel brush or card, which will bring out the beautiful, bright, wavy luster. When laminated steel barrels are subjected to this operation, the results will be similar.

The browning of Birmingham shotgun barrels is done as follows: Dissolve as much corrosive sublimate as possible in a 6-oz. drinking glass full of alcohol. Mix this solution in one pint or more of distilled water. Combine a small quantity of this mixture with a little whitening and lay on the barrel rather lightly with a sponge. As soon as dry, brush off and apply a fresh coat. Proceed until the barrel is dark enough, which generally takes two or three days. This affects the steel so that the softer parts of the metal are a beautiful brown, and the harder portions remain light. The rusting process is neutralized by washing in hot water, after which the barrels are quickly immersed in cold water. The latter has the effect of heightening the brightness of both colors.

Formula No. 14 — Browning —

25 cc.	sweet spirits niter
140 gr. (avoir.)	corrosive sublimate
140 “	sulfur
15 cc.	sulfuric acid
25 cc.	tincture ferric chlorid
4 cc.	nitric acid
110 gr. (avoir.)	copperas
645 cc.	distilled water

Mix in order given. Allow to stand for eight hours before pouring into brown or blue bottles.

Treatment—Apply solution with swab after preparing as described in first part of chapter. Set away for twenty-four hours in cabinet or under the cover of Tank No. 3. At the end of that time a heavy rust will have formed over the barrel. Card off with circular wire wheel or fine steel wool. Then rub off with clean cotton cloth free from oil. If you find the brown not dark enough, cover again with the solution and set away for twenty hours longer. Remove the rust exactly as in the first in-

stance, then if the color pleases, wash in cold water or with a wet cloth. Rub to thorough dryness and finish by rubbing with linseed oil to prevent further rusting. This application browns barrels beautifully and in the case of twist leaves the markings prominent.

Formula No. 15 — Browning —

30 cc.	tincture of ferric chlorid
30 cc.	sweet spirits niter
110 gr. (avoir.)	corrosive sublimate
6 cc.	nitric acid
60 gr. (avoir.)	copper sulfate
1000 cc.	distilled water (1 liter)

Mix the first three chemicals together, adding the distilled water, followed by all the other chemicals. Place in brown or blue bottles. Let stand one week so that all chemicals are thoroughly amalgamated.

Treatment—Prepare the work as already described. Apply the solution with a swab. Let stand two hours. Brush off with card. Repeat with four applications and let stand over night. Repeat following day every four hours, until the desired color is obtained. Wash with cold water and apply a coat of linseed oil.

Tincture of steel is difficult to obtain, so it may be necessary to make your own. First secure a stone crock. Place 1½ pounds of carbonate of iron therein and add 1½ quarts of hydrochloric acid. Stir until the acid has dissolved all the iron it can take up. Then pour off carefully into a glass bottle, being careful to keep out the sediment, and add three parts of pure grain alcohol. If one does not care to go to this trouble, the medicinal tincture of iron may be made to answer reasonably well.

Formula No. 16 — Browning Solution —

225 cc.	distilled water
225 cc.	alcohol, pure grain spirits
220 gr. (avoir.)	corrosive sublimate

Mix in order given. Place in brown or blue bottles.

Treatment—Apply with swab and stand in warm dark place until rust is formed over the whole surface; this will require, in warm weather, from ten to twelve hours, and in cold weather, from fifteen to twenty hours. Card off the rust and clean with a cloth free from oil. Repeat the process until the brown color pleases, for each coat produces a darker shade. This is one of the best formulas made in a simple manner for the common cold-drawn steels. It also works very well on the Winchester, Remington, Savage and other arms of a similar nature.

Formula No. 17 — Browning Solution —

480 cc.	distilled water
430 gr. (avoir.)	copper sulfate
30 cc.	sweet spirits niter

Mix in order given. Place in brown or blue bottles. Let stand three days before using.

This is a very simple formula, and produces very good results. Proceed as in Formula No. 13.

Formula No. 18 — Browning Solution —

50 cc.	alcohol, pure grain spirits
50 cc.	tincture of ferric chlorid
600 gr. (avoir.)	corrosive sublimate
50 cc.	sweet spirits niter
430 gr. (avoir.)	copper sulfate
10 cc.	nitric acid
500 cc.	distilled water

Heat the water to 130 degrees Fahrenheit, and pour over the six chemicals as mixed in the order given. Place in brown or blue bottles. Proceed as in Formula No. 13.

Formula No. 19 — Browning Solution —

180 cc.	sweet spirits niter
30 cc.	alcohol, pure grain spirits
50 cc.	tincture ferric chlorid
50 cc.	tincture gum benzoin
600 gr. (avoir.)	copper sulfate
1500 cc.	distilled water

Heat the distilled water to 130 degrees Fahrenheit. Add the copper sulfate and completely dissolve. Add this to other chemicals. Mix in the order given and let stand for five days before using. Place in blue or brown bottles. Proceed as in Formula No. 13.

Formula No. 20 — Brown Tint for Iron or Steel — Dissolve in four parts distilled water, two parts crystallized chlorid of iron, two parts chlorid of antimony, and one part gallic acid. Apply the solution with a sponge to the parts or barrels, letting dry in a warm place. Repeat the process according to the depth of color desired. Wash with warm water and dry. Then rub over with boiled linseed oil. The metal receives a brown tint and resists moisture. The chlorid of antimony should contain as little acid as possible.

Most browning and bluing formulæ are preserved as trade secrets by gunsmiths for reasons of protection and because of the fact that an air of mystery enhances the selling qualities of the project. It appears absurd to me when I think of one man preventing another from accomplishing an object by withholding from him the foregoing simple formulæ, which at any time could be uncovered with little effort.

The foundations of the formulæ are laid with the idea of a number of diverse approaches and the formation of solutions all of which will oxidize the surface of steel and iron. They are compounded in such a manner that one may carry out a great variety of work, not only for firearms, but for any other metal articles which require coloring.

After the reader has experimented with the various formulæ, he will be able to compound some of his own which may be suited to some particular work he wishes to do. At times the patience of Job is required, but this quality, combined with persistence, will in the end obtain the results he is after.

MISCELLANEOUS FORMULAS

Heat Methods of Coloring Metal — There are a number of methods used to secure, by heat, the blue color which has a lasting durable finish. Others are just a quick method to color small parts.

Formula No. 21 — Niter Process of Bluing Steel —

8 lbs.	potassium nitrate
1 "	black oxid of manganese

This mixture is heated to a temperature of 700 degrees Fahrenheit. The parts to be blued are polished and cleaned to remove all traces of grease. Immerse them in the molten nitrate and manganese. Let remain until a uniform color of the desired shade is obtained. The articles are then removed and plunged immediately into warm water at a temperature of 110 degrees Fahrenheit. Dry in fine sawdust and apply a coat of heavy cylinder oil. Bake in an oven at a temperature of between 300 and 350 degrees Fahrenheit from five to eight minutes until the black finish is developed. If you wish only a light blue finish, dip the parts in a light paraffin oil before baking.

When placing work of this nature in the oven for baking, handle the parts on wires, keeping them free from any contiguous objects. You will find the oxid of manganese is deposited on the work, which must therefore be frequently replenished in the nitrate mixture. The preparation of oils to obtain a black or light black rust-protecting finish may be applied to harden and temper parts alike.

Formula No. 22 — Bluing Steel by Heat Treatment — Polished steel parts may be given a blue color by treating in hot sand, wood ashes, or pulverized charcoal. Place the parts in an iron receptacle and stir constantly while heating, in

order to heat uniformly. Heat just enough to char a pine stick. The parts to be blued must be free from grease. They are placed in the heated substance until the desired color is obtained. Further coloring is then checked by immersing in oil. The illustration in Chapter IV, Volume I, will show the arrangement used with a Bunsen burner. I have used discarded Stearn Knight pistons as retorts. The blue finish can also be obtained by laying a steel plate over the top of a stove, upon which the article to be blued is placed. The quality of the color depends largely upon the fineness of the finish.

Formula No. 23 — Cyanid Bath for Blue Mottled Color — The cyanid bath gives to the surface of the metal an exterior hardness with a mottled blue appearance; however, it does not have the admirable effect that the pack-hardening gives to best-quality shotgun actions. This method will answer in a number of instances for a "hurry-up" job, being difficult to differentiate from work done by the regular pack-hardening process.

The bath is composed of potassium cyanid placed in a crucible. "The amount to use is governed by the work you wish to do." The crucible is heated in a furnace so arranged that the top will not be exposed to the flames. A hood should be placed over it so that the fumes will escape to the outside atmosphere. Heat the cyanid to 1400 degrees Fahrenheit. Make a wire basket for small parts. For larger parts, wire the work so that it can be transferred conveniently from the cyanid to the solution. (Formula No. 24.) The quantity of the mottled color depends mostly upon the preparatory polishing finish.

Before a part is placed in the cyanid, make sure it is free from oil or any other foreign substance, especially water or potassium nitrate. This causes the cyanid to splatter, which might cause severe skin burns; for this reason the eyes should be protected with goggles and the hands with clean cotton gloves. Allow to remain in the heated cyanid between five and ten minutes, according to the quality of the metal and the mechanical uses for which it is intended.

Formula No. 24 — Prepared Solution — The solution is composed of potassium nitrate and water. To one gallon of water add one ounce of potassium nitrate (saltpeter) and 10 cc. sperm oil. Test pieces should be tried out as a preliminary experiment. The correct amount of nitrate will give the blue and mottled effect desired. If too light a color develops, add more nitrate, and if too blue, more water. To get the best results, air should be forced in the solution by blowing through

a pipette which keeps the mixture in motion and also improves the appearance of the mottling. After removing the work from the solution, dry in hot sawdust. Wipe and apply a coat of gunlock varnish (Formula No. 48). When a fine-grained mottled effect is desired, introduce one ounce of sodium nitrate into the ready-mixed solution.

Formula No. 25 — Gun-metal Finish — Several additional chemical solutions have been used successfully for giving steel a gun-metal finish or black color. Among those are the three following formulæ, which work very well.

No. 1.	1 part	bismuth chlorid
	1 "	copper chlorid
	2 "	mercury chlorid
	6 "	hydrochloric acid
	50 "	distilled water
No. 2.	1 part	ferric chlorid
	8 "	alcohol
	8 "	distilled water
No. 3.	2 part	copper sulfate
	3 "	hydrochloric acid
	7 "	nitric acid
	88 "	perchlorid of iron

Other solutions have been prepared from nitric ether, nitric acid, copper sulfate, iron chlorid, and water. The method of applying these and finishing the work is practically the same as with other formulæ.

The surface of the metal is given a very thin coating of either of the last recipes, applied with a soft brush or sponge that has been well squeezed and allowed to dry. The work is then put in a cabinet to which steam is admitted, and maintained at a temperature of about 100 degrees, until it is covered with slight rust. It is then boiled in clean water for fifteen minutes and allowed to dry. A coating of black oxid covers the surface, and this is carded, after which it will show grayish black. By repeating the sponging, steaming, and carding operations several times, a shiny black lasting luster will be obtained. For the best finishes, these operations are repeated as many as eight times.

Another process employs a solution of mercury chlorid and ammonium chlorid, which is applied three times and dried after each application. A solution of copper sulfate, ferric chlorid, nitric acid, alcohol and water is then applied three times and dried as before. A third solution, of ferrous chlorid, nitric acid, and water is applied three times, boiling in clean water and drying after each. Finally a solution of potassium chlorid is applied and the work is boiled and dried three more times. It is then carded and given a thin coating of oil. Ordnance for the French government is treated in this way. The above methods are applicable to

hardened and tempered steels, as 212 degrees Fahrenheit is not enough to affect or reduce their quality. For steels that can endure a 600-degree temperature without losing hardness, more efficient methods are devised.

The American Gas Furnace Company has developed a process employing a furnace with a revolving retort. The object to be colored is placed in this together with well burnt bone. A chemical solution that gasified when injected into the furnace has been named "Carbona." The color does not form a coating on the outside as with the other processes, but a thin layer of the metal itself is turned to the proper shade. By varying the temperature of the furnace, the time the work is in it, and the chemical, different tints can be produced from light straw to brown, blue, purple, black, or gun-metal finish. Rough or sand-blasted surfaces will have a frosted appearance, while smooth polished surfaces will have a shiny brilliant appearance.

Formula No. 26 — To Produce a Brown Color on Steel — A bronze-like color is produced by exposing iron or steel parts to the vapors of heated aqua regia (equal parts nitric and hydrochloric acid), dipping them in melted vaseline, and heating them until the vaseline begins to disintegrate. Then it is wiped off with a clean cloth.

Another method of producing a bronze-brown is to heat the work slightly, cover the surface evenly with a paste of antimony chlorid (known as bronzing salt), and let the object stand until the desired color is obtained. The paste can be made more active by adding a little nitric acid.

Formula No. 27 — To Produce a Gray Color on Steel — A gray color on steel is obtained by immersing the work into a heated solution of:

10 gr. (avoir.)	antimony chlorid
10 "	gallic acid
400 "	ferric chlorid
150 cc.	distilled water

The first color to appear is pale blue, and this passes through the darker blues to purple, and finally to gray. If immersed long enough, the metal will assume the gray color, but any of the intermediate colors may be produced when used cold. This is also one of the bronzing solutions.

Formula No. 28 — Coppering Solutions — A coppering solution for coating finished surfaces so that lay-out lines may be more easily seen is composed of the following ingredients:

120 cc.	distilled water
Add all the copper sulfate it will dissolve	
1 cc.	sulfuric acid

Test by applying to a piece of steel, and if necessary add a few more drops of acid. The surface to be coppered should be polished and free from grease. Apply the solutions with a clean piece of waste or cloth, and if a bright copper coating is not obtained immediately, apply the second coat, and so on. When the desired color is obtained, oil the surface and wipe off. The object of the oil is to terminate any further action of the acid. If the piece is to be hardened after coppering, remove the plating, for the reason that steel will not harden well where this has not been done.

Formula No. 29 — Etching Fluids for Different Metals — A common method for etching names or simple designs on gun parts or steel is to apply a thin even coating of beeswax or similar substance which is not soluble in acid. Mark the required lines in the wax with a sharp-pointed scribe, exposing the steel to the action of the acid which is finally applied. To apply a thin coating of beeswax, place the latter in a silk cloth, warm the piece to be etched, and rub the pad over it. Regular coach varnish is also used instead of wax as a "resistant."

Formula No. 30 — Etching Solution for Carbon Steels —

1 part	nitric acid
4 "	distilled water

It may be necessary to vary the amount of water, as the exact proportion depends upon the carbon in the steel and whether it is hard or soft.

Formula No. 31 — Hardened Steel —

2 parts	nitric acid
1 "	acetic acid

Formula No. 32 — High-speed Steel, Nickel, or Brass —

For high-speed steel it is sometimes better to add a little more nitric acid.

Formula No. 33 — Solution for Etching Bronze —

100 parts	nitric acid
5 "	hydrochloric acid

For Etching Brass —

First combine 16 parts nitric acid with 160 parts distilled water. Second, dissolve 6 parts potassium chlorate in 100 parts of distilled water. Then mix the two solutions together and apply.

Formula No. 34 —

The gun maker may wish to obtain a frosted appearance on work to offset a particular effect. The following mixture may be used, either for producing a frosted effect or for deep etching (depends upon the time it is allowed to act). It is composed of:

1 oz.	sulfate of copper
¼ "	alum
½ tsp.	salt
240 cc.	vinegar
20 drops	nitric acid

The action of etching fluids on steels varies according to the composition of high-carbon and alloy steels, as they are acted upon more slowly than low-carbon steels or wrought iron. Etching fluids that act efficiently on low-carbon steel may not do so well on high-carbon steel or cast-iron. The usual trouble is that the carbon liberated by the etching fluid settles to the bottom of the scribing and prevents further action. That difficulty can best be overcome by frequently washing out the carbon deposit and renewing the acid so that it will come in direct contact with the metal. A great help also is to sprinkle a little table salt in the acid when it shows a tendency to act slowly; this tends to give it new life.

The student may find need to color brass, copper, or various other metals, to give them an antique appearance. The following *modus operandi* is explanatory of the coloring of such metal surfaces.

Copper is more susceptible to coloring processes than any other metal, hence the alloys containing varied percentages of copper are possessed of differing shades of yellow, brown, red, blue, purple, and black. Alloys with smaller percentages of copper, or none at all, may be given kinds and degrees of color, but not as easily as if copper were the principal ingredient. The higher the copper content, the more readily can the alloy be colored. The shades and even the colors may be altered by varying the density of the solution, its temperature, and the length of time the object is immersed. This can also be altered by finishing the work in different ways. If a cotton buff is used, one shade will be produced; a scratch brush will produce another, etc. Thus in color work, to obtain the same shade as that of a former lot, all the data in connection with these operations must be preserved so they will be repeated with exactitude.

In making the solutions it should be remembered that a strong solution will produce the color quickly, and a weak solution more slowly. When a uniform coating is to be produced, a strong solution is the best, owing to the time factor, but the most effective and lasting results are obtained with

weaker solutions, hence they are used in high-grade work. While these solutions are often employed cold, there are many instances where better results can be obtained when they are heated.

After the enumeration of the foregoing instructions relative to the bluing and browning of metal parts, I cannot stress too urgently the importance of preliminary cleaning. The same applies to antiques, special decorative parts for muzzle-loading rifles, brass furniture, and special museum pieces. Metal surfaces to be colored chemically must first be thoroughly cleaned, and must present a smooth and polished surface. To remove grease from small parts, dip in benzine, gasoline, ether, or some other solvent for grease. Boil large pieces in a solution of one part caustic soda and ten parts water. For zinc, tin, or britannia metal, do not use caustic soda, but a bath composed of one part carbonate of soda or potash and ten parts water. Do not touch the clean surface with the fingers, but handle the objects with tongs, forceps or wires. Also wear clean cotton gloves.

The grease removal should be followed by chemical cleansing; this principally serves the purpose of removing the greenish or brownish films which form on copper, brass, bronze, etc.

Formula No. 35 —

The composition of the bath or mixture of pickling, used for removal of foreign substances from metal surfaces in the preparation for production of color, varies for different metals. For copper and its alloys, use a mixture of 100 parts concentrated sulfuric acid and 75 parts nitric acid. If the metal is to be given a luster instead of a mat or dull finish, add about one part common salt to the pickling solution by weight. A better dip for a mat surface consists of:

Formula No. 36 —

64 parts	water
64 "	commercial sulfuric acid
32 "	nitric acid
1 "	hydrochloric acid

After immersion the work should be thoroughly rinsed several times in distilled water. If such treatment is so far satisfactory, proceed as follows: Heat to a dull red and plunge object into diluted sulfuric acid; allow to remain in old aqua fortis and finally rinse thoroughly in clean hot water. The metal should be soaked in aqua fortis until it has a uniform metallic appearance, and the bath should be large enough in volume to prevent an excessive increase in temperature. The results are obtained with straw-colored aqua fortis, as white is too weak and red too strong.

Formula No. 37 — Coloring Brass —

Polished brass pieces from old guns may be given various shades, from golden yellow to orange, by immersing them for a time in a solution composed of:

5 parts caustic soda (by weight)
50 " water
10 " copper carbonate

When the desired shade is reached, the work must be well washed with water and dried in sawdust. Golden yellow may be produced as follows: Dissolve 100 grains lead acetate in one pint of water and add a solution of sodium hydrate until precipitate which first forms is redissolved; then add 300 grains red potassium ferrocyanid. With the solution at ordinary temperatures, the work will assume a golden yellow, but heating the solution darkens the color until at 125 degrees Fahrenheit it has changed to a brown.

Formula No. 38 — To Produce a Rich Gold Color —

Brass may be given a rich gold color by boiling it in a solution composed of:

2 parts (by weight) potassium nitrate
1 " common salt
1 " alum
24 " water
1 " hydrochloric acid

Formula No. 39 —

Another method is to apply a mixture of:

3 parts alum
6 " potassium nitrate
3 " sulfate of zinc
3 " common salt

After applying this mixture the work is heated over a hot plate until it becomes black. After it is washed with water and rubbed with vinegar, it is again washed and dried.

Formula No. 40 — White Colors or Coatings —

The white color or coating that is given to such brass articles as pins, screws, and various other antique fittings may be produced by dipping the articles in a solution made as follows: Dissolve two ounces of fine grain silver in nitric acid. Then add one gallon of distilled water, and put this in a strong solution of sodium chlorid (table salt). The silver will precipitate in the form of chlorid and must be washed until all traces of the acid are removed. Testing the last rinse water with litmus

paper will show when the acid has disappeared. Then mix this chlorid of silver with an equal amount of potassium bitartrate (cream of tartar) and add enough water to give it the consistency of cream. The work is then immersed in this solution and moved about until properly coated, after which it is rinsed in hot water and dried in sawdust.

Formula No. 41 — Silvering —

A solution of silvering that is applicable to such work as clock gauge dials, and accessories such as parts of brass furniture on old flint-lock pistols, is made by grinding together in a mortar one ounce of very dry chlorid of silver, two ounces cream of tartar, and three ounces common salt. Add enough water to obtain the consistency of a paste, and apply it to the work with a soft cloth. This will give to brass or bronze surfaces a dead-white, thin silver coating, but it will tarnish and wear if not given a coat of lacquer. Before adding the water, the mixture as it leaves the mortar can be kept a long time if put in dark-colored bottles; if left in the light, it will decompose.

Formula No. 42 — Gray Color —

A solution of one ounce arsenic chlorid and one pint of water will produce a gray color on brass, but if the work is left in this solution too long it will become black. Brass fittings or other objects should be left in the bath until they have acquired the correct shade, and then washed in clean warm water, dried in sawdust and finally in warm air.

Formula No. 43 — Blue to Violet Shades —

To give brass a blue color, dissolve:

1 oz. antimony chlorid in
20 " water and add
3 " hydrochloric acid

Warm the work and immerse it in the solution until the desired blue is obtained. After that, wash in clean water and dry in sawdust. A permanent and beautiful blue-black may be obtained by using just enough water to dissolve two ounces copper sulfate and then adding enough ammonia to neutralize and make it slightly alkaline. The work must be heated before immersing.

Formula No. 44 — Violet Shades —

A beautiful violet color may be produced on polished brass with a mixture of two solutions.

First: 4 oz. sodium hyposulfite is dissolved in 960 cc. of water. Second: 1 oz. sugar of lead is dissolved in another 960 cc. of water. The two are

stirred together well. By heating this to 175 degrees Fahrenheit and immersing the correct length of time, determined experimentally, a violet color is obtained. The work first turns a golden yellow and then gradually violet. If left immersed longer, the violet will turn to blue and then to green. This same preparation can therefore be used for all of these colors by correctly limiting the time that the work remains in the solution.

Formula No. 45 — To Give Brass a Green Tint —

This solution will produce a "verde antique" or rust green:

3 oz. crystallized chlorid of iron
1 lb. ammonia chlorid
8 oz. verdigris
10 " common salt
4 " potassium bitartrate
1 gal. distilled water

If the objects to be colored are large, the solution may be applied with a brush. Several applications may be required to give the desired depth of color. Small work should be immersed and the length of time it remains in the solution will govern the intensity of the color. After immersion, stippling the surface with a soft round brush dampened with a solution will give it the variegated appearance of aged brass or bronze. This formula produces a very pleasing effect when used on some of the old muzzle-loading rifles.

Formula No. 46 — Blackening Brass —

There are many different processes and solutions for blackening brass. During the World War the aircraft ammunition was given such treatment to identify the tracer and incendiary cartridges. The projectiles of the incendiary ammunition were blackened as well as the cases of the tracer cartridges. It was therefore necessary to employ two distinct solutions to perfect the required blackening process. Trioxid of arsenic, white arsenic, or arsenious acid are different names of the chemical most commonly used. It is the cheapest substance we know of for producing black on brass, copper, nickel, German silver, etc., but has a tendency to fade; however, a coat of lacquer will preserve it for a long time. A good black is produced by immersing the work in a solution composed of:

2 oz. arsenic
5 " cyanid of potassium
1 gal. distilled or rain water

This should be boiled in an enamel or agate vessel and used hot.

Formula No. 47 — Blackening Brass —

Another cheap solution is composed of:

8 oz. sugar of lead
8 " hyposulfite of soda
1 gal. distilled or rain water

This must also be used hot and the work afterward lacquered to prevent fading. When immersed, the brass first turns yellow, then blue, and finally black, the latter being a deposit of sulfid of lead.

Formula No. 47 — Gun-lock Varnish: To Preserve Colors —

After a part has been given the desired color, it is washed in water and then dried in clean sawdust. The colored surfaces of alloys are in many cases protected and preserved by coating with a colorless lacquer, of which Japan lacquer is an example. Small parts are coated by dipping and large ones by coating with brush or swab. They can then be washed without injury.

When it is desirable to preserve the brown finish on parts, such as the barrels, etc., the lacquer or varnish is prepared as follows:

Dissolve 10 parts clear grains of mastic
15 " sandarac
5 " camphor
5 " elemi

Use pure grain alcohol to secure the desired consistency. The articles treated with this varnish will not only be preserved from rust, but their metallic luster will not be in the least dimmed by exposure to dampness.

Another varnish may be made as follows:

Formula No. 49 —

1 oz. gum shellac
1 " gum sandarac
30 cc. Venice turpentine
1200 cc. alcohol (pure grain spirits)

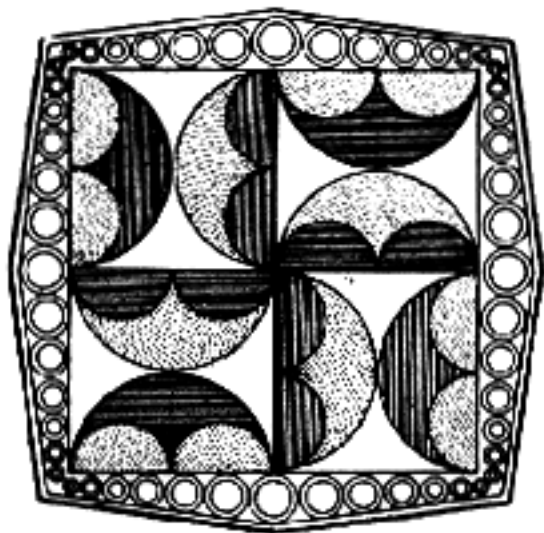
These two formulæ are also known as gun-lock varnish and may be used for case-hardened parts as well. Articles thus treated will have the case-hardening colors accentuated; the treatment acts also, in a measure, as a preservative.

Receivers, floor plates, trigger guards, butt plates, sling swivels, etc., are rather difficult parts to blue because they are thin, and it is no simple task to attach suitable holders for handling. All such parts can be blued in much the same manner and by the same solutions.

Receivers: First, all screw holes must be plugged by tightly screwing wooden plugs into them. Let the plug which is screwed into the threaded end

CHAPTER XVII

Care of Firearms: Cleaning Bores and Removing Obstructions



Care of Firearms, Cleaning Bores and Removing Obstructions

AN ASSOCIATION of several years with the average American rifleman has convinced me that there are two leading schools of thought regarding this matter of cleaning firearms; the first comprises the serious-minded individuals who take to it as a sort of religion, while the second looks upon it as a curse. The members of the former are forever cleaning and scrubbing away at their arms; those of the latter, negligently, if ever. The introduction and universal use, during recent years, of the non-corrosive type of primer, with the widespread advertising that it is no longer necessary to do any cleaning of firearms, has resulted in a great many converts to the non-cleaning sect—and in a great many ruined rifle bores.

I am still of the opinion that it is necessary to clean the bore of a rifle after firing, and I still clean just as quickly as I can after shooting the gun. I do not consider that this new non-corrosive type of primer is as yet the perfect product the manufacturers would have us believe. Certainly they have yet to produce a stable priming mixture which will stand up in a hot and humid climate for any appreciable length of time. A number of my readers may question the necessity of the instructions which follow, but I am basing my opinions on the great number of ruined rifle barrels which have been brought to me of late—barrels in which nothing but the new types of ammunition have ever been used, and yet which are pitted hopelessly beyond removal. I admit that in the majority of cases the primer acts as claimed, but I also know of a sufficient number of instances where it does not; hence I shall give instructions for the proper cleaning of firearms irrespective of what type of primer may have been used. It should also be kept in mind that there are other parts to a firearm besides the bore—parts which will rust as readily from the mere handling of the arm or from its exposure to the atmosphere and elements.

As a first consideration it is well to take up the exterior treatment—the means by which the barrel and mechanism are kept clean and free from rusting. Many owners who are careful to the extreme in attending to the care of the bore of their rifles are at times neglectful of their external condition and appearance. Human perspiration comes first

as a rust-producing agency on the outside of firearms, and it is especially destructive to appearance, because rust resulting from the contact of bare hands forms tell-tale patterns of the thumb-print order all over the barrel and grip. It is an odd fact that some persons are not so provocative of this fault as others. There are people who can pick up and handle a rifle without rusting it in the slightest, while others will badly rust whatever part their hands touch. Goutily inclined persons are especially bad in this latter respect; and any gun owner who is conscious of this condition—as shown, for instance, by the inability to keep a bunch of keys in a bright condition—should be especially careful of the manner in which he picks up firearms and should be generous in the use of an oily cloth whenever he handles his own guns or guns belonging to others.

There is one very simple method by which any one may keep his firearms in perfect outside condition; and yet, strange to say, it is an idea seldom encountered. It consists of keeping always at hand—on the workbench or in the gun cabinet or cupboard—a special small jar containing one or two pieces of well-oiled chamois. Get a small stoneware or metal jar having a loose-fitting top to keep out dust, and in it always have an oiled fine chamois cloth ready for use to wipe over the outside of any firearm after handling. It takes but a moment to run this cloth over the entire surface of the arm, and the habit of always doing this before laying the arm away will keep the exterior clean and free of rust. This very simple expedient should be known to all shooters, yet it is seldom one finds such a logical preventive at hand. The most common method of wiping off the outside of an arm seems to be the use of the last patch with which the bore was oiled. The oily chamois and jar at hand will enable the rifle to be wiped off every time it is picked up. Use a chamois about fifteen inches square, and oil it well with the gun oil mentioned in Chapter XXV, Volume I.

Another simple expedient which every shooter should become acquainted with is the use of a small camel-hair brush in oiling the inside or the mechanism of firearms. Whenever it becomes necessary to lay away a gun for any length of

time, the outside should first be covered with a thorough coating of heavy oil or thick-bodied gun grease. The simplest manner in which this can be applied is to paint it on well with a small flat varnish brush, say about one-half inch in width. Such a brush works readily into all cracks and angles, or into any part of the mechanism. When laying the arm away, the best grease to use is the gun grease described in Volume I; this can be heated slightly until it flows readily from a brush, and it will then cover perfectly.

A smaller artist's brush, say about a No. 10 size, is best for working oil in the mechanism of the action; also for the proper cleaning out from the mechanism of any dirt or unburned powder grains. Another thing worth knowing is to use a squirt oil can filled with gasoline to wash out parts of the mechanism hard to get at with the cloth or brush; in fact the entire action of the rifle can be cleaned by this method in a few seconds.

The rifleman who is in any way careful of his rifles is generally well equipped with cleaning rods, brushes, patches, and oilers; but it is seldom you encounter such elementary preparations as the oily chamois, oil brushes, or squirt can. Yet these are about the most effective means possible to employ in the care of the rifle.

Naturally, there will be many occasions when the firearm will become subject to rust through exposure to snow or rain, or to the moist air around salt water. When a gun has become coated with water or snow, the very best thing to do upon getting inside again is to lean it, muzzle down, close to a hot stove or open fire and allow it to dry out thoroughly. Then immediately go over its entire surface, mechanism, and bore with suitable cleaning cloths and oils; get a protective coating of oil on it just as soon as possible. Salt-water exposure induces exceedingly persistent and dangerous rust, which only constant vigilance and care can counteract. The very air about salt water will rust a gun, and it is not a wise procedure to use the best-grade weapons around the seacoast. To the sportsman who is taking a brief trip over salt water I would suggest the painting of his barrels and exterior metal parts with one of the gun-lock varnish formulas given in Chapter XVI, plus a coating of heavy grease. If the exposure is constantly repeated a permanent remedy may be provided, admittedly at the expense of appearance, by painting the entire exposed steel parts of the arm with a good spar varnish.

Despite almost constant care and attention there will be times when small patches or spots of rust will form in places on a barrel and action; these can best be removed by means of fine steel wool.

After burnishing off any rust with steel wool, always go over the spot with the oily chamois and rub the oil in well. A particularly bad patch of rust may necessitate the rebluing of the entire part by one of the formulas given in Chapter XVI.

Once the exterior of the firearm is properly cleaned and oiled, the arm should be put away so that atmospheric changes or humidity will not rust it unknown to the owner. Nothing can be more fatal at times than the mere standing of a rifle in a corner of the room and leaving it there for weeks without touching it. This is especially risky if the room is steam-heated, as condensation of moisture from a leaky radiator can quickly cover the entire rifle with red rust. A cold attic or unused room without heat is also bad, as sudden climatic changes may settle moisture on everything, and then rust promptly follows. Also, women and servants have a provoking habit of unthinkingly picking up a rifle by the barrel with wet hands. The best possible storage is in a properly-made gun cabinet with the door kept closed and locked. Not having this, the next-best place is a small cupboard, first slipping the rifle into one of those full-length flannel covers. The conventional full-length canvas cases are also very good, and if the rifle is to be left in a corner of the room or behind the door it should be in one of these by all means. Any kind of case is better than none, provided there is nothing in the material of the covering to cause rust.

The owner is advised to make periodic inspection of his firearms, not necessarily on particular dates, but often enough to prevent long periods elapsing during which an unsuspected lodgement of rust may be working havoc. Such a precaution is also desirable in view of the ever-present possibility that the use of a new primer, powder or gun oil may produce unexpected results.

Cleaning the Bore — The procedure invariably followed by the individual rifleman in cleaning his rifle is to lay out on a convenient table-top all the rods, brushes, patches, cloths, oils, etc. Holding the rifle in one hand he proceeds to pump patches up and down the bore with the other, the muzzle being on the floor. This is an awkward and inconvenient manner in which to work.

Perfect cleaning of a rifle bore can best be effected by the aid of a suitable vise; the shooter will experience a wonderful increase of convenience after installing this fixture on any available work bench. The gunsmith who reads this book will naturally have a proper vise at hand, but to the active sportsman I recommend the purchase of a small parallel vise. One such as the Stanley #776 can be purchased for about \$4, and it is entirely

satisfactory for all cleaning purposes. As a steel-jawed vise is apt to do more harm than good unless fitted with suitable padded jaws, it will also be necessary to make or obtain these. Volume I, Chapter II, describes the proper type. For cleaning, the felt-lined jaws are essential. As the vise will be clamped to a substantial work bench and used mainly for cleaning and similar purposes, you might as well go ahead and fit it up with a few other cleaning conveniences. Fit a gunmaker's brace or bench horse, as shown in Chapter II, Volume I. Notches can be placed on the back arm of this brace for the purpose of keeping the cleaning rods out of the tools and litter which will soon clutter up the bench top.

With the rifle clamped tightly between the felt jaws of the vise, you can use a much tighter cleaning patch than in the extemporized operation on a kitchen table. A word of caution is advisable here: never clamp the vise too tightly on the barrels of a shotgun—you may collapse or dent the tubes. The lumps are the correct place to hold these barrels while cleaning.

A proper understanding of the principles of rifle cleaning is necessary to obtain the smallest expenditure of labor and material. The mechanical treatment consists in reaching into every part of the bore with a patch until the sharp corners between the lands and grooves are scrubbed clean and free of fouling. The chemical treatment consists in the use of boiling water or a suitable powder solvent of special penetrating powers capable, when applied, of neutralizing acids or other harmful residues of fouling. Both treatments are interwoven, and the two can hardly be separated except in theory; in practise they operate in unison, and the rifleman should understand this cooperation; he will then realize that elbow grease alone is but a partial remedy for the rusting proclivities of rifle bores.

Judgment should be exercised in the selection of cleaning rods and cleaning tips capable of pressing a patch almost as tightly as the bullet itself into the grooves of the rifling. In Chapter II is a complete description of how to construct these rods. Good rods are scarce, and once a good one is obtained it will pay to keep it in proper shape. A rack for cleaning rods, built on the order of a billiard-cue rack but with the rods hanging free from a notch, will keep them clean and straight—and ready at hand.

In addition to a series of proper-sized rods for cleaning, the gunsmith's shop will need to keep on hand a few heavier rods for drilling and driving out obstructions, and it will pay to lay in a few standard sizes of drill rod in 36-inch lengths for this

purpose. The following tabulation indicates most suitable sizes for the various calibers:

<i>Caliber</i>	<i>Land Diameter</i>	<i>Full-size Driving Rod</i>	<i>Drilling Rod</i>	<i>Drill Size</i>
.22	.217	No. 3	No. 3	Size 5
.25	.250	$\frac{15}{64}$	$\frac{15}{64}$	C
7 mm.	.276	$\frac{17}{64}$	$\frac{17}{64}$	$\frac{17}{64}$
6.5 mm.	.256	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
.30	.300	$\frac{19}{64}$	$\frac{19}{64}$	$\frac{9}{32}$
.32	.311 app.	$\frac{19}{64}$	$\frac{19}{64}$	
.38	.350	$\frac{11}{32}$	$\frac{11}{32}$	$\frac{11}{32}$

With the right-sized rods at hand, the shop will be prepared to undertake properly the removal of any obstruction; repair jobs of this kind are always wanted in a hurry, and there may not be time to get a drill that is not in stock. The use of too small a drill in an emergency may ruin the barrel.

As every one knows, the simplest and safest method of cleaning the rifle bore is to pour through it a few quarts of hot water—the hotter the better. Once the bore has been dried—through the combined action of the heat of the barrel and a prompt wiping with dry patches—it can be oiled with a good gun oil and laid aside with the feeling that things are right. However, it is an odd fact that, simple as this hot-water treatment is, there are few occasions when it is adaptable to the immediate needs of the average rifleman; and it is invariably more convenient to clean the rifle bore by means of one of the many commercial solvents or gun oils now on the market.

To start the cleaning process, push a dry patch through the bore to remove the loose residue and dirt, which is plainly visible and will only clog the scouring brushes which are to follow. If desired, this dry scrubbing may be followed with another patch dipped in powder solvent. Should the rifle have been neglected too long, so that the fouling has dried up, it will be best to use an oiled patch the first time to obviate any risk of its sticking in the bore.

There are three different types of rifle-cleaning brushes of a good substantial make. First, there is the steel brush, then the bronze-bristle brush, and the bristle brush. Begin by dipping the bristle brush into a suitable powder solvent. Don't make the mistake of dipping a dirty bristle brush into a bottle of clean solvent; this only contaminates the latter with residue—and annuls its usefulness. Keep the bristle brush clean by squirting a few jets of gasoline over it when through using, and it will be in proper shape for the next occasion. Give the bore a good scrubbing with the solvent-soaked brush; use full-length strokes which will completely loosen up all residue, and then follow with a patch or two to clear out the bore of all loosened fouling.

It may be well to follow with another scrubbing, using one of the bronze-bristle brushes this time; or possibly a "one way only" brush, which is made of fine steel wire and is very thorough in its action. Some shooters consider the last-named brush a bit too drastic for use in a rifle bore, but if properly used it will do no harm. Suit yourself as to the brush used, but a good scrubbing with any of these brushes is much better insurance of a clean bore than a long-continued rubbing with cloth patches and elbow grease.

Having scrubbed and scoured the bore clean of all corrosion, wipe it out dry of all solvent, and coat the entire surface with a good-bodied, pure gun oil or grease. A great many shooters are of the belief that it is possible to combine a satisfactory gun oil with a powder solvent, making the one solution do the work of two. This erroneous idea generally results in a ruined barrel. A powder solvent should be light-bodied, thin, and penetrating, so that it will readily spread over the bristle brush and penetrate into all the corners of the rifling; also, it should wipe out easily and cleanly by means of a suitable patch. Such a thin-bodied oil will not remain evenly on the metal surface of the bore for any length of time, but will soon evaporate or run, leaving patches of steel bare and subject to the rusting influences of the atmosphere. What is necessary for this second or protective oiling is a pure, heavy-bodied oil or grease which will "hold" on the metal surface through extremes in temperature or the passage of time.

Powder Solvents — There are a number of satisfactory commercial powder solvents now on the market, most of them standardized as to amount in the bottle, price, and directions; you "must shake well" and "use freely." In general they are a mixture of thin-bodied oils tinted to an attractive color and containing one very potent smell. Any of these will do the work if used in accordance with the directions I have just given. But the formula given in Chapter XXV, Volume I, is as good as the best of them when it comes to dissolving powder residue and fouling; and it can be compounded by the shooter himself.

The above-mentioned solvent is designed for use in thoroughly cleaning out the powder residue and fouling left from firing; it should be applied according to the instructions in the preceding pages, and then completely cleaned out of the barrel, as any traces of the solvent remaining in the bore will dissolve oil and expose the metal to the action of rust through moisture. Do not labor under the impression that it is possible to combine a solvent with an oil.

Gun Oil — After the solvent has done its work and been promptly removed from the rifle bore, it is necessary to use a protective coating of some suitable gun oil. The fact that there are few oils fit for this work or for lubricating the mechanism of firearms does not seem to be commonly known; arms are continually coming in so badly gummed-up that special treatment is necessary to get them apart and to clean them. This is especially the case when linseed or castor oil has been used as a lubricant—not as rare an occurrence as you might think. The finest lubricant or bore protection we can use is the best quality of sperm oil.

Further information relative to oils and lubricants will be found in Chapter XXV, Volume I.

Any firearm may be kept in perfect condition by the methods I have just outlined; and it is not much of a job if taken in time. The best incentive, and a labor-saving device as well, is to have available the necessary materials for proper cleaning—and have them conveniently arranged for prompt use when needed.

There is another type of fouling which occurs in the bore of the high-velocity rifle at times, and this calls for the use of the metal-fouling solution.

Metal-fouling Solution — The gunsmith is often called upon to remove metal fouling from the bores of high-velocity rifles. This requires a special process—a very simple one when understood. Such fouling consists of patches of metal left in a rifle barrel from the jackets of bullets, particularly when using bullets having jackets of "cupro-nickel." This metal is fast disappearing in the manufacture of jacketed bullets in the United States, but in England and Germany they still use cupro-nickel bullets. The present manufacture of bullets in this country is from gilding metal or an alloy of copper. Some are made with the pure copper, which is rather a soft material to use. But the gilding metal, as used by the Frankford Arsenal for the manufacture of the National Match ammunition, is a much harder alloy which gives better results in accuracy and reduces the problem of metal fouling to a minimum.

To determine the presence of metal fouling in the rifle bore, first clean it with the powder solvent and then thoroughly clean and dry the bore by using clean patches. Examine from both the muzzle and chamber ends by holding it in a good light; the presence of metal can be detected in different forms such as long streaks, small flaky spots, or even lumps and smears adhering to the lands and grooves. When any such condition exists it should be removed at once, for it will interfere with accuracy, and if left long enough, rust will form

under these patches and in a short time you will have a ruined barrel. The formula for metal-fouling solution is given in Chapter XXV, Volume I.

The "doping out" of rifles was an essential operation for military rifle shooters during the years 1908-1920, but it is not a common procedure now. It is advisable to apply the treatment to any high-velocity rifle that is being laid aside for a long period, or to a barrel used in important matches, where the highest possible accuracy is necessary. The presence of metal fouling can best be determined by the use of a gauge plug such as manufactured by the A. G. Parker Company of Birmingham, England, and a few of these plugs are an essential part of a shooting kit.

Cleaning the Neglected Rifle Bore — The experienced rifleman looks upon the average shooter who permits the bore of his rifle to become rusted, as a pretty careless individual. True, the largest percentage of such cases is due to carelessness; but, on the other hand, rust is often attracted to even the experienced shooter's arms. No one ever hears of this, however, for it is removed as soon as discovered. But as a general rule, when a rifle barrel comes into the gunsmith's shop for cleaning it will have corroded beyond repair. The most common models will be the .22-caliber rifles ranging in price from \$4.95 to \$17.98; the owners of these arms seem to figure that a .22-caliber gun need never be cleaned. Most .22-caliber barrels are made of low-carbon steel, and because of their softness are readily damaged by rust; greater care must be given these arms than is necessary in the case of the harder and tougher barrels of modern high-velocity rifles.

In a number of instances the rifle barrel has been neglected for only a few days, but as the weather has been mild and the humidity low, only a light coating of rust has formed. This can readily be removed and the barrel be returned to proper shape by using a bronze-bristle brush dipped in powder solvent and the bore given a thorough scrubbing. Keep the brush well saturated with the solvent and scrub the barrel well. Wipe clean with patches, and inspect. If you should find a dull appearance in the bore, try one of the "one-way" steel-bristle brushes, working this back and forth but taking care not to let it run out at the muzzle until you consider this scrubbing operation finished. This should brighten up the bore sufficiently, but it may be necessary to use one of the lapping operations described in Chapter XVIII. In fact, a lapping operation is the last step necessary to restore the bore to its original condition if any degree of rust has formed.

There will be various stages of these rusted and semi-rusted barrels, and the exact treatment depends upon the degree to which the bore is affected. After you have tried scrubbing with the powder solvent on the metal-bristled brushes, should the bore still appear dull, I suggest filling the barrel with fresh cow's milk—as fresh and warm from the cow as you can get it. This may seem like a strange remedy for the rust which has begun to attack the bore, but I have found it an excellent one. Come to think of it, this is not such an odd preparation, after all; it is only recently that the scientists of this enlightened day and age have succeeded in mixing oil and water together, and the results of their efforts are being highly recommended for use in rifle barrels. Now, cow's milk is also a most satisfactory, if older, mixture of water and oily fat which, when fresh, remains in a perfect state of mixture and suspension.

Another treatment often recommended is the use of the cleaning funnel and hot water. Altho this is conducive to the removal of powder and primer residue, or for dissolving any harmful chemicals which may have been left in the bore, it is not of much value for removing rust. Hot soapy water or soap-suds have also been recommended, but I consider the fresh cow's milk far better than either.

The semi-rusted barrel may often be restored to its original condition of brightness by use of the following lapping compound. Mix pulverized Vienna lime with straw-colored paraffin oil to the consistency of a paste. Vienna lime has a polishing effect on metal only, and will do no harm whatever to a rifle bore as an abrasive may. This polishing preparation is used on a felt or leather lapping rod such as described in Chapter XVIII; or it may be used by taking a worn bronze-bristle brush, wrapping it with a cotton-flannel patch, and screwing this on the end of a cleaning rod. Keep this brush well supplied with the compound, work it from breech to muzzle for about half an hour, and the bright finish will be restored to the bore.

Pitted Rifle Bores — The badly pitted rifle bore is a serious problem, and it is not often that it can be restored properly without reborring the barrel, which means giving it a different caliber. About the only thing you can do is to scour out or lap these bores to a semblance of their former condition; often this leaves the rifle in as good shooting condition as before, provided appearance is not being considered.

The lapping operation is always the final step in scouring out the badly rusted or pitted barrel, but there are various means of leading up to this. First, wrap a flannel patch around a worn bronze-bristle

brush and coat or soak it in a paste made of fine flour emery and olive oil. This is pulled back and forth over the surface of the bore until you have a bright surface above the pits. If you have a very bad case of rust, apply the rust-removing formula given in Chapter XXIV. This will prove effective in most cases, but if desired results are not obtained, try the pickling solution given in the same chapter. When using either of these solutions, the chamber must be plugged very tightly and the muzzle protected with the rubber hose as prescribed for the treatment given for metal fouling. With either of these treatments, and especially the latter, the solution must not remain in the barrel any great length of time, as its action is rather severe. After either treatment strong ammonia must be poured into the barrel to neutralize the effect of the acid on the steel. Then wash out and clean the bore as when using the metal-fouling solution.

The last step in treating any bore rusted so badly as to require the application of a rusting or pickling solution will consist of a thorough lapping out, following the general procedure as outlined in Chapter XVIII. Before doing any of this it will be well to measure the bore by forcing a lead slug through it from breech to muzzle; this will give you an exact index to its size and will detect any tight or loose places throughout its length; should any be found, they can be corrected by proper lapping methods.

All the advice given above will never remove deep rust pits which have eaten their way into the steel; the best you can do is to scour out the barrel and smooth it up to some extent; its accuracy is gone, but in most cases the rifle can be made to perform very well as a knock-about gun. In many cases a new barrel is much cheaper in the end, unless in trying out all this you only wish to carry out experiments and methods for your own satisfaction and experience; then the results are well worth the labor. But for the complete restoration of a ruined barrel, nothing has yet been discovered.

Cleaning Shotgun Barrels—You may have noticed that the greater part of the information and methods covered in the preceding pages have been devoted to rifles and the rifle users. It is a fact that these are about the only shooters who take their art seriously when it comes to cleaning their arms. And it is also a fact that the well-to-do shotgun owner who would not give a second thought to paying \$500 for a high-grade scatter gun will not give even a first thought to the cleaning of that fine arm after he has shot it. Rather than go to the trouble of cleaning a shotgun, some men postpone the task until they can take it to a

gunsmith before the opening of the next hunting season. And then they casually remark just before they leave, "I'll leave this gun here for a day or so for you to look over; and, oh, by the way, I don't remember whether I cleaned it or not the last time I used it." Before you have an opportunity to inspect the gun, they disappear. And after the accumulation of rags, residue, rust and what-not has been removed from the bores, those barrels generally need lapping out or possibly reboring to remove the bad pits.

It is just as important to keep a shotgun barrel clean and spotless as it is a rifle or pistol barrel; that is, if one expects the proper results, with a pattern that shows every possible pellet within its killing circle. The badly deformed pellets which leave the pattern (called flyers on this account) are mostly caused by coming in contact with the deep pits scattered along the bore. The smooth and even bore of the shotgun allows us to clean and keep it in perfect shape much more easily than in the case of the uneven lands and grooves of the rifle or revolver. The methods and formulas I have given for use in rifles will work equally well in the shotgun.

If in a semi- or lightly-rusted condition, the same treatments may be applied to shotgun bores as I have given for rifle barrels. All that is generally necessary for the slightly-rusted bore is to wind cotton-flannel patches around a suitable barrel scourer and then use the Vienna lime lapping compound to bring back the high polish. And since there is such a large inside diameter to work to, by making suitable lapping rods it is an easy matter to draw-polish the bores. Figure 96 illustrates these rods, made with small wooden adjusting screws which are necessary to keep the laps always up to the full diameter of the bore, and so they will always properly perform the polishing operation. The degree of rust may be such that a compound of flour emery or rouge may be necessary to apply to the laps; this is a matter soon learned by experience.

Make up a number of these laps ahead of time and have them ready for use. Coat them with a very thin glue and then cover the surface with the lapping compound and let stand for at least twelve hours before using. Some may have fine emery or crocus cloth glued to the surface, while one or two will necessarily be prepared to use a light lapping compound for only a bright polish.

When a shotgun barrel is full of deep pits, it will be better to rebores it, provided the thickness of the barrels will permit such an operation. But if the defects in the bore are less severe, they may often be polished out with a number of hand operations.

and these will have no serious effect upon the patterns. Naturally the bore will be somewhat enlarged, but as you will be using the abrasive material from the breech end, such a slight enlargement usually improves the patterns, provided they are even and turn toward the muzzle. When working close to the muzzle, try not to bell-mouth the extreme point of delivery—the end of the bore.

If deep rust pits have appeared in a Damascus barrel, it is ruined, because the rust has eaten out the iron strands between the steel and it is almost an impossibility to rebores the barrel without enlarging it to such an extent that standard wads will not hold back the powder gases. It would be extremely dangerous to use such a rebored barrel with modern high-velocity shotgun ammunition.

There is one serious menace to shotgun barrels which I might as well mention here, and that is the cotton ropes, or barrel wicks, which are sold for the purpose of preventing barrels from rusting. Contrary to expectations, they generally rust the bore completely in time. The fault lies in the fact that the oil or grease with which the rope is impregnated has dried out and left the cotton dry. Moisture then collects and is retained by the cotton, causing heavy rust in the bore. And I have removed many of these ropes from shotgun and rifle barrels which were covered with heavy rust from using the wrong oil or grease, the owner having regreased them with what he considered a correct protective oil, but which rapidly dried out. These ropes are particularly destructive in a Damascus barrel, as when rust sets in, it rapidly eats out the iron from between the steel, as mentioned above; often such rust will eat completely through the barrel. They are equally bad in rifled arms and in smooth bores. If you must use them, see that they are kept well lubricated with one of the oils or greases I have mentioned previously, as many of the light oils or solvents on the market are unsafe for such use. However, my advice is to use only the proper oils or grease and exclude the ropes altogether.

After being cleaned of rust of any nature the shotgun barrel should always be given a mirror-like finish or high luster. If a barrel picks up lead excessively it is an indication of minute circular grooves or scratches, which at times are not perceptible to the naked eye. If much of this is in evidence, very poor patterns are the result and the gun should be bore-polished.

Removing Obstructions from the Barrel—Whenever a rifle or shotgun is brought to me for the removal of some obstruction in the bore, I cannot help laughing as I imagine the surprized owner's

bewilderment and dismay when it happened. To listen to his explanation and scrutinize his countenance is enough, for his sheepish expression divulges all. If I could enumerate all the various materials I have removed from rifle and shotgun barrels, the list would cover this page and would consist of such extremes as taking a coat-sleeve lining from a 12-bore shotgun down to working on a .22-rifle barrel filled with cement.

No one puts a piece of some foreign material into a barrel with any intention of its sticking; but, strange as it may seem, it usually does. The .22-caliber rifles and shotgun barrels seem to have the greatest trouble of this kind. In the .22 the two articles which are the worst offenders are broken brass cleaning-rod tips and lodged bullets. Shotguns come in wadded tight with a mass of cotton rags, often rusted in and making one of the most troublesome things to remove. Most of these obstructions have become lodged through carelessness; and in the excitement which ensued, and the frenzied efforts to render first aid with anything that came to hand, the obstruction has only become wedged in all the more tightly. Often, in these first hasty efforts to drive the obstruction out, the barrel has been ruined.

When a solid substance such as a bullet becomes lodged in the barrel, it is invariably most satisfactory to drill it out. Select a drill about 0.010-inch under the bore diameter (top of lands). Turn the shank end down to a suitable size for about a half-inch in length, and then drill the end of a rod (drill rod is the most suitable), selecting the size which will just clear the bore diameter. Sweat the drill and rod together, care being taken to have the drill perfectly true and in line with the rod. Such an extension drill may be used in the hand drill or brace, and it is an easy matter to drill out, in a few minutes, any solid obstruction which may have become lodged in the rifle bore. Should the obstruction be in the form of cotton or cloth, do not attempt to drill it out, but use a special wormer. This will be described later.

When drilling out any irregular obstruction of metal such as part of a brass cleaning rod or tip, great care must be exercised in making the extension drill so that it will run perfectly true on the end of the drill rod. Use a drill about $\frac{1}{64}$ inch smaller than the bore of the rifle, and a rod as near the diameter of the bore as possible. Aline the drill to the rod very carefully. The point of the drill must be ground close to a 60-degree angle, which is about 30 degrees to a side, in order to hold to the center and not run out while drilling, as this would cause it to gouge out one side of the rifling.

One of the most difficult things to remove from a

rifle barrel is cotton after it has become rusted. This generally clings to the bore so tenaciously that it is necessary to make up a special "wormer" and pick it out piece by piece. When an obstruction has become lodged in the barrel in the form of a piece of cloth, the first and best policy is to pour a liberal amount of light paraffin oil into the bore and allow it to stand for an hour or so, or even over night. Reverse the barrel and pour the same amount in from the opposite end, allowing it to remain for a similar length of time. Then "feel" the obstruction by trying to tap it out with a close-fitting, square-ended rod; and if a few moderate blows will not start it out you will have to pick it to pieces. Solder a suitable-sized wood screw on the end of a steel rod and remove the material by screwing this into the cloth a bit at a time, gradually getting out what is possible until the complete mass is removed. A similar type of "worm" may be made by filing a specially pointed thread on the end of a drill rod and using it with a tap handle clamped on the opposite end.

Once the drill has penetrated an obstruction it is generally an easy matter to drive it out with a rod made flat on the end; in fact, there are many occasions when a solid obstruction may be driven out of a rifle barrel by means of a suitable driving rod. The diameter of such a rod should be near to that of the bore and the end should be flat and full size. First oil the bore thoroughly from both ends and then set the driving rod up firmly against the obstruction; now take a heavy hand hammer of about four or five pounds weight, and give one or two solid blows to the rod; if this does not start to move the obstruction—stop! You have a job of drilling on your hands.

In general, this attempting to drive out an obstruction is wrong, merely because too light a hammer and too small a driving rod are used. The average shooter almost always attempts to use a regular cleaning rod and a bench hammer for the operation. When a small end rod is used, the result is invariably a wedging into the obstruction while the comparatively light blows resulting from use of the average hammer only expand the mass and cause it to grip all the tighter. What is needed for a driving operation is a full-sized, one-piece, flat-ended section of drill rod and a heavy hand hammer. Hold the driving rod steadily against the obstruction and strike a solid blow, with the barrel clamped *firmly* in a heavy vise and everything good and solid so nothing will move but the obstruction. This operation, remember, is only performed on rifle barrels; never attempt to drive any obstruction out of a shotgun barrel, as the walls are too thin.

When the .22-caliber rifles, especially the cheap factory arms owned by the average boy, have a bullet lodged in the barrel, the owner's first idea is to shoot it out. The first trial is probably not a success, so he continues to fire additional shots until the bore is full of lead bullets and the barrel entirely ruined. However, this will not seriously affect the rifle in the owner's opinion as long as it can be made to shoot again. These bullets must be drilled out, and the barrel must then have a mercury treatment to remove the lead from the grooves. Here is the procedure:

Mercury Treatment for Lead Fouling — Mercury or quicksilver is the small-bore shooter's special friend when it comes to removing lead from the bore of his rifle. Lead fouling in a .22 rifle is somewhat similar in effect to metal fouling in a high-velocity arm, and can usually be removed with a bronze-bristle brush. When a vigorous scrubbing with the brush fails to bring about the desired results, we apply the mercury treatment. Quicksilver has a strong affinity for lead, and an application of it will completely free the lands and grooves of the metal. First thoroughly clean the rifle bore, eliminating all oil and grease; then place a tight-fitting cork or soft wooden plug in the chamber end. With the butt of the rifle resting on the floor and the barrel clamped perfectly vertical in the vise, pour enough mercury into the barrel so that it will come flush with the muzzle. Let it stand this way for between thirty and forty minutes and then pour the mercury back into its bottle, as it can be used over and over again. After pouring back the mercury, remove the plug from the chamber, wipe the bore clean, and examine it in a strong light. Should any fouling remain, run a *clean* bronze-bristle brush through the bore several times and then repeat the process. A single treatment is usually sufficient for any .22 barrel, however.

It only requires a very small patch of lead fouling in a .22 barrel to cause it to shoot inaccurately; frequent examination of the bore for this trouble is always necessary, especially on target rifles. Many shooters carry a complete set of barrel plugs, running from .216 to .219 inch by half-thousandths; these are especially useful in determining the presence of lead in the bore. If you have a small-bore barrel which is continually picking up lead you should examine it carefully for the presence of tool marks or a rough spot on either the lands or grooves. The only treatment which will repair this defect is to lap the barrel.

One encounters some amusing displays of ingenuity at times in connection with lodged bullets. Once on a hunting trip in Northern Quebec, I

failed to take along a .22 rifle for grouse; so I used a Model '90 Winchester belonging to a trapper with whom I was staying. There were five rings on the outside of the barrel, caused by trying to shoot out lodged bullets; and the inside of the bore was a sorry sight. A cleaning rod had never been used; instead, when a bullet had lodged it was finally melted out. I at once passed up this rifle as hopeless, but the trapper insisted that it was as fine and accurate a gun as he had ever owned. I was somewhat amused and incredulous, so to prove his statements the owner placed the cover of a small magazine on a tree a good thirty yards off, and out of the five shots he fired at it, every one was well centered on the paper. I could scarcely believe my eyes; and when I took the rifle and did as well I was completely baffled. One of the rings in the center of the barrel bulged out until it was very noticeable. But in spite of all this I never missed a grouse with it and the shooting of that rifle will remain one of the unsolved mysteries of my life.

This melting out of a lodged bullet is quite frequently done, but it is a bad mistake as heat should never be applied to a rifle barrel to remove any obstruction. It must be remembered that there is always some mechanical means at hand, if only you can use your ingenuity and figure matters out calmly and logically.

Obstructions in Shotgun Barrels—The commonest obstruction we find in shotgun barrels is invariably a tightly packed wad of cloth, caused either by ignorance of proper cleaning methods, or by a desire to protect the bore more fully from rust. In the former case the owner tries to ram a red flannel undershirt through the barrel, only to have it stop midway and refuse to function any further in either direction; in the latter the more careful and conscientious owner does what he believes to be the right thing and stuffs some oiled rags in both muzzle and breech ends of the tubes before he lays the gun away for the closed season. The oil soon evaporates, or the rag in the breech is forgotten and unthinkingly shoved forward into the barrel—and it sticks there. This idea of protecting the bore from rust by sealing both ends is entirely wrong, and such a thing should never be done; keep all corks, rags, tissue paper, and ropes out of shotgun tubes. Clean the bore properly with extra care, grease it heavily with some pure and heavy gun grease, slip it into a case, chest or gun cupboard where it is protected from sudden atmospheric changes, and the barrel will never rust.

But we are concerned here with some cloth obstruction that has been wedged into the barrel. The best and safest method of removal is to pick

the material out piece by piece with a shotgun wormer, which can be obtained from any dealer in gunsmith supplies. It is somewhat different from a rifle wormer, being made just like a corkscrew, but with two "threads," and will fit any standard cleaning rod. It may be necessary to soak the obstruction with oil for several hours, and then to work from both ends of the barrel; but one seldom encounters a job where the cloth is wadded so tightly that the wormer will not bring it out.

A particularly bad obstruction to take from a shotgun tube is a tightly wadded cleaning patch which is fastened in the rod tip or brass eye; this cannot always be picked out. Sometimes a patent brass cleaning brush will break off in a barrel, and this also is hard to operate on with safety. It may be advisable to try drilling out such obstructions, in which case a drill on the order and size of the regular rifle-barrel drill described in previous paragraphs is used. This had better be of at least .30 caliber and it must be used only through a bushing made a close fit to the barrel. Thread the drill rod through the bushing and keep the latter as close to the obstruction as possible while the drilling is done. In this way the drill is kept to center of the obstruction and will not run off center and drill through the side of the barrel. On a particularly obstinate case, work from both ends of the barrel. Once the drill has penetrated, try the wormer.

Shotgun tubes are surprizingly thin between the choke and cone areas, and it is very easy to bulge them out or break through by harsh or improper methods in work of this nature. For this reason it is invariably a mistake to attempt to drive or hammer out the obstruction. This should only be attempted as a last resort. I am not here recommending that it be done, but in case you have no other means of accomplishing the end and must take the risk of ruining the barrel, make up a driving rod of hard wood to a full-bore size and have the end perfectly flat; this *should not* work off center or wedge the obstruction any further. Oil thoroughly with a thin oil and do all the driving from the muzzle end of the barrel. Never make the slightest attempt to hammer things out with a small-diameter rod—it is certain to work to one side and bulge the barrel.

Despite all our care and efforts, obstructions will continue to be lodged in barrels, and the ensuing excitement generally wedges things more firmly in place. When something does become stuck in the barrel of a firearm, do not become excited and attempt to drive it out with the first thing you can pick up; sit down and quietly and calmly figure out the logical thing to do. In fact, the best rule that can possibly be followed is immediately to pour

plenty of a light penetrating oil in from both ends of the barrel; then lay it aside until the next day, and think matters over in the meantime. Go easy at first, as you may have a serious job on your hands; use your own ingenuity and follow out the suggestions given here. Always apply sensible treatment, for drastic measures usually result in a partially or completely ruined barrel.

Chamber Obstructions—One of the meanest breaks in the shooting game is to have the cartridge case part, and the body of the case remain lodged in the chamber. This invariably happens when forty miles from a shell extractor—and nothing to do but use the guide's rifle for the rest of the trip. When this occurs it is usually an indication of too great a headspace between the chamber shoulder and the bolt face; seldom does a cartridge part in a bolt-action rifle when the headspace is of correct length. The most common cause, just now, concerns those individuals who load their own ammunition and use cases which have previously been fired with a mercuric primer; they do not realize that mercury has a rapid deteriorating effect on cartridge brass, which usually results in its parting at some point—usually right back of the shoulder. If there is the least bit of excess head space the condition is aggravated and the case usually parts about $\frac{1}{2}$ or $\frac{3}{4}$ inch from the head.

The Marble Manufacturing Company of Gladstone, Michigan, make a broken-shell extractor to remove just such ruptured cases. At times these are very effective in the complete removal of the part still in the chamber; and at other times they fail. Still, they are a good thing to have along in the wilderness. If, in the act of removing the ruptured case with one of these extractors, it does not come out readily with gentle treatment, insert a cleaning rod from the muzzle and with it gently tap the forward end of the extractor as you raise the bolt handle. By so doing, you imbed the threaded end more deeply into the case neck, and the tapping also usually breaks the brass loose from the walls of the chamber.

If a shell extractor fails to remove the broken case there is much work ahead; especially if the case has become lodged in a badly rusted or corroded chamber. The most effective method to use then is to chase a fine thread on the end of a piece of drill rod which is 0.010 inch larger than the inside neck diameter of the case. Notch the end at three points with a small rat-tail file, and file a slight lead on the end so it will be possible for the threads to cut their way into the brass. This form of extractor should be long enough so that it can be inserted into the chamber through the receiver

of the rifle and be worked with a dog or tap wrench from the rear end; therefore make it sufficiently long. Harden and temper the threaded end to a blue. To use, screw the threads up into the neck of the case, not quite to the end; then insert a rod from the muzzle and gently tap the stuck case out. A little oil applied previously and allowed to penetrate will do no harm.

If this method fails, it will be necessary to break the barrel apart from the receiver and chip the case out with small specially made chisels. Do not attempt to do any chiseling through the receiver; you cannot work from the proper angle and will only scratch and ruin the chamber. Strip the rifle and dismount the barrel. Then make up a small chisel or two on the nature of a thin wood-carver's sweep, the curve to be the same as cartridge, point not too sharp, and with a double radius to the edge so it will wedge in between the broken case and chamber walls without scratching the latter. Work and tap the rear edges loose, and when you have gone around the circumference of the case try the cleaning rod from the muzzle end and back the case out if possible. Be careful not to chisel up into the shoulder of the chamber. This is an operation requiring skill and *care*; *great care* must be used that you do not scratch or gouge the walls of the chamber in the slightest or that particular barrel will have extraction troubles until the end of its days.

Having successfully chiseled out a lodged case, it may be advisable to lap out that chamber and polish it again. This is covered in Chapter XVIII. Once you have encountered this disagreeable experience of a broken case in the rifle chamber, look for the cause and remedy it at once. You may be far away from any correction methods the next time it occurs; however, this rarely happens with everything in perfect shape.

Cleaning and Repair Kits—Every rifleman who takes any proper care of his rifles will in time assemble some sort of a cleaning and repair kit; some of these kits are quite simple and elementary, while others, such as are taken by a large party on safari into Africa, are complete and pretentious field armories. At one time I made what I believe to be one of the most complete cleaning and repair kits ever made for an individual sportsman. It was a de-luxe outfit belonging to Colonel Whelen and was made for the .30 '06 Springfield. The cleaning rod was jointed and had a knurled fiber handle running in ball bearings. Such small races could not be purchased so it was necessary to make them, using $\frac{1}{16}$ -inch steel balls in two races, front and rear; this construction made the perfect ball-bearing handle. By unscrewing the joint near the handle,

a separate round knob could be screwed on the rod; this was a handy means of turning the rod for the purpose of drilling or tapping out an obstruction. Among the fixtures of this chest were: two oil cans, a grease box, three specially-made gunsmith's screw-drivers, a Jacobs drill chuck, two small brass funnels for cartridge loading or similar purposes, a complete set of 6-inch needle files in their special container, three-cornered scraper, small chisel and drift punch, broken-shell extractor, light hammer, fiber hammer, set of oilstones, and a selection of spare repair parts. Included with the

cleaning-rod tips were the three special ones used for removing obstructions. The case was made of American walnut, beautifully finished and lined with plush, and the lid contained a brass plate etched with the Colonel's name and the Camp Fire Club insignia.

Not every shooter will need as pretentious a cleaning and repair kit as the one just described, but it is well to have at hand a full set of properly-made cleaning rods and fixtures. In Chapter II I have given a complete description of how to construct good cleaning rods.

CHAPTER XVIII

Lapping Barrels and Polishing Shotgun Bores



Lapping Barrels and Polishing Shotgun Bores

LAPPING is a refined abrading process usually employed for correcting errors and polishing the interior of rifle and shotgun bores. The purpose of this class of work is to give a barrel a smooth surface or a mirror-like luster. Lapping bears about the same relation to the interior of a firearm as the finishing and polishing described in Chapter XV does to the exterior surfaces. There are many essential factors in the process of lapping steel surfaces, both flat and cylindrical, and a separate book could be devoted to this subject alone. A student will do considerable lapping before he becomes in any way proficient; there are certain motions, touches, feels, sounds, and refinements which one can acquire only by practise, and it would be almost impossible to describe them in a way that would be intelligible.

In lapping rifle barrels, the laps are made of lead, but for shotgun bores we shall often refer to various other materials and methods. The lead lap used for the rifle barrel is charged with an abrasive which is imbedded in its surface. The grade or coarseness of the abrasive depends upon the finish required and the amount that must be removed by lapping. In a rifle barrel the highest finish is usually required, hence a very fine abrasive must be used.

In lapping any form of barrel which has spiral grooves, a lap must be cast on the end of a steel rod. The lead is then the exact form of the interior. By coating the surface of the lap it is charged and becomes a means of cutting the steel surface to a certain extent. Oil and emery paste must be used freely upon the surface of the lap or the opposite condition will exist—the barrel will cut the lap. The tendency of lead laps to lose their form is an objectionable feature. They are, however, easily moulded on the end of the lapping rod. It is always well to change these often, so that it is possible to keep the form well in the grooves and lands.

The correct abrasive to use when lapping a barrel is *flour of emery*, or a very fine grade of carborundum. The latter being the fastest cutter, is of course more desirable, especially on a rusted barrel. It is mixed with sperm or olive oil to the consistency of molasses, and is applied sparingly to the

surface of the bore, from where it is taken up by the lap which becomes charged as it passes over. Insert this well into the barrel.

When the operation is almost completed, however, this is discontinued, and a drop or two of oil charged with the finest particles of flour emery is substituted. This is obtained by sifting a teaspoon of flour emery into a tumbler full of sperm oil. After standing one hour, the oil should be poured off; the residue will be found to be charged with the finest emery, the coarse particles having settled to the bottom. This abrasive is applied a drop at a time, from the end of a pointed stick well inside the barrel. This will make a remarkably smooth and bright finish, if one wishes to leave it this way; but to secure the highest luster, a new lap must be cast.

Mix powdered rouge together with sweet oil—or powdered Vienna lime with paraffin oil—to the consistency of a paste. The latter produces a remarkably fine luster upon the work, whereas the former gives the high dark luster. Keep the lap well supplied with these finishing abrasives and do not allow it to become dry in any part of the barrel. Apply it from both ends of the barrel, as the lap is drawn back and forth.

Measuring Bores—The first stage of lapping a rifle barrel is to measure the bore, having first carried out all the operations given in Chapter XVII. It is essential to know the diameter of a barrel before starting the lapping operation; also to know if it has tight or loose spots.

The bore diameter is the size over the lands or the distance from the top of one land to the top of the opposite one, measured across the bore. The groove diameter is the depth of the rifling measured in a like manner, or the distance from the bottom of one groove to the bottom of the opposite one. These diameters should be measured with a micrometer and the student should always know, before the lapping operations take place, the exact bore and groove diameter of any rifle barrel and keep these in mind.

The Frankford Arsenal had an instrument which was called a "star gauge." Two of these were made: one was kept at the Frankford Arsenal, and

one sent to the Springfield Armory. The gauging head was fastened to a tube; on the inside was a rod which was fastened to the projection, and on the opposite end a vernier scale reading in 0.0001 inch. Master ring gauges were made in 0.3060, 0.3070, 0.3080, and 0.3090 inches. They were used to check the measuring points, and as the scale has ten graduations on it, it could always be kept in perfect adjustment. On the steel tube this had rings one inch apart, and measurements could be taken one inch apart the full length of the barrel. A *star-gauged rifle barrel* is simply a barrel measured with this gauge. Other gauges are also made to determine the diameter, but when it is star-gauged it means that the full length of the barrel was measured at intervals of one inch and came within certain limits set as maximum and minimum dimensions. We found a measurement which gave the finest results in an accuracy test:

Groove	0.3082	maximum
	0.3080	minimum
Land	0.3002	maximum
	0.2999	minimum

A star gauge is a very expensive instrument, and the two which were made at the Frankford Arsenal cost about \$500 each; thus these are somewhat out of the reach of the private manufacturer, let alone the average rifleman.

There are always two ways to do a thing: the simple method and the advanced or technical one. To work out ideas in a technical manner takes years of study. To measure the bore and groove of any rifle barrel, simply drive a lead slug or bullet through the bore and measure the diameter. Select a piece of pure lead, and if you have a lathe, turn this about 0.002 inch over the groove diameter of the barrel; if not, hammer and shape a piece about three-fourths inch in length which can just be driven into the bore, not necessarily tight, but so it can be pushed in. Insert a steel rod which is close to the bore diameter, and with the bolt locked in place, insert the rod from the muzzle, hitting against the bolt. The length of the rod makes no material difference as long as it comes about half-way into the barrel. Apply a light coat of thin oil to the interior and then insert the rod and the lead slug. Insert another rod, which is near to the bore diameter, from the muzzle against the slug, and with a hammer give good sharp blows which will upset the lead and fill all parts of the grooves. When withdrawn and measured, this gives a true reading.

Before withdrawing this lead master-slug from the bore, shove it up near the chamber and then work it out slowly to the muzzle. Note every tight and loose spot that you encounter throughout the

barrel length and apply more time on these spots when the lapping operation takes place.

When you wish to measure the breech and muzzle, cut rods to the proper length to rest against the bolt or breech block. First upset the lead at the chamber end, then take another rod which will reach up to the muzzle or to a distance from which a true measurement can be taken. Then upset a master slug at that point with these two before you, measure them, and compare sizes. It is a very simple matter to check the groove diameter from these master slugs, but the land diameter is rather difficult to determine unless you have special ball points on the micrometer, as Figure 18 shows. These fit over the anvil and spindle of the micrometer and it is an easy matter also to check this size in the grooves of the master. In measuring these lead slugs, measure all sides, as you will often find one side greater in diameter than the other. Do not clamp the micrometers too tightly over the outside surface or you will never get a true reading, but adjust gently by the spindle ratchet. After being measured, these can be placed in an envelop and marked with the exact sizes, rifle number, and date. If placed in a box so they will not be damaged in any manner, this will be your future record of that particular barrel.

When you are testing for tight or loose places in the bore, notice the smoothness of the bore and locate the rough spots and pockets. To do this in the correct manner, clamp the barrel in the vise between felt jaws. To free the bullet through the barrel, make a wooden knob for the end of the rod, and have it just fit the palm of your hand. If you are forcing the bullet through the bore from the muzzle, grasp the rod by the wooden handle in the palm of your hand, and with the weight of your body, force the bullet through the barrel with a steady motion. Do not allow the master to stop in the entire passage; the slug should go through with an even and gradual speed so that one can easily detect the slightest difference in pressure indicating the tight and loose spots. A little practise is essential; if you repeat this test two or three times you are sure of your findings, which can be chalked on the outside. The best barrels are those which have no tight or loose places, but are of an even and true diameter from chamber to muzzle.

All rifle barrels are at times greatly improved by a careful lapping operation. Most barrels which come from the factory are made in various sizes, particularly the cheap arms, as they require a greater manufacturing tolerance than such government-made arms as the Springfield M/1, and Model 1903. Accuracy depends upon correct bore and groove diameter and a high finish free from

any tool marks. The only way these can be achieved is by a lapping process, after the correct sizes and conditions of the interior are known. Perhaps you have trouble with your barrel picking up lead and metal fouling because of tool marks which are impossible for the eye to detect. The tool marks which pick up this metal fouling can often be eliminated by a careful lapping operation.

I must impress upon the student that every barrel does not need lapping. If a barrel is performing in a satisfactory manner with fine accuracy, lapping the interior is unnecessary. Figure 85 is a full-detail drawing of one of the finest types of lapping rod that can be made. Of course, special tool equipment and a considerable knowledge of mechanics are required to make one. If you should have a number of barrels to do in the course of a year it would pay you to have one made, as an ordinary cleaning rod cannot be used for the purpose.

The improved lapping-rod head, when once made, can be used for any rod. The short shaft is reamed on the end with a standard tapered pin reamer and different rods can be inserted and changed very readily. Two rods are shown; one for the lead to be cast to the end and the other for the leather washers, using fine powdered rouge or lapping compound. All rods are made from drill rod; this gives the required strength, as a lapping rod receives rather hard treatment, and the handles must be large enough to allow of a good grip. In addition you will need a melting pot, a small ladle, and a supply of lead.

The amateur who is not prepared to make so elaborate a rod at first can use a front bicycle hub. Two large wood screws are welded in the center and large file handles screwed in place. Then a rod is welded on the end of the axle, or it can be annealed and drilled out to take the rods and a set screw used to hold these in place.

A wooden handle is also made, about 12 inches long by $1\frac{1}{2}$ inches square in the center. Ends are formed in the shape of handles similar to the old-time hand augers. Different small ball races can be picked up from a junk yard and set in the center of the handle with plates holding them in place, and a small shaft used, extending out long enough to take the rods. Various methods may be used to construct a satisfactory lapping-rod holder of the material at hand, but the best will require some time to make.

The length of time required to lap out a barrel depends upon conditions and what you found when you measured it with the lead masters. The usual time is between two and eight hours, but you had

better count on the longer time, for to do the best job you must go slowly and feel your way.

If you have not prepared the barrel for lapping as described in Chapter XVII, the bore must be thoroughly cleaned before work is started. Scour it out and use the metal fouling solution if the barrel is a high-velocity arm, or use mercury to remove the lead if the opposite. Dry and clean the bore after using any of these, and examine it to see if it is free from any foreign substances, such as small pieces of metal alloy which may come off and be imbedded in the lead lap. This might cause a deep scratch in the steel as it is worked back and forth. The lapping rod is first run through the barrel from the breech, and the end is allowed to project far enough to expose the canelures below the jagged tip. Cotton string is then wound carefully into these grooves and the rod withdrawn until the jagged tip is about $\frac{3}{4}$ inch below the muzzle. The cotton string is used as a seal to prevent the melted lead from running down the bore of the barrel.

With the barrel clamped in a vertical position between the felt jaws in the vise, take a gasoline torch and heat the muzzle of the barrel slightly down as far as the grooves where the cotton string is wound. The required heat is about 350 degrees Fahrenheit; this is done to prevent the lead from shrinking and at the same time to give a full and perfect lap, the same as a perfectly cast bullet when a mould has been heated to the right temperature. Pour the melted lead carefully into the bore until it is flush with it, and allow to cool before examining. If your hand is not steady in the act of pouring it will be advisable to have some kind of support to rest the ladle on so that a steady stream of lead may be accurately poured into the center of the bore.

After allowing a few minutes for the barrel to contract, the lead lap is pushed forward for an examination. Here is a word of caution: at no time should a lead lap be completely withdrawn from the bore. If this happens a new lap should be cast. Before withdrawing the lap to a degree where it is possible to examine it, push it out from the muzzle only about $\frac{1}{4}$ inch, and with a fine hack-saw cut off the "spew," being very careful that the saw does not touch the muzzle. Then trim the end straight, and with a jack-knife turn a small angle around the end so that the lapping material can enter around the lead, which charges the lap as it is drawn back and forth. A well moulded lap should not show any deformation but be a perfect cast of the lands and a sharp and well proportioned groove. Should the lap when examined show a poor construction full of blow holes and deep grooves caused by the barrel or the lead not being hot enough,

withdraw it and cast a new one, heating both muzzle and lead much hotter for the next attempt.

Having at last produced a satisfactory lap, clamp the rifle barrel between the felt jaws in the vise and rest the muzzle on the gun brace or pan as Figure 86 shows. The bench should be substantially made and must not vibrate. The end of the lap is pushed out from the muzzle about $1\frac{1}{2}$ inches and the collar placed on the rod, so that it will not come out any further. Also make a suitable stop on the bench, so placed as to hit the rod when it is drawn out from the chamber end and still not be a hindrance. Before any abrasive is used, a small amount of sperm oil should be applied to the lap. This is worked back and forth in the barrel to have the lap set and function properly and turn easily in the grooves. The bearing in the handle should work freely, so that the lap will not ride on either side of the lands and round them too greatly. If you do not have a stop collar on the rear end of the rod a wooden stop can be set at the correct distance from the muzzle in order to eliminate any danger of the lap passing through the barrel. It will be well to cut a mark in the end of the lap and also a mark on the end of the barrel so that it will be possible to enter it again in the same grooves should it accidentally slip out.

The proper abrasive material to use on the lap depends upon the condition of the barrel and the exact results desired. For a badly rusted or pitted barrel where bore size is at the minimum, flour of carborundum should be used mixed with sperm oil to the consistency of a paste heavier than molasses. This may be used very freely. At times it is necessary to use as coarse a grade as 90. In a semi-rusted barrel the flour of emery or carborundum is the most satisfactory. For the slightly rusted barrel 320-M optical emery mixed in olive oil will prove very good. Mixed emery and oil may be applied to the exterior of the lap from a small thin stick, as the end of the lap is exposed from the muzzle. A small amount may also be applied to the interior of the barrel. Flour of carborundum cuts very rapidly and should not be used for too long a time.

The bore is lapped by grasping the auger-shaped handle with both hands and keeping up a steady motion back and forth, coming up to the back and front stops. This steady back-and-forth motion may continue for some time if the barrel is true and straight; but if a bore has tight and loose places the lap must work over these places with short even strokes. These have been marked out with chalk marks on the outside, but the feel of the lap will indicate them also. When the lap begins to wear down and it is difficult to detect these places, take a rod of the same diameter as the bore

and upset the end of lap slightly by tapping the end of the rod with a light hammer. Then pull the lap back through the bore; by this slight enlargement on the end it is an easy matter to continue in the tight and loose sections once more as they disappear in the bore. Then the full-length strokes may be applied again. From time to time the paste must be placed on the end of the lap. It is not advisable to use the emery paste continually, but to alternate with special oil mixed as described with emery or carborundum.

The length of time given to use a lap will vary according to the condition, but between five and twenty minutes is about correct. Withdraw the lap, wipe the barrel clean, and inspect. To clean a barrel thoroughly after a lapping operation, use gasoline and then powder solvent. Wipe dry with as many patches as necessary. Examine to see if all the rust marks or pits have disappeared. Measure the bore again as previously described to see how much it has been enlarged, and compare with measurements taken with the masters.

After the required conditions are attained, a new lap is cast and powdered rouge or lapping compound is used for the final high luster. No particular length of time for this operation is required, for these materials do only a slight amount of cutting but give a higher polish. You may continue for one hour and produce no material effect upon the size.

When using flour of emery or carborundum the enlargement of the bore should not exceed 0.0003 inch, particularly in a barrel using jacketed bullets; nor should it be any more for a .22 caliber target rifle, altho .0004 can be lapped out of a barrel which uses lead bullets.

Upon examination one can determine about how much of the paste to use together with the length of time to lap a barrel. If the desired effect is not produced with the first trial, another lap is cast and proceeded with as before. The exact amount of time is not considered when one seeks a fine and highly polished bore. You can never expect to own one by buying a factory-made barrel, for the necessary time cannot be expended on such barrels.

At times it is well to use the lapping compound on a new barrel, as you can often spend between two and three hours with greater results. The lap should be kept in perfect shape and be removed occasionally. It is scarcely possible to lap too much with this compound as it has a greater polishing than cutting effect upon any bore, and there is without a doubt a great improvement resulting in the accuracy of the barrel. At the end of such a treatment the interior of the barrel should be finished with the highest degree of luster, such as

we see on the working parts of a watch. It will be well for the student first to practise on a barrel which has lost its accuracy or one that he does not care much about. Carry out exact instructions, for such experience is of great benefit and the practise will enable you to do the same on some barrels in your collection, improving the accuracy appreciably. With this practise you will be able to detect the "feel" and other essential points which I cannot explain or describe. By way of illustration, ask a carpenter how he knows that he is sawing a board straight and he will be unable to tell you. Nevertheless, he has acquired a peculiar sense of touch or such general acuteness of the senses that he knows when the saw starts to "run out." His mind and arm automatically return the saw to a straight line without missing a stroke. It is the same when you are filing out a die. You can file a die, looking only at the surface line, and can detect the instant the file "rocks" from a straight line. I can tell you that I "feel it" but I am unable to tell you what the sensation is. Likewise I cannot explain some of the finer points of barrel lapping; as I have pointed out, they are fundamental, and proficiency and skill must be acquired by practise and experience.

Lapping Shotgun Barrels — The lapping of shotgun barrels requires the use of power in the form of a polishing head, reaming machine, lapping head, or speed lathe. In Chapter XVII, instructions were given to lap a shotgun bore with laps made from hard wood. Such forms can be used by hand very effectively, but when you have power of some description a lap made as Figure 96 shows will produce the desired results. A wooden lapping rod, when used with any means of power, causes too much vibration in the rod and similar conditions on the surface of the bore. This is why cold-rolled steel rods are used with power.

It is necessary to cast the lead over the end of the rod, using a piece of gas pipe as the mould. The pipe should be cleaned out on the inside and made slightly tapered, so that it can be easily removed when the lead is cast. The rod is first drilled on the end and then reamed out with a taper-pin reamer, using a tapered pin in proportion to the size of the rod used. A very good size for either a $\frac{1}{2}$ or $\frac{5}{8}$ -inch rod is either a No. 4 or 5 taper pin. After the rod is reamed it is sawed through the center with a hack-saw to a length of about 4 inches. Before the rod is split, suitable gashes are made similar to the ones made on the rifle lapping rod to hold the lead. When this is done, remove the burrs from the inside of the reamed hole and insert the tapered pin.

To mould the lead over the end of the rod, clamp the rod in the vise, allowing between 4 and 5 inches of the end to extend over the face of the jaws. Place a washer over the end large enough in diameter so that the piece of pipe can rest on it, and with a piece of putty, moist clay, or asbestos, form a joint and rest a piece of pipe on it so the lead will not run out at the bottom when poured. To center the pipe you can use your eye to get the proper distance between the rod and pipe. If this cannot be done, use inside calipers to center the two.

It is necessary to heat the mould and pipe as you did on the rifle barrel, by using the gasoline torch. The rod and mould must be well heated; have the lead prepared at a heat ready to be poured. Pour in the same manner as you did for the rifle-barrel lap. Maintain a steady stream until it reaches the end. If you stop pouring for an instant, the lap is usually in two or more pieces. Just as soon as the lap sets, drive off the piece of pipe in the direction of the taper.

It is now necessary to turn the laps to the proper bore diameter on a lathe; in the following table are the diameters of the cylindrical portions up to the choke of shotgun bores:

4 gauge	=	0.935	inch
8 "	=	0.835	"
10 "	=	0.775	"
12 "	=	0.729	"
16 "	=	0.662	"
20 "	=	0.615	"
28 "	=	0.550	"
410 "	=	0.410 to 0.425	inch

Many makers vary from these sizes, in some cases as much as 0.005 inch, so it is always well to measure the bore before the lap is turned to the correct size or continue to try it as you turn down the lap, always from the chamber end. After the lap is turned to fit the bore just so it can be pushed through with freedom, turn shallow rings about $\frac{1}{2}$ inch apart for the oil and emery to lodge in, and to help keep the lap lubricated with the cutting compound.

For good lapping, the speed should not be too fast, but about the first cone on an open belt on the lathe. If the speed is too fast on such a large surface as a shotgun bore, the emery or carborundum does not have time to do its most efficient work. Always keep the lap well supplied with the cutting abrasive and also with the oil mixed as it was prepared for the lapping of rifle barrels. As the lap begins to wear down, lightly tap the tapered end to expand it well against the walls of the barrel; not too tightly, but just so that it will do its best work at all times. When it is too tight it tends to heat the barrel too much, and when you only have

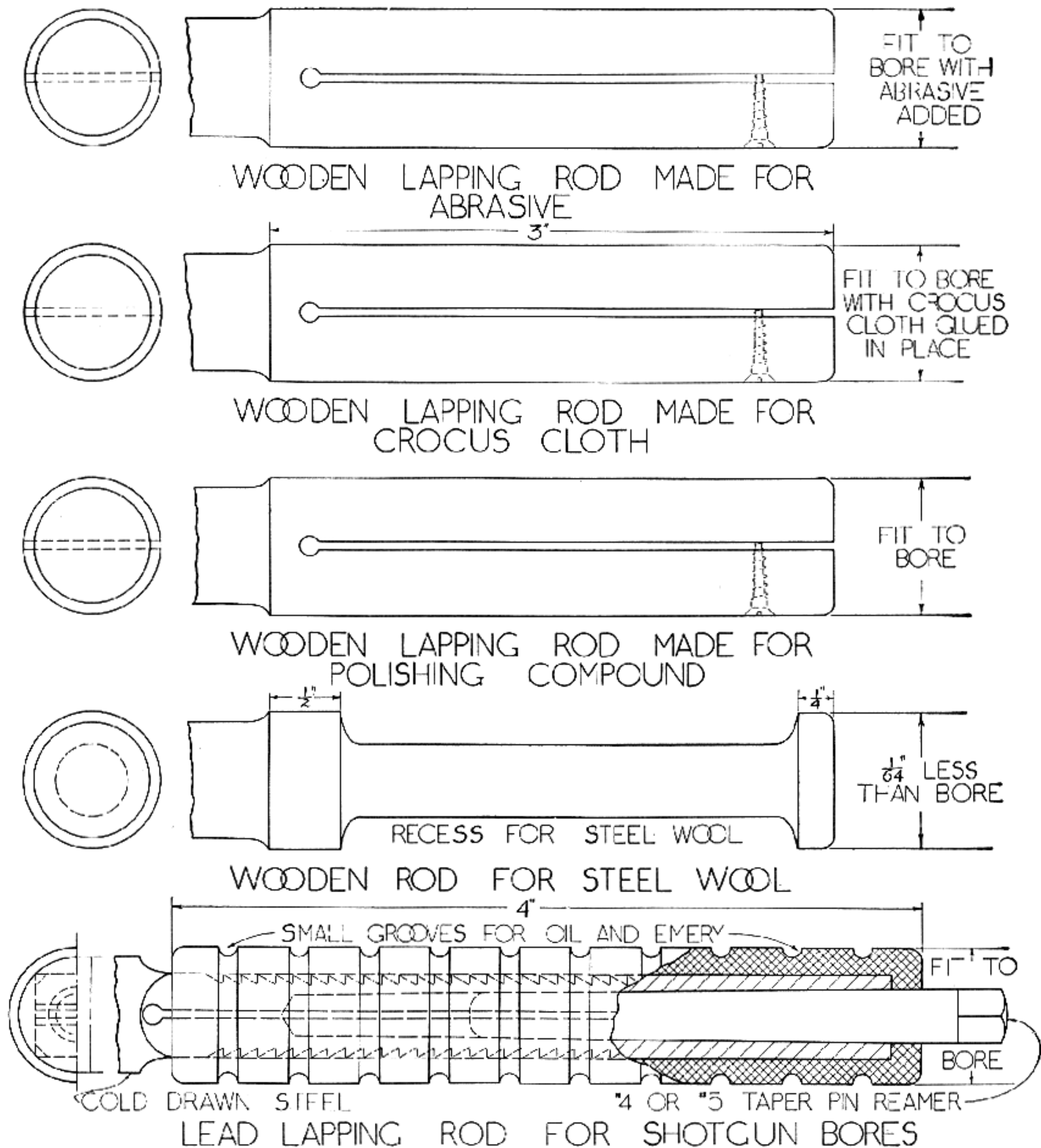


Fig. 96

Lapping-rod tips used for polishing shotgun-barrel interiors

ribs which are soldered to the barrel, extra care must be used to see that the heat is not generated to a degree which will separate the barrels from the rib. If it is a single-barrel trap gun, care must also be used so that the heat does not affect the ventilated rib, which is also soldered on.

A lead lap made in this form will cut very rapidly; therefore examination of the bore should

be made to see that too great an amount of metal is not removed. The abrasive to be used depends upon the condition of the bore. If it is pitted very badly, it will be best to use No. 120 at first, and then gradually use the finer grades when finishing up. If you find it necessary to reduce the choke, turn down the lap to fit it, and then continue to lap it out for the desired pattern.

Lapping Out Choke for Pattern — Shotguns are given different chokes, such as full choke, three-quarters choke, modified choke, quarter choke, or improved cylinder, straight cylinder. These may also be expressed as a certain percentage of pattern; a full choke barrel usually gives about a 75 per cent pattern; a three-quarters choke will give about a 55 per cent, and a modified choke 40 per cent or better. Then we have the true cylindrical bore, which is the straight barrel.

You may have a full-choke gun which you wish to reduce to about a 60 per cent pattern. Since the choke on a full-choke gun is about 0.030 smaller than the bore, you must lap out between 0.008 and 0.010 inch to produce these results, or you may spoil the pattern altogether. A full-choke gun is usually adapted for trap shooting; such a choke as this is really out of the question for the all-around gun, and a 60 per cent pattern is far better to use.

Two lapping rods should be made, one for the bore and one for the choke of the barrel. The barrel lap, when completed, can be washed out with gasoline, and then the finishing operation with the powdered rouge and oil or the lapping compound is employed. It will be well to make these two lapping rods if you have a number of barrels to lap, and then the expansion will not be too great in either rod. When you change from the bore to the choke or vice versa, the length of time you spend to polish a shotgun bore with the rouge or lapping compound is of no material difference as these do not cut very much but give a highly polished surface to the metal.

When lapping a shotgun barrel, be careful not to get it too greatly oversize; judge by the figures given in the table for shotgun bores. We have the same conditions to consider in shotgun barrels as in rifles—the badly pitted bore, the semi-rusted and slightly pitted condition, and the slightly rusted bore—so we must treat each in a different manner but all with the same degree of forethought.

There is a much simpler method of polishing out shotgun bores and chokes—with the split lapping rod, emery cloth, and No. 7/0 sandpaper. Use a piece of cold-drawn steel rod; $\frac{5}{8}$ diameter for 16, 12, and 10 bores; $\frac{1}{2}$ for the 20 and 28 gauges; $\frac{3}{8}$ for the .410. With a hack-saw, split the end about 4 inches through the center, and wrap emery cloth around the rod, one end fastened in the hack-saw slot, to hold it in place during the lapping process. The grades of emery cloth used depend upon the condition of the barrel; coarse for the roughing operation, medium for the intermediate condition, and the fine, together with the crocus to finish, or the No. 7/0 sandpaper to be used before the crocus, when it is found necessary. It is sur-

prizing what a wonderful finish the fine sandpaper will produce; it is just a matter of choice between it and the crocus. When using the emery cloth, paraffin oil or lard oil must be supplied to the inside of the barrel as well as to the surface of the cloth to produce the best results. Fine sandpaper or crocus cloth must be dry to produce the high finish desired, but before using either one of these the barrel must be washed out thoroughly with gasoline and wiped clean with cotton-flannel patches. The speed should be the same as for lapping with the lead lap, and the emery cloth must always be tight against the inside; not too tight, but so that it will do its best work. You will be surprised to see what good work can be accomplished with such a simple method of lapping.

Lapping Chambers — This is an operation which requires much care, and only in rare cases will a chamber require such treatment. It becomes necessary when the chamber has become rusted and small pits have formed, making extraction more or less difficult, and then only on the taper where these places exist. The usual method employed is to cast a lead lap into the chamber on a cold-rolled steel mandrel. The length of the lead cast must be gashed in a manner similar to that of the ends of the lapping rods. The mandrel is made or turned down on the end to allow enough lead to be cast to form the neck portion of the chamber, with enough body to allow it to work effectively at that point.

To cast the lead lap in the chamber, the barrel must be removed from the receiver, a cork or piece of soft wood driven into the rifling, and the mandrel inserted, well centered. The chamber end is heated to a much higher degree than at the muzzle to expand the steel at that point, so that when it cools off the lap will fit the chamber very tightly. Pour the lead in the same manner as you did for the barrel lap, and when it cools to a certain degree, remove by inserting a cleaning rod from the muzzle and back it out. Examine the lap to see if it is a true reproduction of the chamber; if not, a new lap must be cast. Assuming that a perfect lap has been made, the barrel is clamped in the chuck and trued up so that the chamber does not run out over 0.002 inch. A lathe dog or a similar holder is fastened to the lap mandrel in order to have a means of holding it while lapping.

Very fine flour of emery is used mixed with olive oil to a very thin consistency. The lap is then coated with this and placed in the chamber. As the rear part of the chamber is on a taper, the lap will have a tendency to work ahead rapidly, and at times to a degree where it will stick and be torn out of the hand. The proper motion given to such an

operation when lapping a taper is gradually to let the lap work forward until it becomes tight, withdraw it at once, and start over again. This motion is only a means to prevent the forming of rings on the taper. When the lap becomes loose and hits the shoulder it must be filed back, only allowing the lap to work upon the taper. If the shoulder only is to be lapped to increase headspace, at least six laps must be cast, for one alone would place very bad rings on this part. Laps for the shoulder alone must be made to be effective at that point only; the other part of the lap is relieved and does no work.

This method of lapping a chamber is liable to prove very unsatisfactory. In the first place, it is difficult to secure a smooth surface because the tapered lap cannot be moved across the surface; moreover, the lap tends to cut round grooves into the work, as it often remains in one position, and imperfections in the chamber will to some extent be transferred to the lap. Care must be exercised to see that the end of the chamber is not enlarged too much, because the abrasive is gradually carried outward toward the mouth of the hole by the centrifugal force, which, of course, increases as the diameter of the hole increases. Two laps should be used, one roughing and one finishing (if a smooth hole is necessary), before the fine emery cloth is used. Shotgun chambers are the easiest to lap as the taper is very slight, and revolver cylinders require a straight or slightly tapered lap. These may be turned out of cast-iron or copper. The lap is chucked in either the lathe or drill press. In Chapter IV, Volume I, an illustration shows a set of lapping arbors together with the style of laps used for straight holes. This is employed to lap the cylinders of revolvers, where each one is the correct

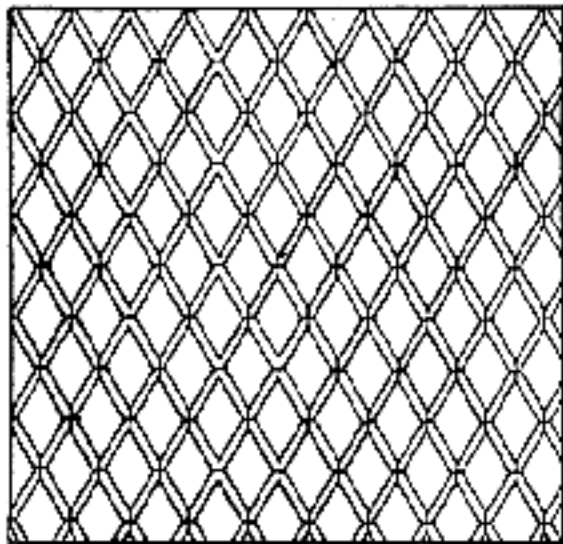
size, for once a lap of this style is set, it is possible to alternate from one chamber to the other and they must all be the same size.

Sometimes when the chambers in .22-caliber arms become very badly pitted, the soft copper of the case will imbed itself in the rust pits, and the extractor will not remove the exploded case. If these pits are not too deep, the chamber is lapped out in a different manner. Take a small piece of drill rod, saw a slot in the end, wrap with fine emery cloth, and tighten in the chamber. With the opposite end caught in the chuck of the hand drill and the barrel clamped between the felt or lead jaws in the vise, continue to lap the chamber until the pits are removed. This is not advisable if the defects are too deep, for this would enlarge the chamber to such an extent that the fired cases would split. Be very careful when lapping a chamber in this manner not to make it larger in the front end than in the rear. This may be avoided by working the lap back and forth a short distance. Frequently the extraction is perfect after such an operation on these chambers.

On .22-caliber automatic rifles such as the Winchester and Remington, which are difficult to clean from the breech, the chambers become rusted and pitted, causing the rifle to jam; but with the above treatment these arms can often be made to function perfectly after the chamber has been highly polished and the rust spots removed.

After the student becomes proficient in lapping operations pertaining to firearms, he will find that a number of them may be profitably employed in other classes of work where close limits are to be made, such as gauge and instrument work, fine tool making, etc. You will judge for yourself what can be done in other lines of mechanical work.

CHAPTER XIX
Special Gun Parts
and Their
Construction



Special Gun Parts and Their Construction

MODERN methods of gun construction often call for parts with greater refinement than those which can be purchased from the usual source of supply. Arms companies specialize only in their standard products, so the individual cannot secure special parts but must construct them himself. Many parts can be made in the shop by hand—presuming that the proper machine tools are available. Very little space can be given to the description of all types of machine tools; the principal purpose will be to explain the parts and the practical problems connected with their construction and with the art of adding beauty to the general outlines of a piece having a definite purpose in a firearm. No attempt will be made to describe all parts, but I shall try to give all the most essential ones in an ideal rifle or shotgun. Modern rifle making, particularly that side of the work calling for custom-made arms, requires the specification for special parts in accordance with an individual's ideas, while others have been made in the gun shop and made part of the gun itself. We shall think of these in terms of improvements; they are not the ideas of one person, but have been developed gradually by many people.

The remodeling of the military rifle has evolved some excellent ideas and brought the target revolver and pistol into popularity. These have brought into accepted use many small parts not known on the standard factory arm. They are, perhaps in many instances, not essential to the functioning of a firearm, but they do offer convenience of handling and greatly improve its appearance. Many parts cannot be adequately covered in this chapter, and in response to a demand for more comprehensive and detailed treatments of the more important ones, they are treated in other chapters. This, however, will cover some of the principal parts which call for various machine operations, even tho these may be treated elsewhere; here they will be treated in a different manner, and there will be conveyed to the reader ideas which he can elaborate upon for his own particular needs.

Front-sight Ramps—There are two styles of front-sight ramps; one is integral with a band which encircles the barrel, and the other rests on top of the

barrel without the encircling band. In my opinion, the latter with its neat, graceful outlines, is the better; the encircling ring on the forward portion of the barrel breaks the outlines of the gracefully tapered barrel ramp. I can remember when Colonel Whelen and I made the first ramp and placed it on a Springfield rifle. The first ramps we designed were short and ungraceful in appearance. I still have one of these in my possession and like to look at it, for it brings back fond memories of our close association. Years have gone by since then, but those experiments were the means of bringing some valuable information to the reader of this book.

The ramp is a great aid in preventing barrel mirage in holding the front sight on an object and consequently disturbing one's aim. It also permits the use of interchangeable front sights. On a ramp where the blades are dovetailed into a tapered slot it is always possible to place them in the exact center and eliminate the standard blade sight altogether. The sight is placed very low in the top of the ramp and protects it from being bent, which happens so often.

Figure 97 illustrates twelve standard styles of plain barrel ramps which are machined from $\frac{5}{16} \times \frac{5}{8}$ inch cold-drawn steel. Others may be formed of $\frac{1}{2} \times \frac{5}{8}$ inch steel and machined to a width at the top of $\frac{5}{16}$ inch, holding the bottom width of $\frac{1}{2}$ inch. This ramp should be made on the milling machine, but if special straight blades are also shaped to fit into a 0.170-inch slot they can be made on a shaper. The blanks for the long ramp are cut to 4 inches in length and then milled with a $\frac{5}{16}$ radius cutter on one side of the $\frac{5}{16}$ -inch width, or to the exact radii of the barrel. The $\frac{5}{16}$ -inch radius is for standard Springfield barrels, but other radii must be made according to the diameter of the intended barrel. The $\frac{9}{16}$ -inch height is used for the Springfield with a standard rear aperture sight which gives a height of $\frac{1}{8}$ inch over the top of the ramp. Ramps for different rifles are made in the following heights: $\frac{5}{8}$, $\frac{9}{16}$, $\frac{1}{2}$, $\frac{7}{16}$, and $\frac{3}{8}$ inch. After the height is determined, the incline is milled, allowing for the straight portion, which is governed in many cases by the height of sight used.

To determine these heights, a sight-setting gauge

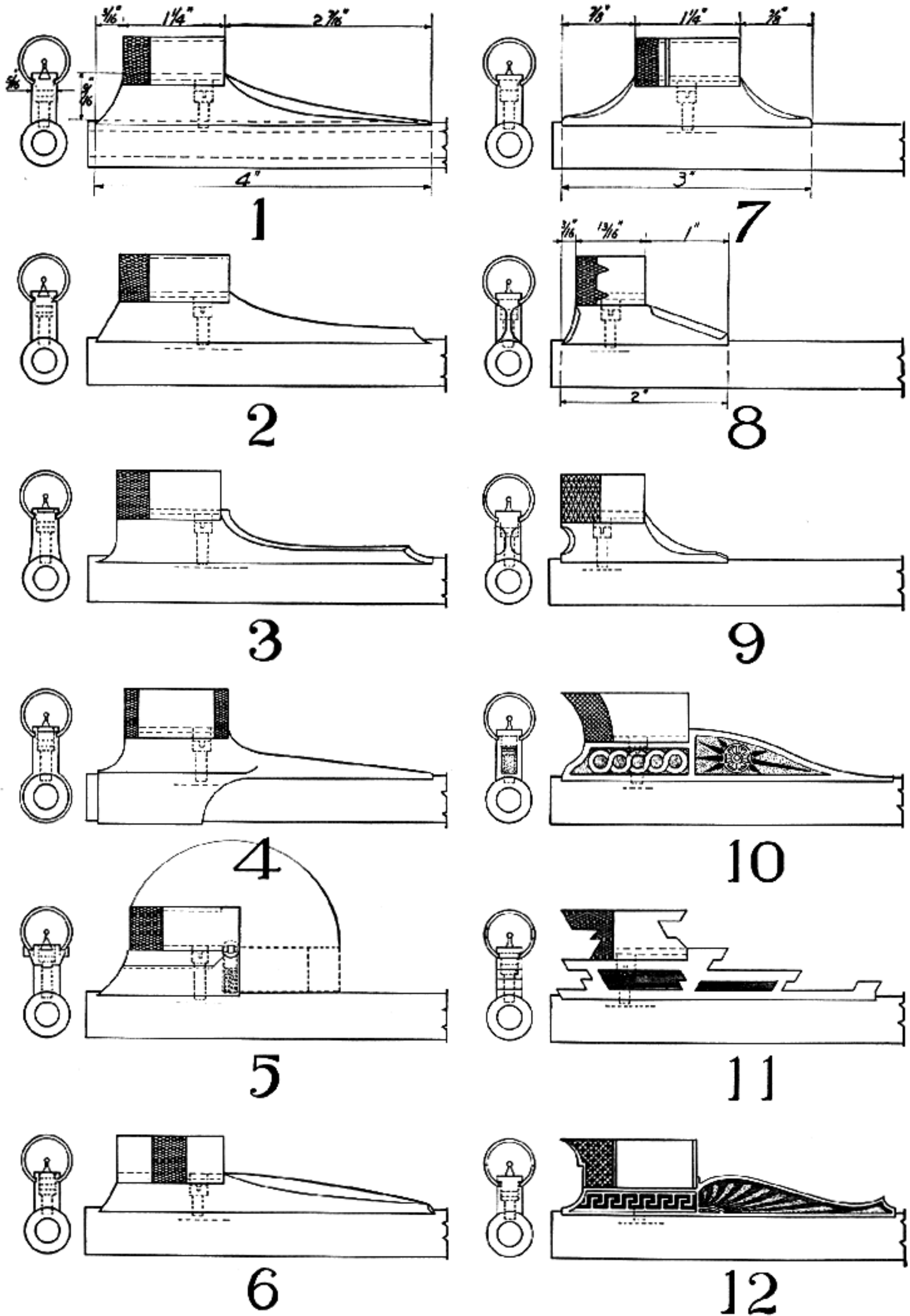


Fig. 97
 Designs for front-sight ramps and covers

is used as illustrated in Figure 98 for the Springfield Model 1903 and Mauser .30-caliber rifles. A gauge of this design can also be made for other calibers and makes of bolt-action rifles, but since

these two actions and the caliber are among the most popular in the United States, a gauge of this nature is almost necessary if many ramps are to be placed on bolt-action rifles of the military type.

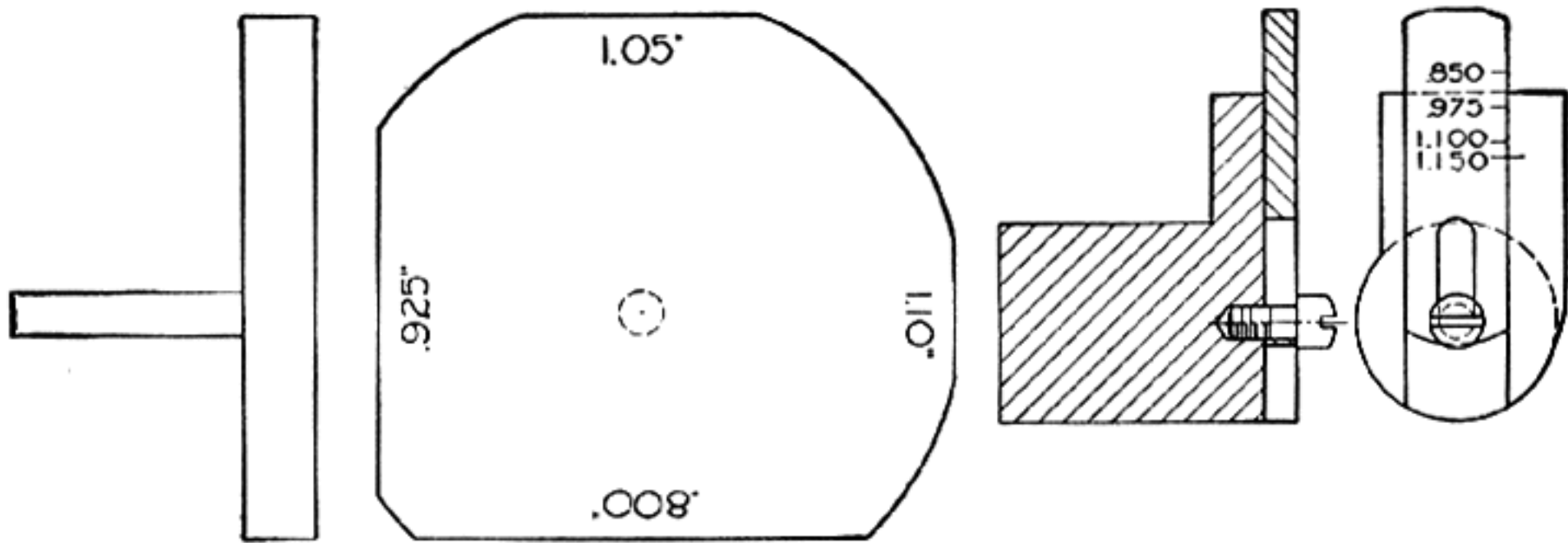


Fig. 98
Sight alining gauges, front and rear

The muzzle gauge is turned from a piece of $2\frac{1}{2}$ -inch diameter cold-drawn steel; the end projection is made to the exact diameter of the bore, and the flats milled or shaped to the following heights from the center: 1.100 inch for target rifles using an aperture rear sight and shooting for long ranges; the 1.050-inch height for the standard Springfield height in connection with a rear aperture sight; the 0.925 height for leaf sights and a cocking piece sight of the aperture type which is set 0.150 inch lower than the standard; the 0.800 height for the low settings of leaf sights, the lowest sighting arrangements on a Springfield rifle allowing the line of sight to clear the bridge of the receiver.

The rear gauge is turned from a piece of cold-drawn steel and the projection just pushes into the receiver at the rear. The end is slotted and provided with a slotted adjustable piece acting as a height gauge. The graduation is plus 0.050 inch, which is a height corresponding to the height of the muzzle gauge. The difference in figures allows for trajectory at 100 yards, or any other discrepancies which might be necessary for sight settings using an aperture sight. When leaf sights are constructed and placed on a rifle barrel, the height of the front-sight blade must be determined by actual firing at an object at a given distance.

Before the slot is milled, a hole is drilled in the center of the ramp at the beginning of the incline and is counterbored to a depth so that the head of a 6 x 48 screw will clear the bottom of the sight. By sinking the head to this depth it is impossible to see the screw after the sight is driven into place. The head should be turned to the sight width; a No. 14 drill size is usually employed, which acts as a counterbore. The milling of the slot lengthwise is of standard width, fits the factory sights made for it, and is constructed in various heights and diameters of ivory or gold beads. The milling of the slot should be just wide enough so that the sight can be pushed in without any play; it is possible to remove it easily whenever it is to be

changed to some other style of sight. Next in order is the milling of the side slots to hold the sight cover or protector. The usual width of these slots is $\frac{1}{16}$ inch and the depth 0.020 inch. The length should be about $\frac{3}{16}$ inch ahead of the sight. These sight-cover slots must be milled opposite each other or the cover will be off to one side, which is annoying to a well trained eye. So that no mistake will be made in the exact location of both slots, a $\frac{1}{16}$ -inch hole should be drilled in the extreme end of the intended slot. In the operation of reversing the ramp to mill the opposite side, the cutter can be set exactly to the width of the drilled hole and the cut taken lengthwise.

Number 4 in Figure 97 illustrates the encircling-band ramp-front sight base. This has become a standard, since it is now manufactured by two or three private companies; however, it is far from having any beauty or graceful outline, and the most satisfactory one will be one made by yourself. The most practical way to make it is from a blank of either machinery or cold-drawn steel measuring $\frac{7}{8}$ x $1\frac{3}{8}$ x 4 inches. The hole is drilled and reamed to the diameter of the barrel, and with a mandrel pressed in the hole, the blank is set in the milling machine vise and two straddle mills are spaced $\frac{5}{16}$ inch apart on the arbor. The end is laid out in exact center to the $\frac{5}{16}$ -inch width and milled the entire length of the blank down to within $\frac{1}{32}$ inch of the mandrel.

Having removed the desired width of the ramp, the blank is reversed and held by the milled section in the vise and a concave cutter is used to the exact diameter of the band, allowing the thickness when completed to be $\frac{1}{32}$ inch of wall. After the radius is milled off the bottom, there still remains surplus material on each side of the band to be removed with a side-radius cutter with the ramp section still clamped in the vise; first one side and then the other is removed until a complete band is formed. Remove the mandrel and with a $\frac{3}{4}$ -inch diameter end mill, remove the rear portion of the

band to the desired length. Be very careful that the end mill does not remove too much stock alongside the ramp; since there is only a small amount left, it can be filed until the sides come flush with the under radius of the ramp.

The next operation is the milling of the ramp incline, which can also be done in the vise by holding the back section of the ramp between two parallels clamped between the jaws of the vise. All surplus metal being thus removed, the ramp is now filed and polished; the dovetailed slot and sight cover slots are milled, and the ramp is ready to be sweated to the barrel. The method of securing the top barrel ramps without encircling bands is to secure them to the barrel with a 6 x 48 screw. First, line the ramp in the exact center of the barrel, spot through the drilled hole into the barrel, and then drill for the tap size. Be very careful not to drill through the barrel. The depth should be within $\frac{1}{32}$ inch of the bore; this gives between three and five threads or even more on a heavy barrel. While the ramp is still in place with the parallel clamp, tap the hole. After the clamp is removed, the screw may be fitted until it clamps the ramp very tightly; thus the ramp is prepared to be sweated in place. Tin both the ramp and barrel and then screw the ramp down on the barrel; use as much pressure as is necessary to pull the screw into place. After heating both the barrel and ramp until the solder will run, bring the screw down in position and cool in water. A ramp of this kind sweated and screwed into position will never come loose, and after it is finished as the illustration shows, it has graceful outlines. A matted or checkered surface on the incline is very attractive. Artistic forms of ramps can be made, as the illustration will show; with these before you, others may be figured out which may be far better in appearance.

Sight Covers — All ramps should be provided with a sight cover or protection to be attached to the ramp. There are two styles of covers illustrated in Figure 97, and both are made of $\frac{5}{8}$ x $\frac{1}{2}$ inch Shelby tubing. The plain type which slides in the grooves milled on the side of the ramp is first knurled on the end and cut off to the desired length. A $1\frac{7}{32}$ -inch drill is run through, making the wall thickness of the cover $\frac{3}{64}$ inch; then a $\frac{1}{4}$ -inch hole is drilled close to the knurled section and with a hack-saw this section is cut out to the end to the same width as that which the drill made. The bottom of this slot is then filed flat, allowing only a thin holding edge. The slot is filed until the cover can be pushed on with a little effort, yet not so tight that it is sprung apart. The most satisfactory

method to hold a cover in place is to drill a $\frac{1}{16}$ -inch hole in the ramp slot $\frac{1}{4}$ inch from the rear of where the cover comes in place. A $\frac{1}{16}$ -inch pin of drill rod is driven in; both ends should be rounded and the projection of the pin on both sides should be just under the surface of the sides of the ramp. With a round needle file, remove two cut-outs so that when the cover is pushed over the pin it will snap into this position, which locks it in place. When a catch of this kind is made properly a cover will never be lost even tho the rifle is shot a number of times while it is in its locked position.

The finest and most practical sight cover is the snapover cover illustrated in Number 5, Figure 97. This cover is pinned through the rear; the pin has two flat sides, and in the center, a spring and plunger are used to hold it in either the covered or uncovered position. Sufficient friction is allowed on the front so that it requires a little effort to pull it up. In the uncovered position the cover lies along the barrel in the rear of the sight base, exposing the sight to the full view of light; then when the shooting is over, all that is necessary is to snap the cover back into position, covering the sight from any accidental knocks when returning to camp. The plunger and spring are essential parts of this sight; they hold it in either position; altho a pin could be placed in the end and riveted until the cover becomes friction tight, this soon wears and much lost motion is exhibited.

The forming of the cover must be done on a form, but the making of the cover is done in the same manner as that used on the plain cover described in the first part—except that instead of the hole being drilled next to the knurled section it is drilled $\frac{1}{4}$ inch from the rear section and the front is cut out. After the first section is removed, a hack-saw is used to part the center of the web and then these two ends are turned out, forming two ears to the exact width of the ramp. To form them, a piece of steel must be drilled out and reamed so the cover can be inserted. A section is either milled or sawed out, allowing the thickness of metal to form the width over the ramp. An arbor must also be placed on the inside, and the metal forced well out against the walls of form. With a small chisel, turn the ears up and with a wedge-shaped form, drive it in between, forcing the metal out until perfect ears are formed. Remove the cover from the fixture, file it neatly, and drill two holes through the center of the ear; file a small square in one. When everything is assembled in position, the large hole is drilled through the base in the desired location; a hole is also drilled for the spring and plunger. After all parts are blued, they are assembled and the pin riveted into place, using sets

which will form neat heads on the end of the pin.

Front-sight Fastenings—There are various methods of fastening a front sight, but only two will be given here; one is by a screw and the other by a plunger. The most common method of holding caterpillar sights with dovetailed bases is with a 2 x 56 fillister-head screw; the head is counterbored into the blade and screwed in the ramp. The screws used to hold these sights in place should be case-hardened; if not, when they are set in place for a great length of time they become rusted in and are very difficult to remove. Figure 99 illustrates two plungers that are very practical to use

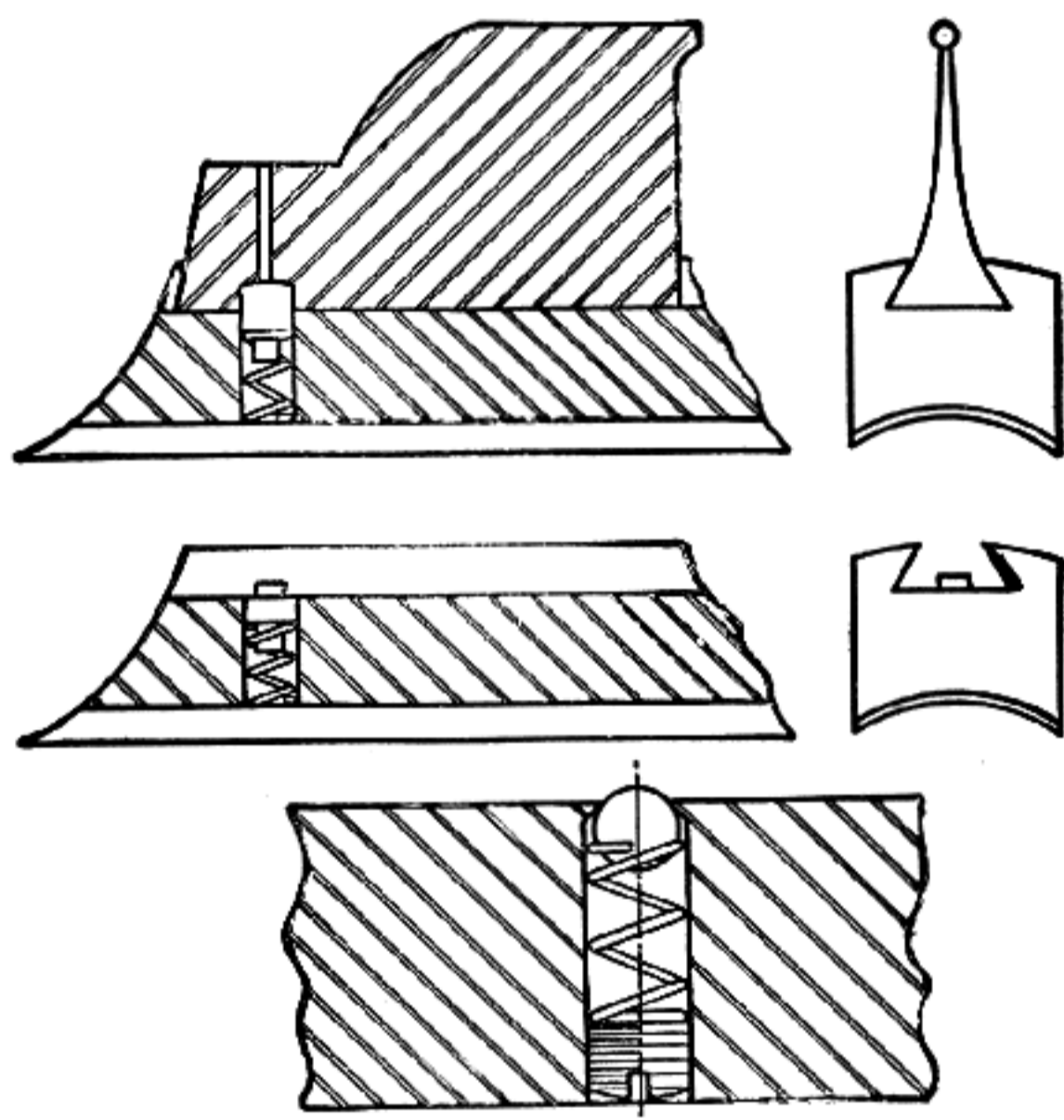


Fig. 99

Plunger positions for holding sights and other movable parts in position

in connection with the caterpillar style of front sight when fitted into the ramp. They may also be utilized for a number of other things in the construction of firearms. One style has a radius formed on the end and the other has a tenon turned on the upper end of the plunger. The plunger is located on the front end of the ramp, and to have these in the exact position, a No. 60 drill is first used to drill in the center of the sight well down into the ramp when the sight is placed in its correct position. With this center hole drilled, the sight is removed and counterbored on the under side to a depth which will allow the radius or tenon to center. The spring and plunger hole is drilled in the ramp to a depth allowing the free movement of the spring and plunger. When the sight is fully in

place with the spring and plunger assembled, the plunger snaps up into the counterbored hole in the under part of the side, thus holding it in place.

If a number of interchangeable sights are required, they should all be fitted first. The plunger and spring are drilled completely through the ramp so that the exact position of the tenon holes can be located in the under side of the caterpillar sight. When sights are to be changed in the field, insert a pin into the small hole, push the plunger down to clear the base of the sight, and gradually push the sight forward out of the dovetailed slot. Always remember to hold the thumb over the plunger as the sight is removed so that plunger and spring will not jump out of the hole. An elongated slot can be placed in the plunger and a pin inserted through the side of the ramp to hold the plunger in place for those who are rather absent-minded.

Plungers are turned from drill rod and should fit into the hole freely. Drill rod of the correct size, which only requires the turning of the tenon or the filing of the radius on the end, should be selected. The center tenon is turned to fit the inside diameter of the spring; this only requires a very short end

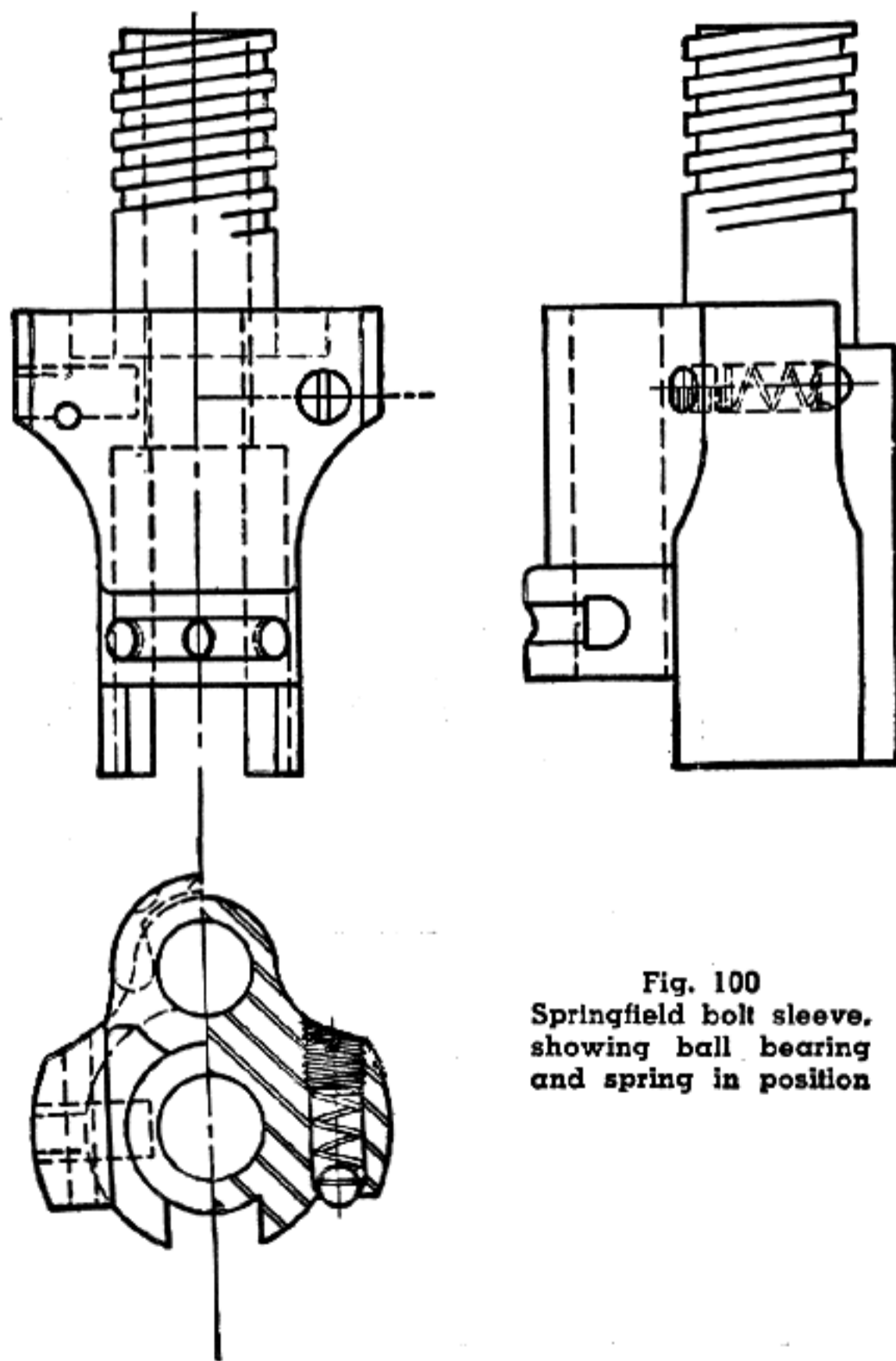
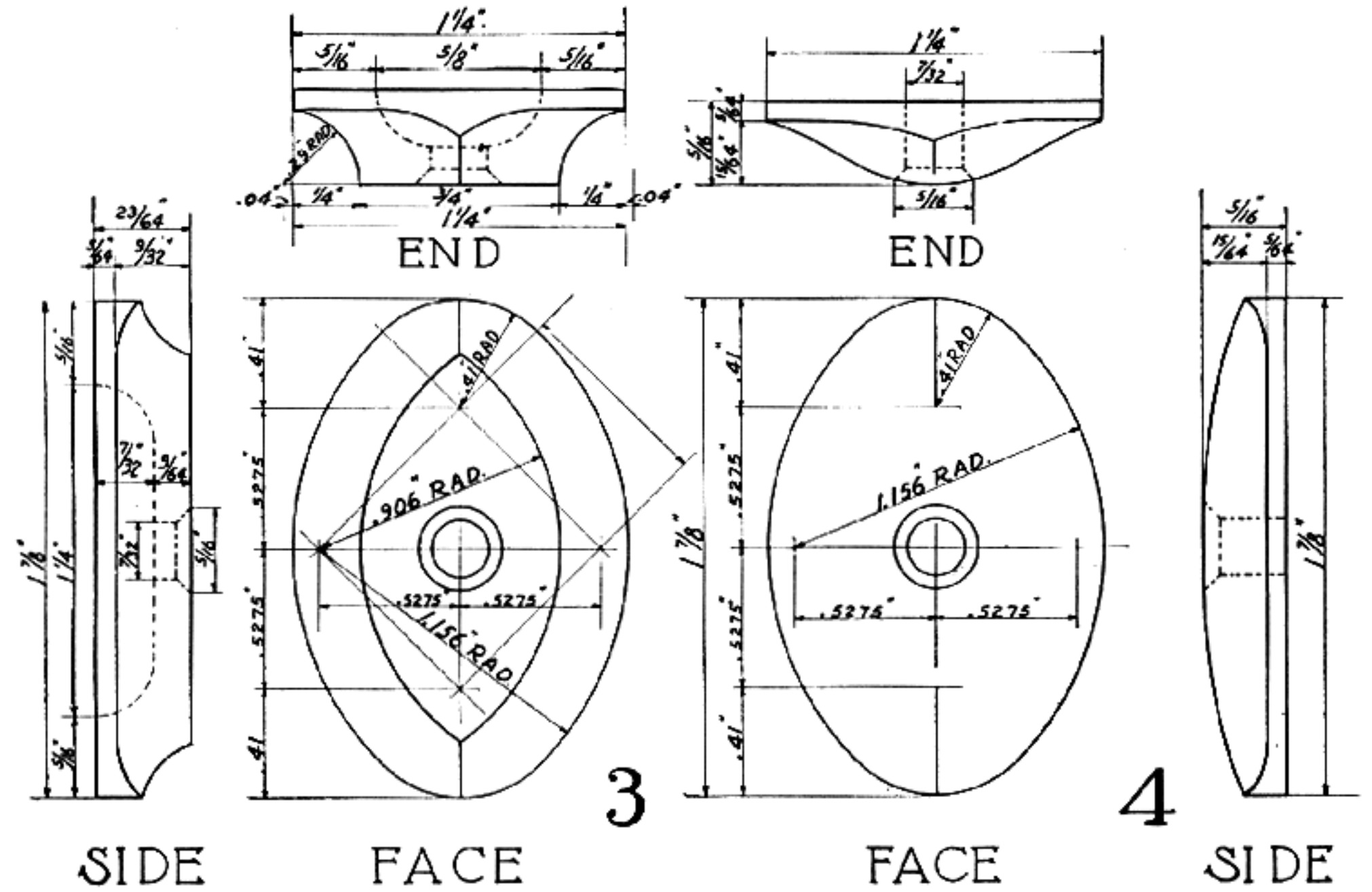
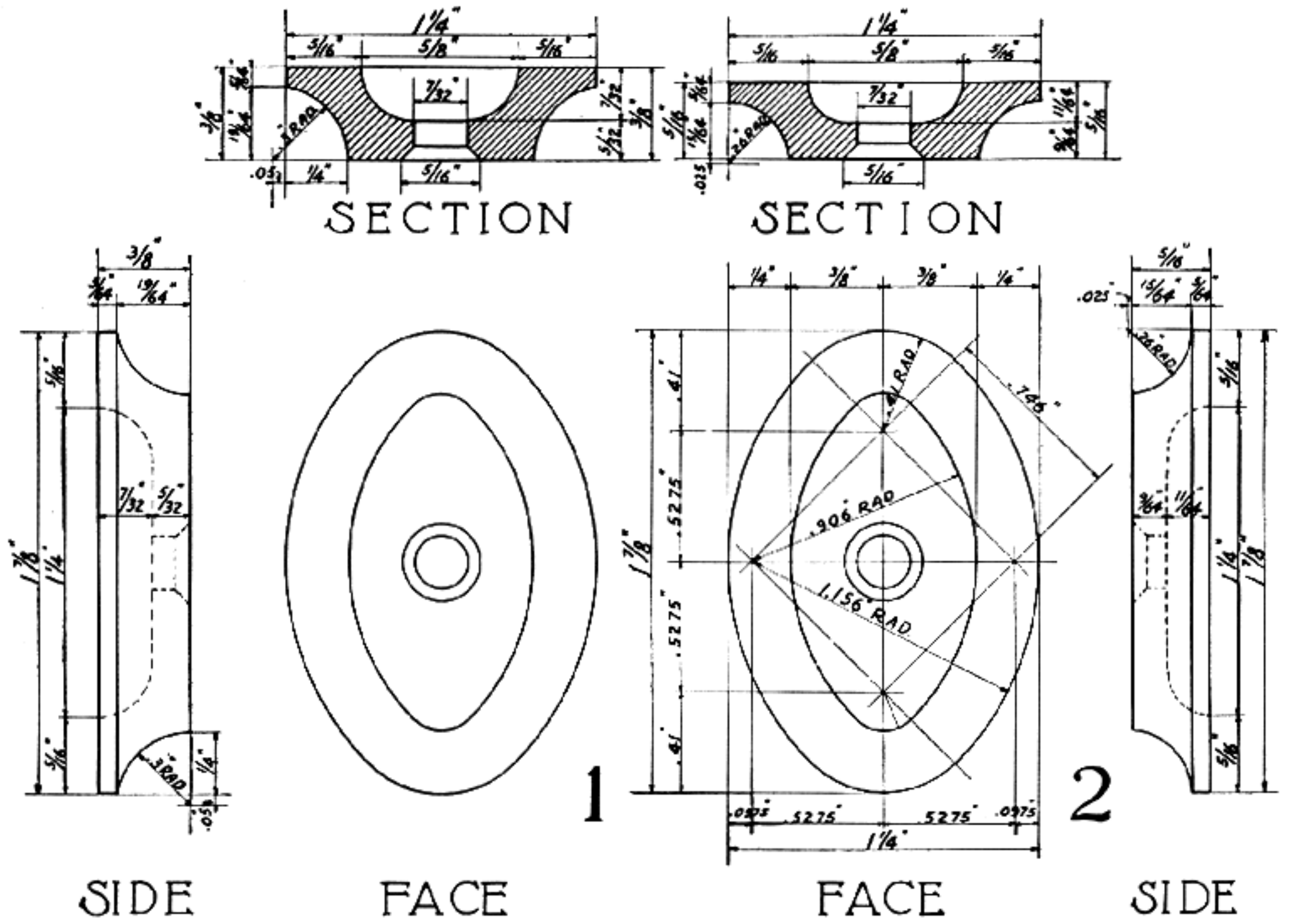


Fig. 100
Springfield bolt sleeve,
showing ball bearing
and spring in position



PISTOL GRIP CAPS MADE FROM BUFFALO HORN, ALUMINUM, BRONZE, BRASS OR ANY MATERIAL

Fig. 101

Layout for specially designed pistol-grip caps

in order to keep the spring centered in the hole. If a pin is inserted through the ramp to hold the plunger in place, the small elongated slot may be filed out on the side with a small square needle file. A plunger which is to be subjected to much wear should be hardened, but those which only hold parts in place, such as sights, etc., do not require any hardening.

The plungers shown in Figure 99 have many uses. Ball bearings can be used in place of plungers with springs back of them; one may be inserted on the right-hand side of the bolt sleeve. Figure 100 illustrates how they are held in place. The main reason for placing a ball bearing at this heavy portion of the metal in the sleeve is to hold the cocking piece in position when a sight is placed on the end. A ball bearing with a heavy spring behind it forces the sleeve over to the opposite side and at the same time gives assurance that the cocking-piece sight will be correctly aligned each time the bolt is closed.

Springfield Armory should drill and tap these holes on all sporting arms, forming the bottom to take a $\frac{5}{32}$ -inch ball bearing and tapping the upper end for a 10 x 32 screw, even tho this hole is not used for any other purpose than to remove weight. Then when any one wishes to use a cocking-piece sight, the hole is there. This would eliminate annealing of the sleeve, which is required when a sight is used on the cocking piece. It is very simple in the sequence of operations before the sleeve is hardened, but when the gunmaker must anneal and reharden it again, it requires the proper furnaces.

Similar plungers or ball bearings may be placed in bolts in some bolt-action rifles to act as a catch. At times the handles of such arms jump up in the act of firing; this may be eliminated by setting a ball bearing in the edge of the receiver wall with a spring behind it or even a ball-end plunger, and then drilling a small depression in the front edge of the bolt handle where it touches the plunger. The spring forces the rounded end of the plunger into this depression, holding the bolt handle down firmly until it is raised, which requires but little effort by the shooter. A similar plunger or ball bearing can be set through the bolt and the depressions placed into the wall of the receiver. Plungers and balls can often be used in places of advantage, and after their usefulness is known they can be applied to all makes of arms.

Pistol-grip Caps — A pistol-grip cap is one of the essential parts of a remodeled or even a new firearm. Figure 101 illustrates standard designs of caps, allowing the maximum sizes to predominate. Naturally, smaller sizes are required, necessitating

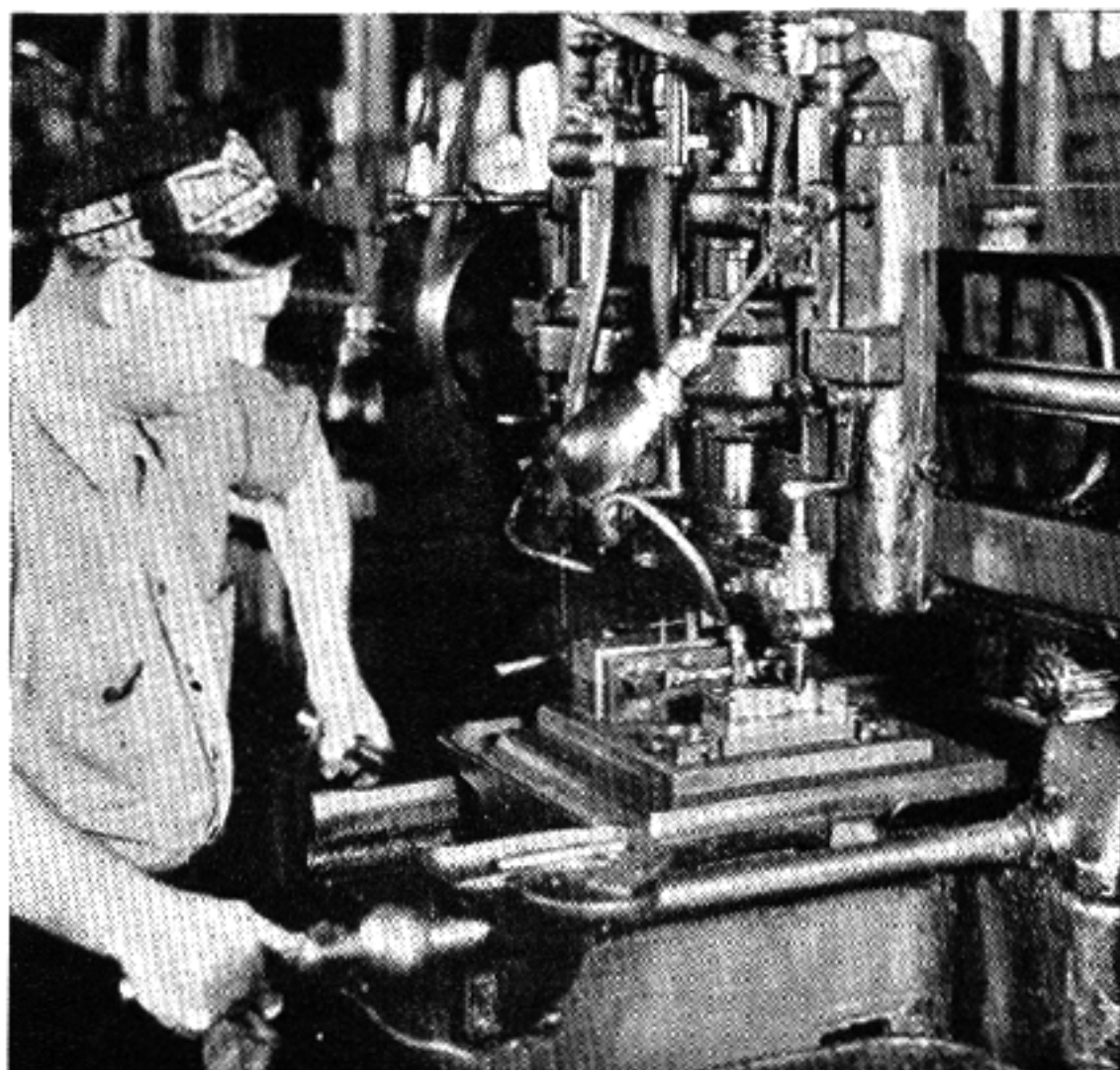


Fig. 102

Profiling of parts as performed in the Remington Arms plant

reduction in proportion to these figures. This rule also applies to larger caps. Grip caps of any material may be constructed from the figures given. Buffalo horn is the most desirable, and next in order is steel.

The construction of pistol-grip caps shown in the illustration requires a set-up on a milling machine or a profiler, using a vertical form cutter in either case. (Figure 102 shows a profiler in operation.) If a milling machine is employed, a rotary attachment is clamped to the milling-machine table and a vertical attachment is set up on the machine. A vertical miller may be used if one is included among the shop equipment. A special disc must be made with a projection to fit into the center hole. Tee-slots are also milled in this place to clamp the cap in position while being milled to the outer edge to get the proper radius. After one side is milled it is reversed and the opposite radius is milled. The end radius may be partly milled and then finished by filing. A profiling machine is a production machine capable of duplicating parts with odd forms, and a profiling operation mills the entire outside from the cap. First, a steel templet or master must be made and mounted on the side the finger rides, and in the revolving head is mounted a form cutter the exact duplicate of the cap wanted; as the finger or indicator rides around the form or templet, the cutter duplicates this and mills the cap out to form. If special designs are desired, new cutters are made for them. It is rather expensive to turn out steel caps on this machine except on a production basis; if only a few are required, the

milling machine is the best set-up for an accurate machine cap.

These caps can also be made by hand from bakelite, radio panels, ebony, aluminum, copper, brass, buffalo horn, and ivory. A templet is first laid out on a piece of $\frac{3}{64}$ sheet brass or steel and from this the caps are laid out and the center screw hole drilled. If a piece of buffalo horn is selected, simply cut out the form with a coping saw, and by the use of a sandpaper disc mounted on the grinder spindle the form can be ground down to the scribed lines and with a little filing the edges made perfectly smooth. Countersink the screw hole. By mounting the cap on the end of a piece of about 2 x 2 inch hardwood it can be tightened in the vise and the form filed on the outside of the cap to any desired shape, as shown in the illustration. After filing it to shape, use fine sandpaper to remove all file marks, and as it is still mounted on the wooden holder, polish on a muslin buffing wheel with rouge. By mounting the templet on the pistol grip of the stock, the wood can be formed up to this until it is perfectly even all around; then mount the cap. A piece of $\frac{1}{32}$ -inch sheet silver may be cut out to the templet and mounted under the horn. The silver forms a neat contrast when worked down even with the wood and cap.

Any of the pistol-grip caps shown in the illustration may be cast from aluminum, brass, bronze, or cast-iron, by making a wooden pattern and sending it to the nearest foundry specializing in small work of this nature. After the castings have been returned they are drilled and countersunk for the screw, then filed and polished very smooth to the accurate form and finally buffed to a bright finish. Cast pistol-grip caps can be finished in any shade or color, as described in Chapter XVI. The man with artistic ability can model various caps in figure design out of plaster of paris or clay, have them cast, and then give them any finish desired. This type has become a little out of date, and artistic lines are striven for rather than ornate decoration.

Trap grip caps are made in a number of ways, but the best come from England, used on most of the magnum bolt-action rifles to carry extra sights. The only purpose a trap is used for in a pistol-grip cap is to hold an extra front sight, otherwise it is merely an added novelty. If a rifle is provided with a trap butt plate a trap cap is not a necessity; however, if a stock has only a rubber recoil pad on a plain butt plate, a trap located some place on a rifle to hold the extra sights becomes a necessary utility. The proper location for such a recess is under the pistol-grip cap.

Figure 103 illustrates one of the best trap pistol caps made from a Springfield or Krag butt plate,

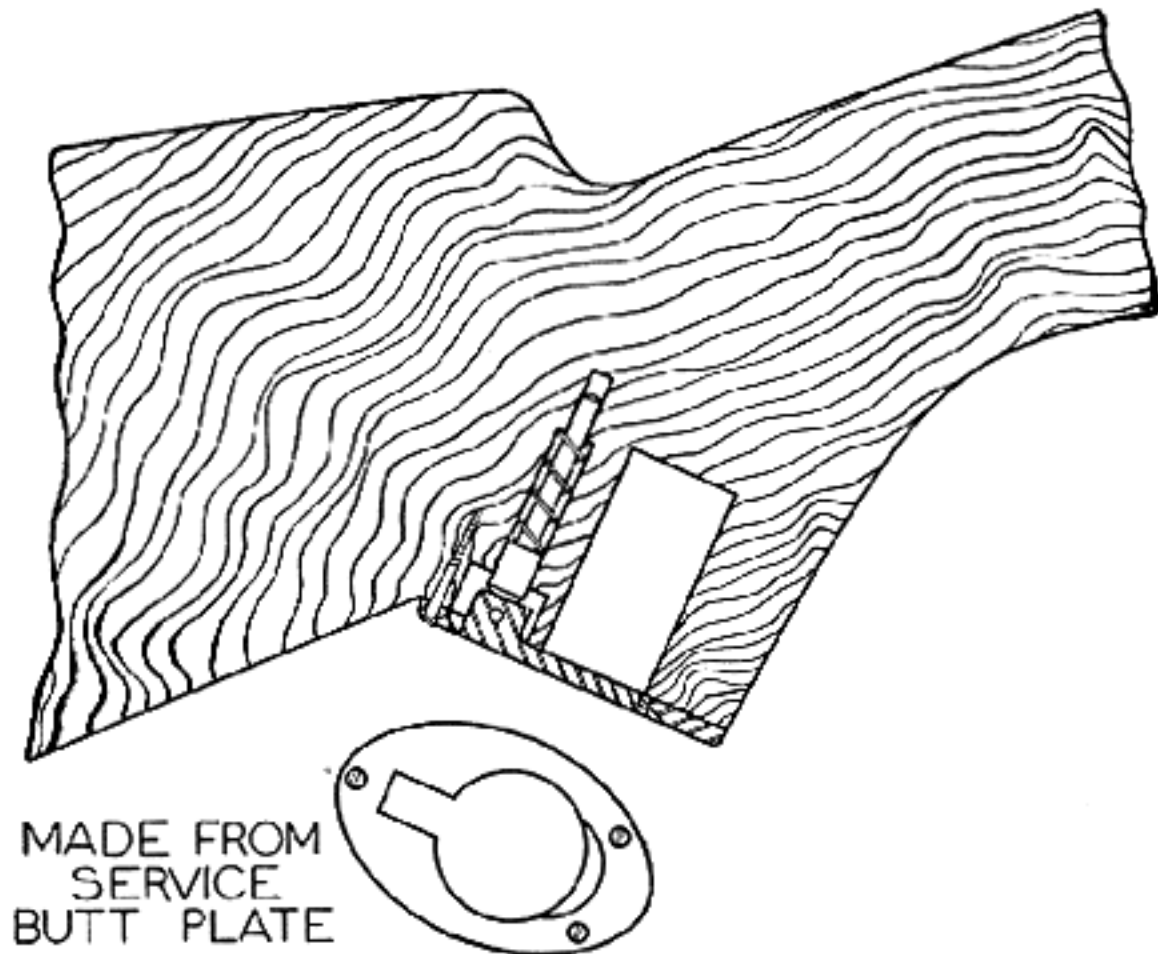


Fig. 103
Trap pistol-grip cap

using the plain plate free of checkering. The checkered plate may also be used, but the plain plates can be engraved or etched after they are mounted. (Refer to Chapter XXII, Volume I.) A templet laid out from the illustration is set over the trap on the plain side of the plate, dividing the distance both for length and width so that the trap will come in the exact center when cut out. Three small screw holes are drilled, one in the front and two in the rear. The two rear screw holes are one on each side of the spring projection. The wood screws used are very small and the heads are allowed to come flush with the top of the plate, the slots pointing north and south. After the plate is in place, a Forstner bit can be run down any depth desired, but the distance should be no greater than the length of the sights that go into this trap.

A good form of trap pistol-grip cap can be made from $\frac{1}{4}$ -inch cold-drawn steel to the templet using the standard figures given in Figure 101. The center is drilled and tapped to take a $\frac{1}{2}$ x 20 special round-head screw with a coin slot. The diameter of the screw head should be $\frac{9}{16}$ inch. A counterbore is used to slightly recess down from the surface, and the same counterbore is used to do the same operation for a specially made container. The bottom is drilled and countersunk to take a small wood screw to hold the cap in position and tight on the face end of the pistol grip. The specially made sight well or container is either brazed or soldered to the under side of the cap. The $\frac{9}{16}$ hole is bored at right angles to the end of the grip to the desired depth. After the hole is started with the standard auger bit it is finished with a Forstner bit to the depth. The cap screw used to close the end must be made on the lathe; three or four

threads are sufficient to hold it in place. After this is fitted, the section of the bar from which it has been made is still held in the lathe chuck. Two small prick-punch marks are made facing north and south on the side. After removing the cap the screw is cut off to length and the head rounded. The coin slot is sunk in the center with a standard slitting saw on the milling machine.

Pistol-grip caps can be made in such a variety of forms and sizes to suit all kinds and varieties of pistol grips that I have merely scratched the surface of their possibilities; but since I have often referred to this subject before, I feel that I have said about enough. However, I cannot leave it without making some comments on the caps which we see on factory arms and which are moulded from hard rubber. They are cheap, of course, but serve the purpose, the American public being satisfied. The caps which most of the manufacturers place on their arms are of small size; when a larger pistol grip is made it is free of a grip cap and only the natural wood shows. The sizes illustrated are only meant for new stocks and are designed to these sizes so that a full grip can be made with graceful outlines. Suitable caps are made in Germany and can be purchased from there, but with this information before you I know that perfect satisfaction can be had by following these instructions.

Butt Plates — The British rifle and shotgun makers call these heel plates, but the American manufacturers apply the name of butt plate to a plate which is fastened to the end of a butt stock to protect the wood from splitting. Many shotguns made in England, even some of the finest, are void of butt plates. It seems that they are of the opinion that a heel plate spoils the beauty of the stock; sometimes they are right. Here in America, however, many use a shotgun as they would a military arm, letting it slide between their hands to the ground and allowing the butt to absorb the shock, regardless of the rocky nature of the ground. I will allow the reader to draw a picture of a stock without a heel plate in the hands of the average American shooter.

The most suitable butt plates are those made in Germany and England. These we class as the shotgun type of butt plate, made plain and with an elongated trap. To design and make the dies for a butt plate similar to the German type would cost a good deal, and I would advise purchasing these from the usual source of supply.

Figure 82, Volume I, illustrates the various standard forms of butt plates suitable for stocks. At times one can remodel a Springfield butt plate very satisfactorily, but they are rather short to have the out-

lines of the stock perfect in every respect. One advantage of such a plate is that it is provided with a trap. Of course, the small round trap is not as desirable as the elongated trap which comes on the expensive German plates, but these military plates are very simple to work over and anyone can make such alterations with the most simple equipment. First, remove the trap and cut off the top projection $\frac{1}{4}$ inch from the face of the plate. Heat the toe and bend it out into a curve which will be just the reverse of the present inward bend. A slight curve can also be formed in this bend and along the sides, but care must be used not to touch the center and thus deform the trap opening. The curve is convex to the outer surface of the plate, which allows it to fit to the shoulder much better than the flat plate. Remove $\frac{1}{16}$ to $\frac{3}{32}$ inch from each side, starting from the top and allowing the line to end before the bottom is reached. The $\frac{1}{4}$ -inch projection is filed to a point similar to the standard plates and a screw hole drilled half-way between the trap opening and the top for a regular wood screw. If it should be a plain plate it can be file-checked or matted and then case-hardened. Before this is done, however, the plate should be well polished.

Satisfactory butt plates can be cast from bronze or aluminum. This type of plate is perfectly favorable for the use of the target shooter who has definite ideas of what a butt plate should be; aluminum is the ideal material for such purposes, as it is better adapted to a target rifle. Bronze can be cast very thin and after being sand-blasted given any finish desired by referring to Chapter XVI. The first stage is to make a pattern of mahogany or wood of a similar nature. Work out the wood to the proper curves, length, and width, and coarse-checker the outer surface. These patterns are sent to the foundry and cast in bronze, or if it is a special plate for a target arm, it should be cast in aluminum. After the castings are returned from the foundry the edges and under surface are filed smooth and flat. The checkered surface is scratch-brushed on a circular steel-wire wheel, and after the screw holes are drilled and counterbored, the plate is sand-blasted and finished in any color desired. The natural sand-blasted appearance given a coat of lacquer is pleasing and deceives the eye.

Chapter XXV, Volume I, contains information regarding pattern making and the requirements for patterns; from this, any kind of butt plate can be made for any rifle, and one may follow his own fancies as to design and shape. Aluminum castings which come from the foundry can be given a high polish by using different buffing wheels with tripoli compound, etc.

Special steel butt plates can be made from $\frac{1}{16}$ -inch cold-drawn flat stock. These plates may be made to any width, length or contour, and very artistic designs can be milled on the surface. Chapter XIII, Volume I, explains, and Figure 82 shows, a few designs. After setting-up in the miller and setting the vise at various angles, artistic checkering can be done. The hand checkering of any large surface with a three-square needle file or graver is a very laborious undertaking. The most dependable and accurate method is on the milling machine, using a vertical attachment and an end mill and setting the head on a 45-degree angle. The sharp corners of the cutter will control the checkering made, and the graduations on the dial on either the cross feed or the transverse feed to the table will regulate the number of spaces to the inch. For an example: if twenty lines to the inch are desired ($1 \text{ inch} \div 20 = 0.050 \text{ inch}$), the handle is turned each time 0.05 inch on the dial for a new cut. The depth is regulated by the sharpness of the diamonds formed; therefore, two or three lines must be cut first to find where the points come out to a sharp edge. When a border is desired on a plate certain distances from the edge or to form diamonds or other forms around the screw holes, it must be chiseled or hand engraved first, particularly around the edges, and the end mill allowed to terminate at these lines. It is much better to allow the cutter to run off the sides of the plate than to form a border, for there will be a good many run-overs with the cutter which are at times difficult to correct.

The $\frac{1}{16}$ -inch cold-drawn sheet stock should be perfectly true and flat, and when cutting out the form it should be held flat, so that it is possible to have a true and even surface to mill out the diamonds. After laying out the form and cutting out the plate, a perfectly square block is made a little wider and longer than the plate to clamp in the milling machine vise, and then the plate is sweated to the surface. First, tin one side of the butt plate and also one side of the block. Clamp the plate in position on a center line. The heat which the block contains will form a perfect union on the two turned surfaces. After this is cooled in water, it is ready to be clamped in the milling-machine vise for the checkering operation.

It would be well to clamp a piece of cold-drawn steel in the vise at first and make experimental designs. Since most milling-machine vises are graduated in degrees of angle, various angles can be used to see just where the vise can be placed to give a diamond as nearly perfect as the design will allow. After such trial pieces are made, it will be an easy matter to mill the checkering on the butt plate to the intended design.

After the checkering operation is finished a cast-iron form is made to the proper contour, slightly rounded lengthwise. Make the form a trifle larger than the plate all around, and as cast-iron is easy to file, the form will be shaped very quickly. After this is finished, a female form about one inch thick is moulded from babbit metal. Take a thin piece of sheet iron and form a band around the entire form, allowing it to extend about one inch over the top surface of the form, and clamp this in position. Use clay or asbestos to chink the small opening so that none of the metal can run out. Warm it slightly, place it on a level plate, pour melted babbit in until it comes flush with the form, and allow to cool.

The plate is now ready to be set into shape; an arbor press is employed for this. By placing the female form on the bottom plate of the press and the heel plate in the center of the die, the male form is set on the plate in the center of the ram. Very little pressure is required to bring out the form that was anticipated without injuring the sharp diamonds. Before the plate is passed through this operation it would be well to drill the screw holes; it is much easier to do so at this moment than when the plate is formed.

If a round or elongated trap is wanted in this butt plate, secure a Springfield or a German plate to study its construction and carry out your trap plates to their ideas, which are hard to improve upon. This will be more simple than an explanation which would require detailed drawings. After one of these plates is finished it should be case-hardened in colors, adding not only a rust-proofing agency but a pleasing color as well. (Refer to Chapter XVI.)

The "free rifle" type of butt plate is made of aluminum. A pattern is made to the desired form and shape; it is not necessary to follow any particular design, and is better perhaps to use your own ideas in the development of a plate which you have been anticipating to suit your requirements. When making your pattern remember the limitations of its moulding and that the pattern should be of a shape easy to draw from the sand. The rough casting as it comes from the foundry can be filed smooth or given a sand-blasted finish. Aluminum, as I understand, can be given a blue finish, but at this writing I do not have the information of just how this is done.

Palm Rest — Along with the information given for a free rifle butt plate of aluminum, it is proper to suggest a palm rest for the same rifle; construction is easy. The ball is a regular water-polo ball of solid cork, obtainable in sporting-goods stores.

An extra magazine floor plate should be secured to attach the palm rest, changing floor plates; this enables one to use the rifle with or without palm rest as desired. No special detailed drawing is required to make up this rest. The parts may be made of any metal desired.

Rear-sight Bases — The mounting of leaf sights on military rifles should have special sight bases made in proportion to the leaf sights used. If only a single leaf is used, a band can be made encircling the barrel. If more than one leaf, a base made as Figure 104 illustrates should be employed. This

ard. These sight bases have been used for years by the British rifle makers, but only of late have we employed them on our sporting military rifles using one or more leaf sights. Colonel Whelen and I expressed the desire for such a base; at that time we had developed bases similar to the British standard, but because of the high cost of applying these to rifles in this country, very few wanted them. Altho the expense is a little high, they are worth all that is asked for them.

The most satisfactory way to construct such a base for a person who only wishes one is illustrated in Figure 104. First, bore out a piece of either

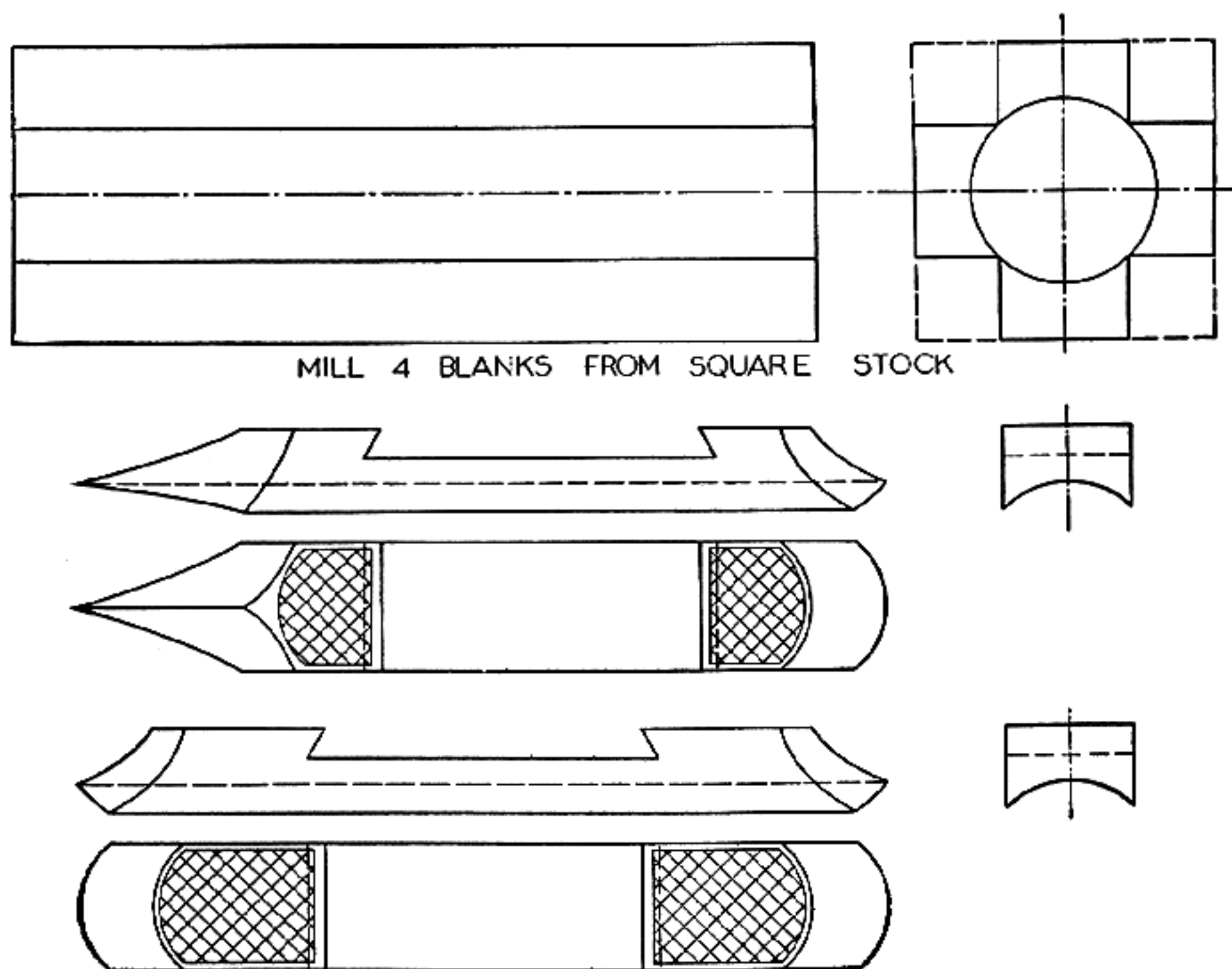


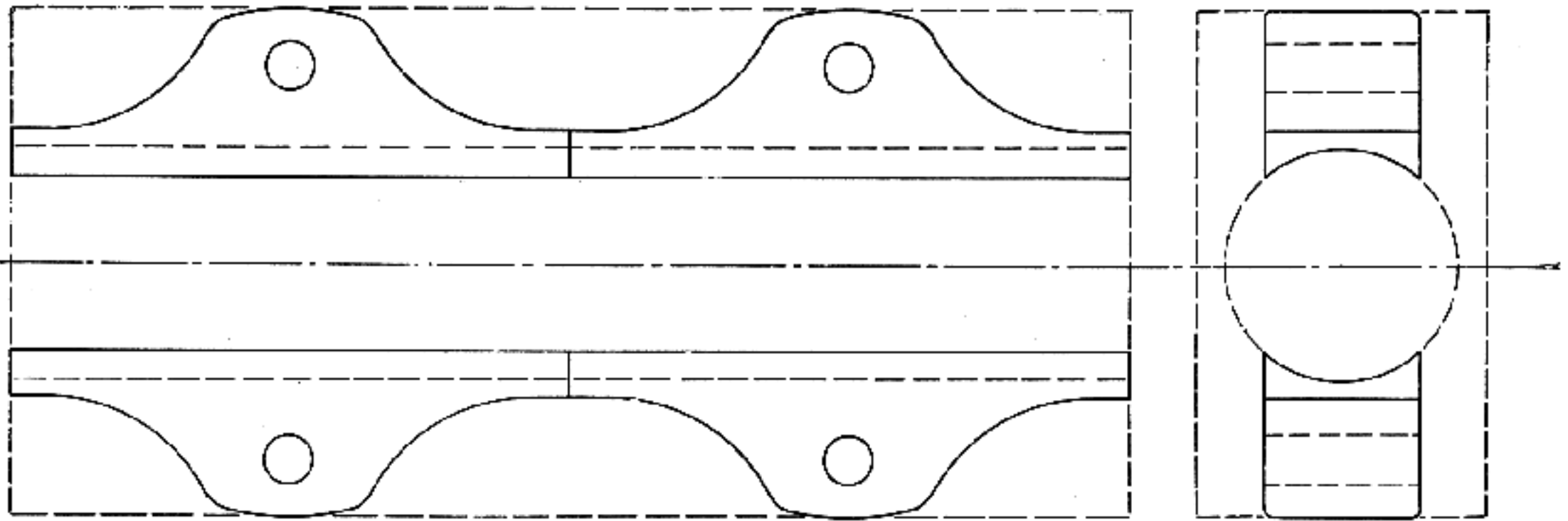
Fig. 104
Leaf-sight bases

base made in either style imparts a neat and graceful outline to the barrel. When an aperture sight is used, a leaf sight of some nature should be used, as for an emergency sight on a hunting rifle. Merely as a check on the alinement of the aperture sight, it will be decidedly useful if ever the latter is broken or thrown out of alinement.

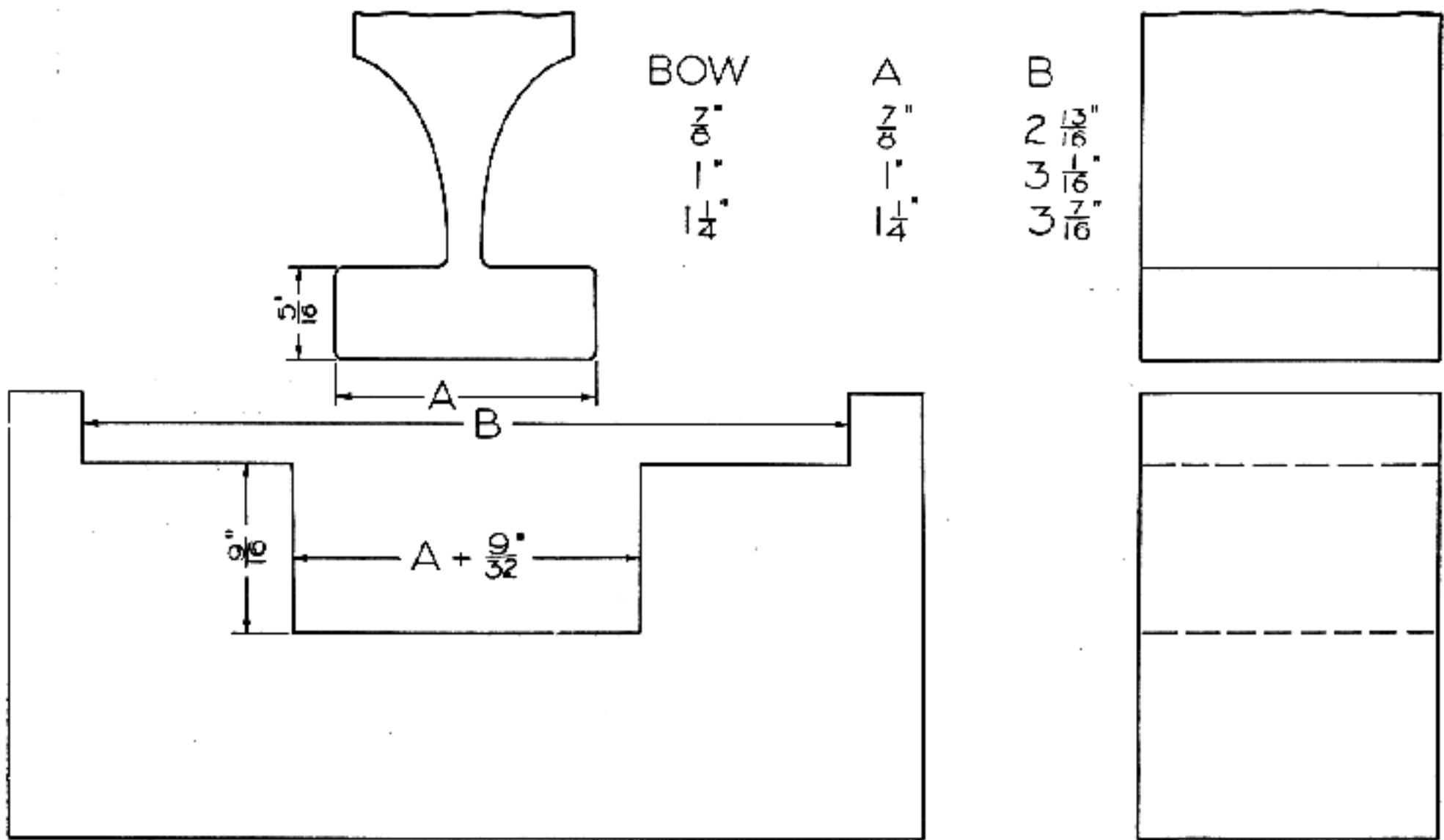
When a band is used this can be drilled and tapped to hold the forearm in position, but we must discard such ideas whenever possible. They sometimes serve their purpose on particular rifles, but today we look forward to graceful outlines, and these cannot be had with this type of base. The base shown in Figure 104 should be made a stand-

2-inch round or 2 x 2-inch square stock, as Figure 104 shows, to a length which will be in proportion to the leaf sight used. From this blank four bases can be made. Lay out the face of the blank and prick-punch the outlines made for the four bases. Bore the blank to the diameter and taper off the barrel in the desired location. After completing the lathe work, either shape or mill out the side section to the desired width. If placed in a milling machine to do this, use a $\frac{1}{8}$ slitting saw or straddle mill to remove these side sections of surplus stock. The milling operations can be brought up to the lines, leaving the file to remove the milling-cutter marks. After the sight bases are cut out, the ends

MILL 4 BASES FROM RECTANGULAR STOCK



BARREL SWIVEL BASES



DIE FOR SWIVEL BOWS

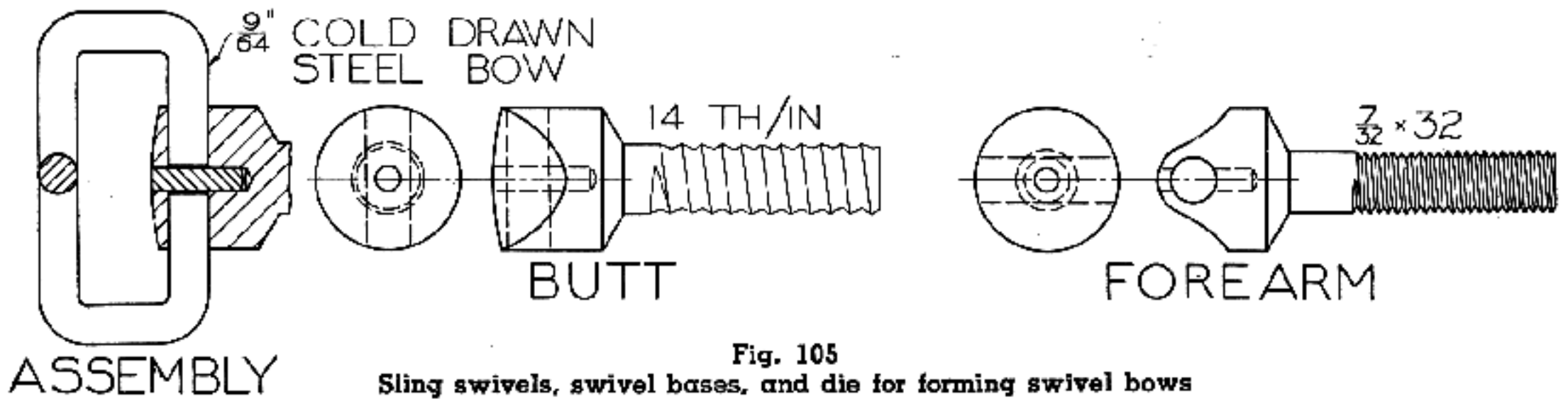


Fig. 105

Sling swivels, swivel bases, and die for forming swivel bows

are milled. The back end of the base is milled out with an end mill of about $\frac{3}{4}$ -inch diameter. After the surplus stock is removed, a slight curvature is filed in this radius which removes the plainness of the straight cut. The top is milled off approximately $\frac{1}{8}$ inch over the estimated height of the finished base, and the front end is milled. Study

Figure 49, which shows the solid ribs attached to the barrels.

The separate bases can be milled similarly, or an end mill can be used to form the front which was used for the rear, making both ends the same. After the milling operation the base is spotted to the barrel, and the end and sides are polished. Two

screw holes are drilled, one on each end, close to the location of intended dovetailed slot, and counterbored to take a 6 x 48 fillister-head screw. The counterbore should reach close to the bottom and have but a thin web for the head of the screw to pull the base in place. Having thus prepared the base to this point, sweat it to the barrel, and the two screws will pull it down into place. Only three or four threads need be tapped in the barrel to hold the base in position; with such preparation a sweated base held by two screws will never break loose. The surplus solder is removed from the sides of the base and barrel and then polished.

The next stage of the operation is to set the barrel and action at right angles in the milling-machine vise; mill the top of the base to the desired height and also mill the dovetail slot and fit in the leaf-sight base. The milling of the dovetail slot is best performed with a vertical head or in a vertical miller. It can also be done in a shaper, but not as successfully as in the milling machine. The center of the dovetail slot must also be milled to a depth which will clear the working of the springs when the leaves of the sight are moved in position. The width should be $\frac{1}{16}$ inch wider than the springs. You have probably noticed that part of the screw heads have been milled off and that the leaf-sight base covers the screw heads completely as the front sight covers the screw that holds the ramp; therefore, no indication will be visible to mar the appearance of the base. There have been various ways suggested to form rear-sight bases, but if the reader will follow this information and the illustrations, a most satisfactory sight base will be designed.

Barrel Swivel Bases—Bases for the attachment of swivels on a rifle barrel ahead of the forearm are made in different shapes—some are good and others are just passable. Two designs of barrel swivel bases will be described which may be used as standards. Figure 105 (at the top) illustrates one of the best and also the method in which it is produced from a piece of 1 x $1\frac{3}{4}$ inch cold-drawn or machinery steel. A straight hole is drilled and reamed in the center of the blank to the barrel size at the point of location, which is usually 2 inches ahead of the forearm tip. The usual length of these bases is $1\frac{1}{2}$ inches, but since boring and milling are so simple, four can be produced from one blank, as the illustration shows. Before anything is done to the blank, one end is laid out and all cut-out lines prick-punched so that it is possible to cut up to lines with the milling cutter. A $1\frac{1}{4}$ -inch end mill may be used for the entire operation. The blank is clamped in the milling machine vise and the surplus stock is removed on the ends and in the

center to the desired depth. After one side is finished the blank is reversed and the operation repeated. Next, the sides are milled for width. A sufficient web is left on one side to hold the blank in the vise and mill out the opposite side. With this web holding the bases in place, the one side is milled into the bored hole. The opposite side is cut out with a hack-saw and the sides are finished with the milling cutter by catching the top of the base in the vise. The bases are now separated, drilled, filed to form, fitted to the barrel and sweated into their proper locations. The bases shown in Figure 49 are the most artistic to use in barrel design. They eliminate the use of a band around the barrel; however, many prefer that design of swivel base.

Figures 106 and 107 illustrate a swivel band made from $\frac{7}{8}$ x $1\frac{1}{8}$ x $\frac{5}{8}$ inch cold-drawn or machinery steel. The center lines are laid out together with the width of the base, and prick-punched, making it possible to work to all lines on the lathe and milling machine in order to have the base come in the exact center when finished. Chuck the blank in the lathe and bore to a standard size, 1 inch ahead of where it is desired on the barrel. After being milled, the band is expanded with an expanding mandrel, as shown in Figure 106, together with a base, to the desired location. The milling of this band is done with a $\frac{3}{8}$ or $\frac{7}{16}$ inch end mill, the band being held on an expanding arbor in the dividing head. Figure 106 illustrates the arbor, which is used not only for this operation but for barrel bands as well. It is best to remove some of the surplus stock from the outside of the band so that the milling cutter does not do a lot of unnecessary removing of material. This is rather a slow operation, for it is only possible to remove a small amount of material on each cut. The dividing head is set crosswise on the table, and the end mill used should be a spiral to eliminate undue chatter. The milling of the cylindrical portion of the band is done by revolving the indexing handle by hand the full cut or entire surface of the band, in contact at all times with the cutter. Very light cuts are removed until the thickness of band reaches $\frac{1}{32}$ -inch wall thickness.

The projection of the bottom of the base is also milled on the same set-up, except that a convex cutter is used in order to secure the correct form and height. The dividing head is now set lengthwise on the table, and with a $\frac{1}{2}$ -inch end mill both sides are milled to obtain the narrow center width shown in the illustration. Instead of having this narrow width come in the center, it can come straight on the back side with a full radius formed at the front. After the milling operations are per-

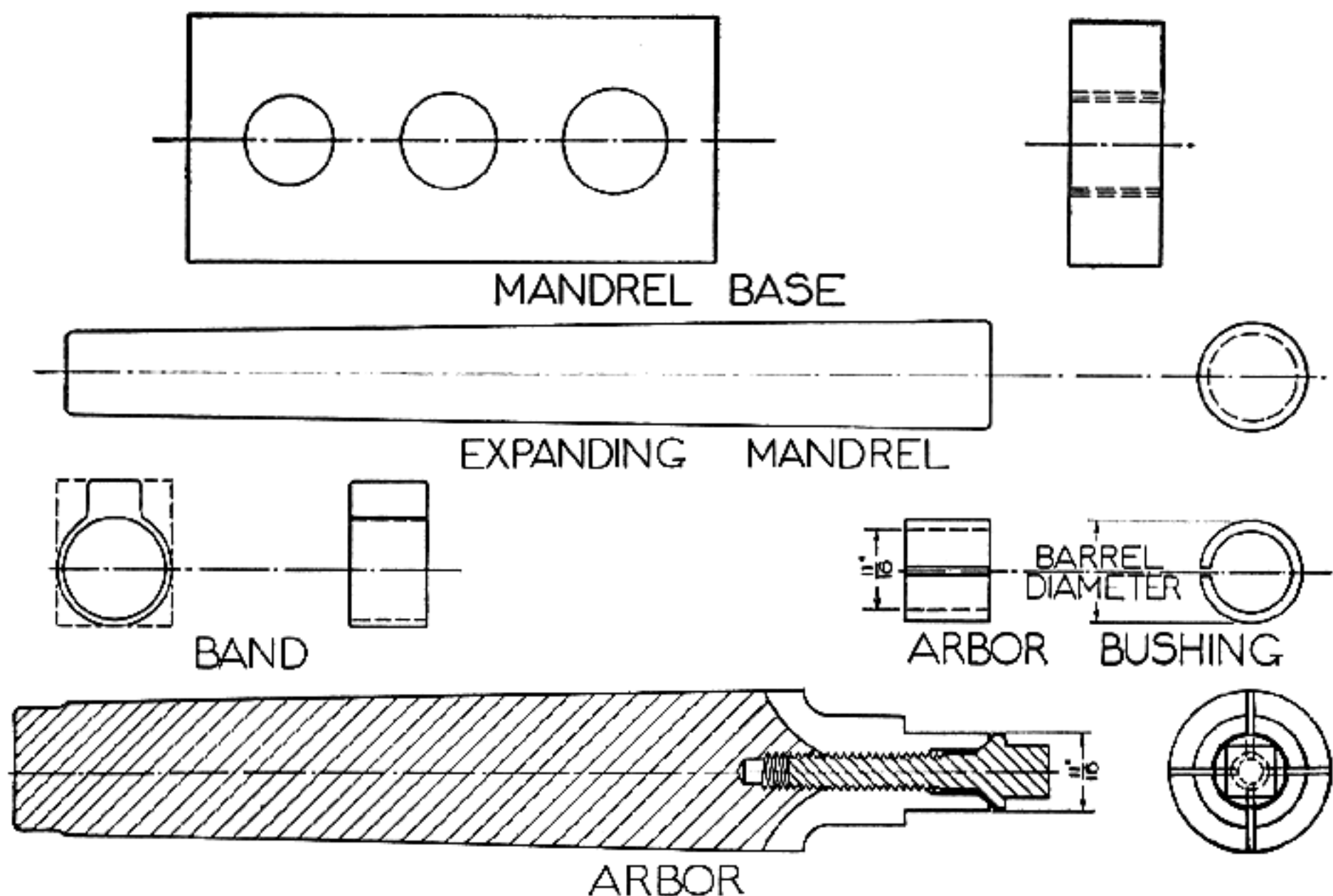


Fig. 106
Barrel-band tools

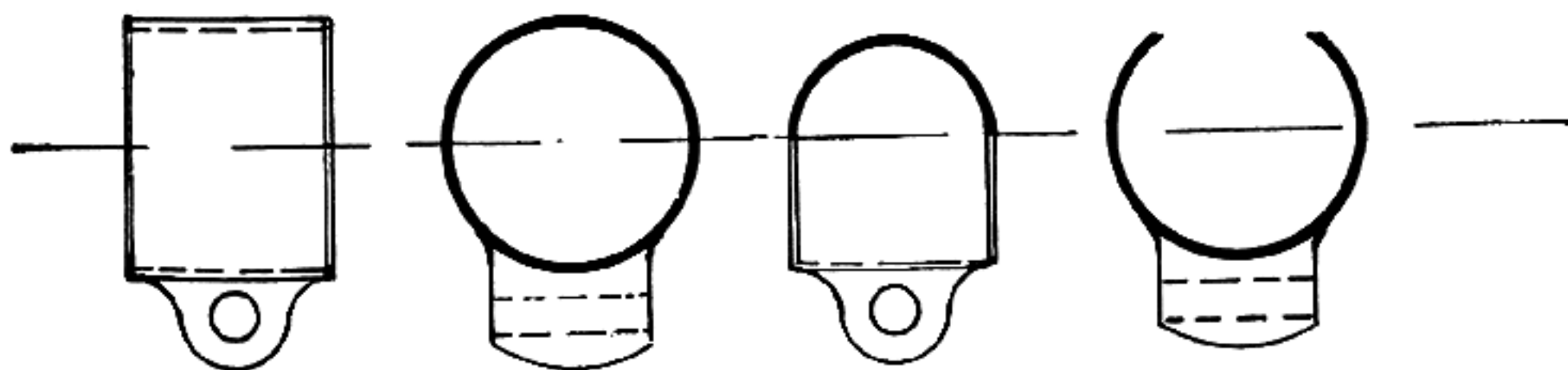


Fig. 107
Barrel bands for quick-release swivels

formed the band is expanded with the arbor to the desired location on the barrel. The hole is drilled, the band filed, giving a high buffed polish, and sweated into place on the barrel.

Barrel Bands — Barrel bands are a necessity on all target arms. A few years ago we had no conception of how essential a barrel was to fine accuracy; the finest barrels were often condemned, but very few ever fathomed what caused the poor results until the discovery of the forearm swivel fastening which was screwed into the barrel itself. Barrel studs are perfectly satisfactory for sporting arms where no pressure is drawn on the barrel in the act of firing, but a target rifle is so different that it is required. The most artistic and best are made from $\frac{7}{8} \times 1 \times \frac{5}{8}$ inch cold-drawn or machinery steel similar to the barrel swivel bases, except that there is not so much work necessary to form the bottom as on the other.

A barrel band must be bored out straight to a standard size; after being milled the band is stretched or expanded over the size in its proper location. Cold-drawn steel will not stand as much stretching as machinery steel; therefore, the latter is the most desirable of the two steels for this purpose. Figure 106 illustrates the manner in which a barrel band is started and finished. There is such a vast difference in diameters of rifle barrels that the dividing-head expanding arbor shown in Figure 106 should be made to a standard size, such as $\frac{1}{16}$ or $\frac{5}{8}$ inch, and then bushings, which are split, also made as illustrated; these are made in different sizes as needed to fit the odd-sized bands, and the diameter on the end of the mandrel is made to a standard. A number of these bushings could be drilled and reamed to the diameter of the mandrel; then whenever they were needed they could be pressed on an arbor, turned to the bore diameter of the band, and split with a hack-saw. A little pow-

dered rosin dusted on the cylindrical surface of both the inside and outside of the bushing will hold the band in place better in the milling operation.

The diameter of the end mill usually used for this operation is a $\frac{5}{8}$ -inch spiral cut. The setting of the dividing head is done in the same manner as for the swivel band, and the same instructions are followed. After the milling operation is finished, the swivel hole is drilled and tapped. Three different sizes may be used for this: $\frac{3}{16}$, $\frac{7}{16}$, or $\frac{1}{4}$ inch. The $\frac{7}{32} \times 26$ inch or 32 thread is the best standard to use if you are making your own swivels. The band is expanded and fitted to the barrel, but since there is such a difference in barrel diameters, various-sized expanding arbors can be made with just a trifle more taper than on a barrel. Bottom steel blocks are drilled so that when a band is set over one of these holes it will have the full support of the cylindrical diameter. If a hole is too large and the band is caught on the base and top portion of the circle, it is stretched out of shape. It is well to remember that even machinery steel will stand just so much expansion and no more. The expanding operation is usually performed on an arbor press, the bottom base resting between or over one of the cut-out slots on the arbor-press base plate.

Shelby tubing has been suggested for barrel bands, but since so much material has to be removed by machine, it does not pay to use it. The inside of any solid band must be bored and if time is saved on the lathe operation it is lost in the other two operations; besides, this material will not stand very much expansion; therefore, select the square machinery steel for barrel bands made in this manner.

A simple method of making a barrel band, if the shop is not equipped with a milling machine or any other machine tools except a drill press, is to form a band from a piece of sheet steel, as illustrated in Figure 108, which shows a band made in two pieces, it being attached to a base block with two small rivets. The method of forming the band is clearly illustrated in Figure 108. A piece of square steel, of the same width as the proposed base of the band, is wired or taped to a mandrel. It should be the exact diameter of the barrel in the location where the finished band will be placed as shown in the cut; a U-bend is made in the sheet steel, and the piece then "straddled" over the mandrel and the vise set up tight.

The base is made from a piece of $\frac{5}{16} \times \frac{3}{8}$ inch square cold-drawn steel. Two holes are drilled through the band and base. The rivets are cut off so they will project over each in the side, allowing enough to rivet over, completely filling the chamfered drilled holes, forming a perfect union between

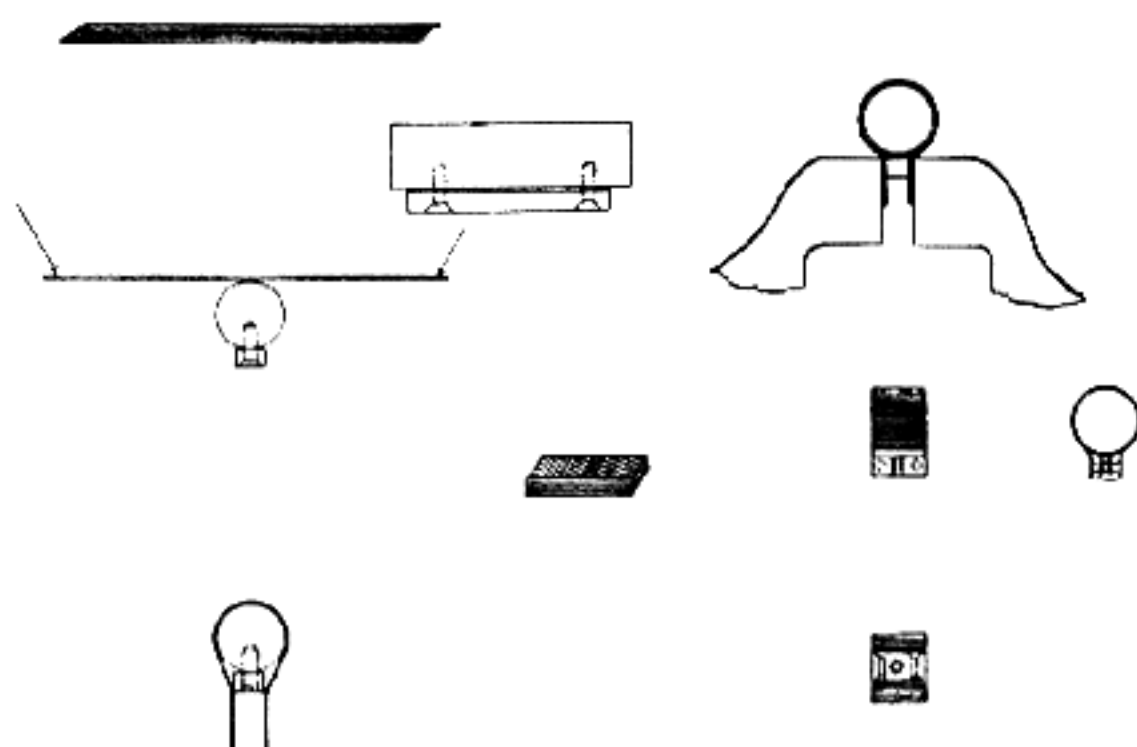


Fig. 108

Method of making a simple barrel band for any sporting rifle

band and block. The use of rivets enables the band to be drawn very tight to the base. Screws can also be used for this operation; they make a very solid band. The band is made from 0.025 inch to 0.030 by $\frac{5}{8}$ inch sheet spring steel, annealed, and it should be fitted to a barrel about $\frac{1}{4}$ inch ahead of its intended location; then hammered or peened on the mandrel to a perfect fit after being assembled. After all operations are completed, it is filed, polished, buffed, and blued, before being placed on the barrel. This type of band answers in a number of places, but whenever machinery is available, a one-piece band is always much more favorable in appearance.

A variation in the use of this band is with either the Springfield or Winchester swivel bases, as illustrated in Figure 108. The base block is made longer and is attached to the barrel band and the swivel; the latter is attached to the base block with two screws that are drilled and tapped in each end. If desired, the swivel band may be removed from the base and detachable swivels used. Such an arrangement is really better for target rifles than the single screw, as the latter often loosens and turns sideways from the pull of the sling; this base is always in line.

Swivel Screws and Bows — The first stage of making the common sling swivels is to construct the swivel screws for the front and rear. The latter is made on the principle of a wood screw while the former is a standard machine screw; therefore, one is made to screw into wood and the other to screw into a tapped hole in a piece of metal such as a barrel band or barrel. Study the construction of swivel screws for the quick-detachable swivels illustrated in Figure 105; they are made in the same manner, except that the heads are made $1\frac{7}{32}$ inch in diameter and the holes are drilled with

a No. 25 drill. The quick-detachable swivels are made by the Winchester Repeating Arms Company and a firm in Germany, but only in $\frac{7}{8}$ -inch widths, the standard for a carrying sling used for a sporting rifle. All such rifles should be equipped with this swivel, for many times a sportsman does not wish a sling attached and these are very simple to un-snap instantly.

The making of swivel screws in either type can be done on a lathe, but if many are needed, it becomes a production operation and is best performed on screw machines. Before beginning the operation of the butt swivel screw, the correct form must be considered for wood. Figure 105 shows the butt swivel and form of thread best adapted for wood; the screw is constructed very differently from any other form of screw used in wood work. (Study Chapter II, Volume I, for the desired information.) The usual lead of this screw is 14 per inch, but coarser threads are recommended. This form of thread is rounded in the bottom with the top left sharp; therefore, the tool used to cut it is made 0.070 inch wide with a 0.035-inch radius on the end. This thread cuts its form into the wood and gives it considerable support in the threads; whereas, the other form of screw breaks or crumbles the wood to such an extent that it often pulls out if much pressure is used.

The forearm swivel screw is the United States standard form of thread; a standard die is used to cut it. The forming of the head of the screw is done in a milling machine with a form cutter, which is the best method when a large number are to be made. When only a few are required they can be filed by hand or the head left round, which has a pleasing appearance; however, the formed head is usually preferred. When drilling the hole for the swivel bow it should be done in a drill jig in order to have the hole come in the center of the form. If only a few are made the hole is drilled first and the form filed to the center of the drilled hole. A $\frac{3}{32}$ -inch hole is also drilled into the end to one-half its depth to keep the swivel bow from working out. The end of the hole is slightly countersunk to give the small pin more support when it is riveted over.

The making of swivel bows for the screws is very simple after the die, shown in Figure 105, is completed. The size of rod ordinarily selected for a bow is either $\frac{1}{8}$ or $\frac{9}{64}$ inch. The correct length of rod is cut and laid between the solid gauges in the die, and the punch is brought down, pressing the rod in the die form; when it reaches the bottom the two ends are bent into the center web of the punch. This operation can best be done in an arbor press with the punch fastened to the ram and the die fastened to the plate. In the absence of an

arbor press a steel block is made the same size as the bottom of the punch and used in the bench vise.

If a large number are to be produced a cam die should be designed and constructed; however, quite a few can be made on an arbor press in a day's time. After the bows are formed in the die, one end is bent out just far enough to clear the head of the screw as it is assembled. The straight end is first inserted in the drilled hole and then the bent end is straightened in perfect alinement with the hole and the swivel screws set in the center of the bow. The $\frac{3}{32}$ -inch pin is driven into place and riveted over. The end is polished, and if it is well done the least sign of a pin is absent. After this operation the entire swivel may be blued by the niter process given in Chapter XVI or the case-hardening method contained in the same chapter.

There are many methods of making sling swivels; altho the best have been described, sometimes a standard base or swivel band must answer for a quick job, or a substitute found. The Springfield or Krag offer a number of ways by using the bands and swivel bases. If a quick-detachable base is required, the use of the butt swivel base will answer the purpose very well. Cut the swivel bow in two and pull the pieces out of the base. Enlarge the hole with a No. 25 drill. When the drill strikes the center pin in the base, be very careful to see that it does not catch the drill and break it.

These bases are of the proper width for quick-detachable swivels and this type of base also answers for the forearm swivel. If the base of this type is to be used for the forearm swivel, the barrel band should be of the wider type so that the fillister-head machine screws would go through the forearm and into the barrel-band base. On a target rifle with heavy beaver-tail forearm it is advisable to eliminate the band entirely, the swivel base being entirely attached with wood screws.

In remodeling a military, obsolete, or standard factory arm, it is often desired to use the old outside barrel band because it fits the barrel and the stock so perfectly. The forward swivel screw can be cut off and threaded to the shoulder which has been previously described, and after drilling and tapping the bottom of the band, the swivel should be screwed in very tightly with the swivel bow standing crosswise when the band is in place. The inside of the hole should be slightly countersunk and the small projection end of the screw riveted over. To do this, stand the head of the swivel and band on a block of lead to prevent its being marred, and use a small-ended drift punch for the riveting operation. The end, after being peened over, should be filed flush with the inside of the band.

Barrel Collars — When top hand guards are fitted to remodeled military rifles a collar must be made next to the receiver to hold the hand guard in place. Figure 109 illustrates two collars used for this purpose. The forward barrel band is prepared to hold the guard in its forward position. This is only done when making a full-length stock of the

fully in the upper part of the band and brazed from the inside. The piece is then filed to fit over the barrel with just a neat clearance. Preparations such as these make a more satisfactory appearance than allowing the wood to show.

In remodeling the Krag or any other military rifle which has much drop between the receiver and

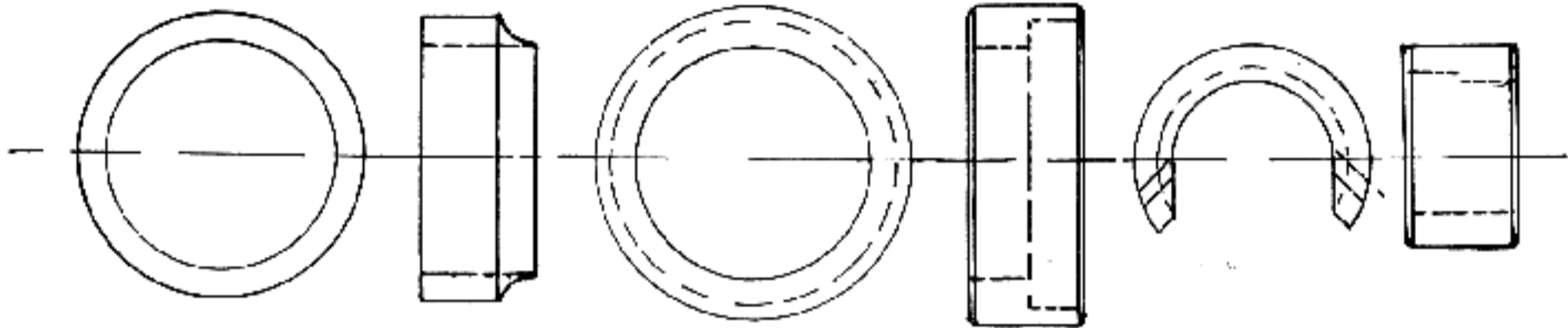


Fig. 109
Barrel collars used in front of receiver and to hold wooden guards in position

Mannlicher type with a top hand guard. There is very little call for hand guards, but it is well to know the methods used for them. These collars need not fit the barrel tightly, but should be made so that they just slip over without undue play. The tenon of the hand guard wedges itself into the recess of the collar and holds it firmly in place. Collars should be turned very thin, and where the tenon of the guard fits, should only remain a thin shell. The forward band is the standard Springfield lower band; a piece of sheet steel is fitted care-

fully in the upper part of the band and brazed from the inside. The piece is then filed to fit over the barrel with just a neat clearance. Preparations such as these make a more satisfactory appearance than allowing the wood to show. In remodeling the Krag or any other military rifle which has much drop between the receiver and

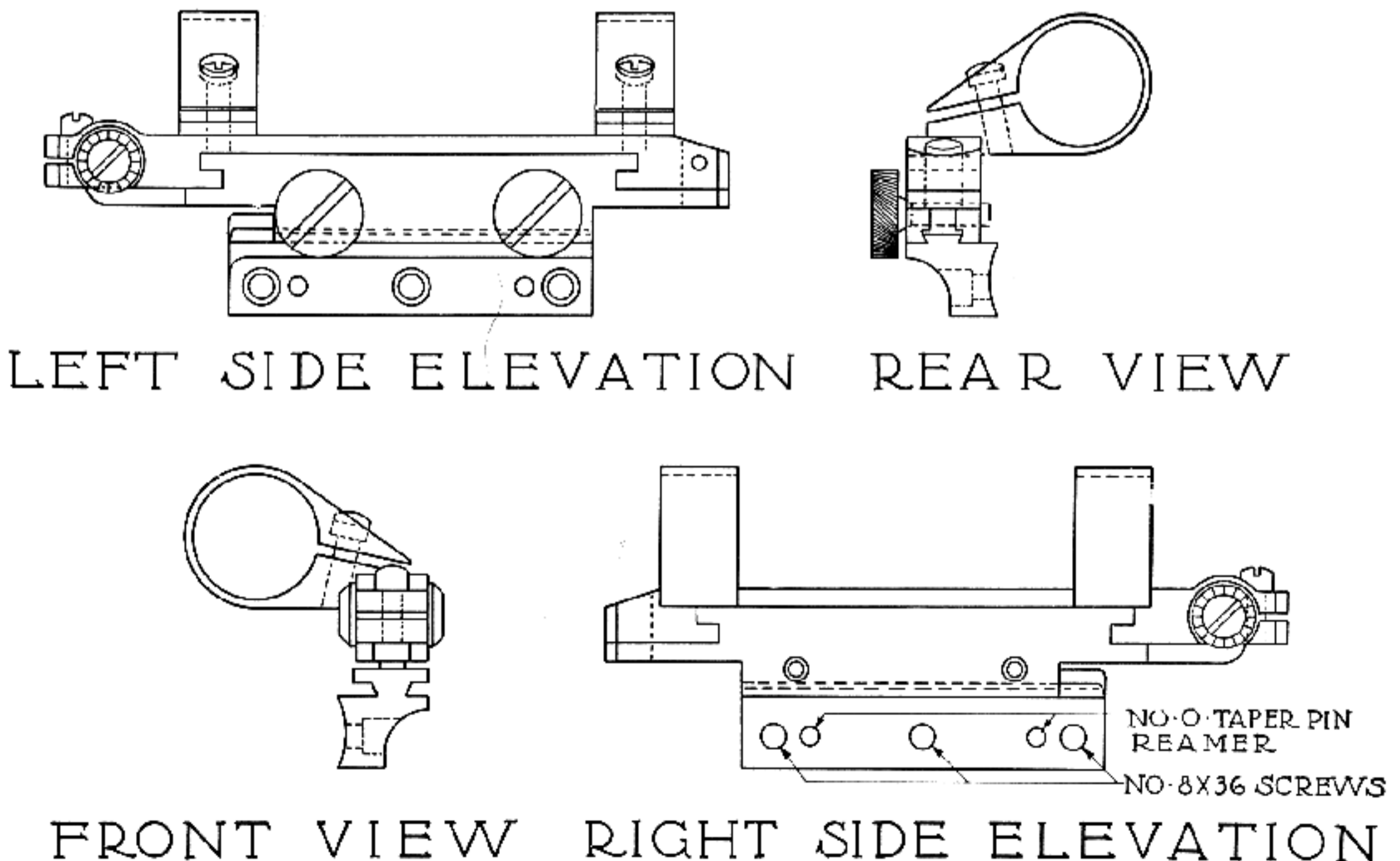


Fig. 110
Niedner sporting telescope mount

band is the most desirable, but if it is a little loose on the barrel it can be closely inletted when it is being fitted into the stock and then it cannot move from its position.

Telescope Mounts — Since these are rather difficult to make, it is much better to procure them from the manufacturer, unless you have ideas of your own which are better in all points of construction. The simple mounts which we are all familiar with need no explanation such as those on the Lyman and Fecker target telescopes. There is room for improvement on all these mounts and bases, particularly in the methods of fastening, but that is aside from what we are concerned with at present.

Telescope mounts for sporting rifles have not undergone very great improvement. The German idea of fastening a telescope is very good indeed except for the windage adjustment, but now that it is possible to make adjustments in the telescope itself for windage, a better development of mounts on the German principle will be an accepted advantage over some of the poor mounts before us today.

Figure 110 illustrates one of the best mounts made in the United States from all angles of mechanical construction, even to the artistic outlines which are so gracefully blended with the lines of the rifle and telescope. I am rather opposed to a telescope on a hunting rifle where it is used on long hard trips, but in the territory adjacent to one's home a telescope is an ideal sight. There are quite a number of sportsmen who, because of defective vision, must turn to a telescope even on a long hunting trip; they must nurse their instruments, not only protecting them from bad falls, but developing the necessary skill to keep them in adjustment even when the odds are against using them.

The mounts illustrated are very positive and will never get out of order because of wear. The two locking screws are made large with the coin slot; the mount is split in the center of the dovetailed

slot with a small slitting saw, and as it is slid over the male dovetail on the base and the two screws tightened, it makes a solid union which can never become loose when once locked tight. The windage adjustment consists of two coin-slotted screws bearing against a center projection which cannot be seen because the mount has a rear swivel pin and closely fitted rotary square T-bearings. The one-screw telescope clamping band is an added feature, but some do not care for this as it is necessary to strip the telescope to place it in the mount. This is a poor excuse, however, for whenever it is possible to eliminate any unsightly projection or unnecessary screws it should be done—it is good engineering practise.

The mount is instantly detached by loosening the two screws and sliding the mount off the dovetail base, and since the base on the receiver is small it is not objectionable. As can be seen from the illustration, the telescope is mounted directly over the center of the receiver. Figure 111 illustrates a mount of this description. In the construction of a telescope mount, all these features should be taken into consideration to make the mountings a success. Those who are determined to design and construct their own mountings for telescopes should consult all makes of mounts and telescopes and avoid those which are just mediocre. Try to surpass all other designs and produce a mount which will stand the heaviest of recoils—a resistance not possible with some mounts now on the market.

Telescope Blocks — Figure 112 illustrates three different blocks; the standard factory block, offset mounts, and a special mount which can be used for different centers such as 6, 7.2, and 8.2 inches. Such a solid block is perfectly satisfactory on a target rifle for those who wish a long base to obtain the various distances, or to vary the eye relief.

The construction of telescope bases is performed on a milling machine. After the blanks are milled to the desired width and height the radius is milled

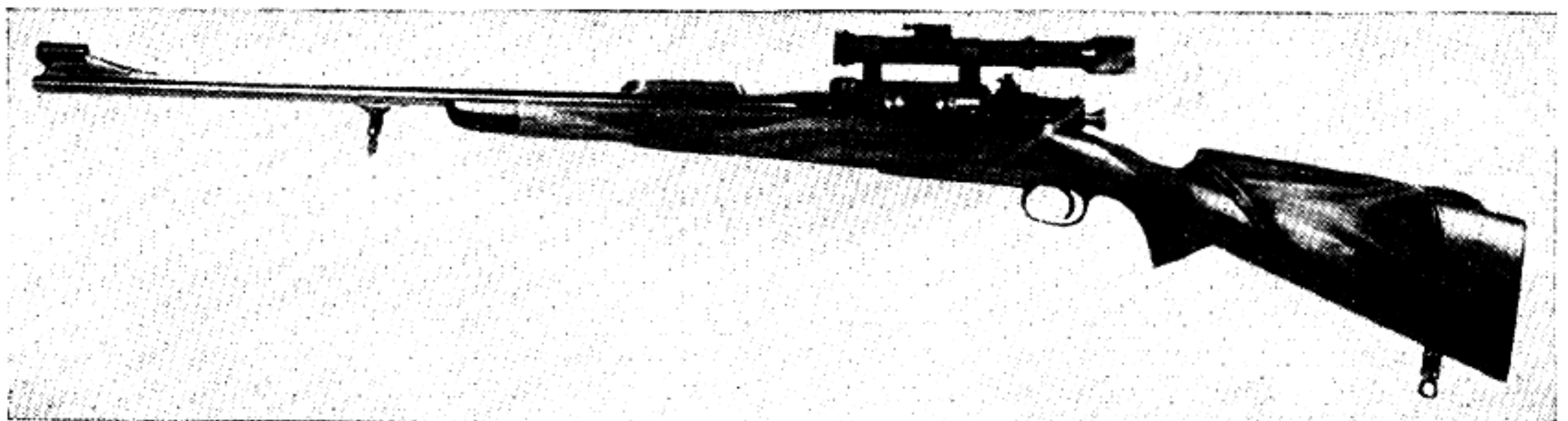
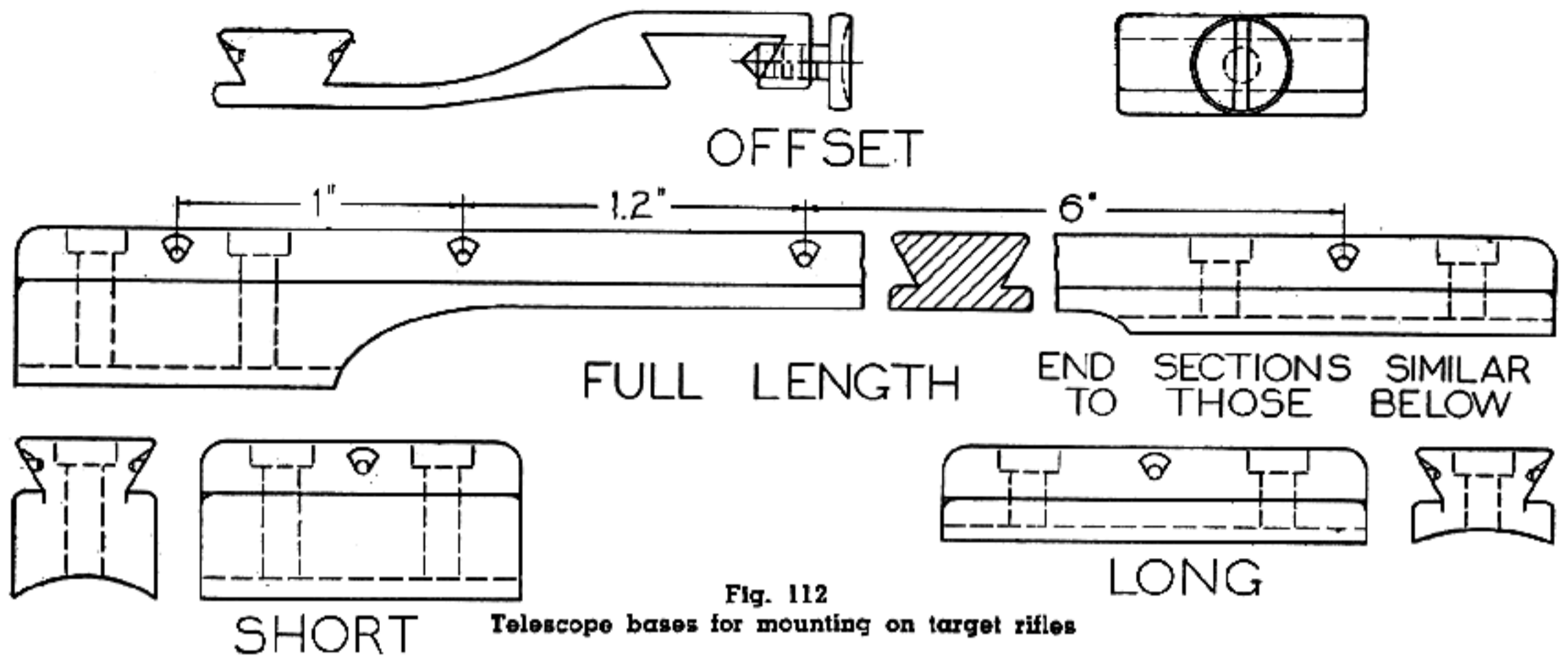


Fig. 111

Remodeled Springfield Model 1903 designed for Mr. Earl Benninghoff. Full sighting equipment



as near to the barrel as possible. The next stage of the operation is to mill the angles on the sides so that the mount can just slip into the dovetail slot. Instead of milling one of these at a time, a 6-inch blank is milled, the first operation being to mill the male dovetail slots the full length. This may be done in two ways, with a vertical attachment or with angle cutters on the arbor. By this method, however, it is necessary to remove the blank from the vise and reverse it; whereas with the vertical head it is not necessary to remove the blank from the vise at all. When constructing the full-length base it is much better to use the vertical head so that it is possible to keep the angular slot the same width the full length of the blank. The long blank to be used for the individual bases should be cut to the desired length and the radius cut separately on each block and also cut on a slight taper the same as the barrel. A small piece of paper is usually placed under one end as it is clamped in the vise, except where very sharp tapers are encountered. End mills are usually employed to mill the radius on the under side of the blocks by clamping the blanks to the edge of the vise; the end mill is fed lengthwise to the cutter by the cross feed. The separate blocks should be exactly the same height; therefore, the rear block is milled first, the front block machine to correspond to the latter. A straight-edge is laid over the top of the rear base, and by measuring down to the barrel at the point where the base is located, this distance will be given.

The illustration of the full-length telescope mounts is very simple. The reader can construct one of these by the explanation given for individual bases, but he must remember that an oil-hardened steel is best to use in their construction.

The offset bases are milled from a solid blank of cold-drawn steel; both bases are made in one

piece and then separated after machining operations are completed. The distance between the male and female blocks is governed by the individual requirements, but the usual distance is $\frac{3}{4}$ inch.

It is best to make telescope blocks such as those illustrated a little longer than the factory product. Provisions are made for well-rounded ends which are filed after all machine operations are completed. The width is also left a little wider so that a good support is had upon the barrel or receiver; the bases below the dovetailed portion should be given a slightly rounded surface. Filing demonstrates the forethought used to make a block look as tho it were not a factory product. The holes are drilled in the exact center; the distance is given on the telescope block drill jig illustrated in Chapter XVII, Volume I. Standard fine-threaded fillister-head screws are used; therefore, the counterbored and drilled clearance hole should just fit the screws. The standard screws for mounting telescope blocks are 6 x 48 with rather large heads.

The offset bases and the short blocks are usually case-hardened. (Refer to Chapter XVI.) The cyanid bath is employed for this. The full-length base is made from an oil-hardened steel and holds its shape in the hardening and tempering operations. The block is given the usual heat and hardened in oil, and the temper drawn in a nitrate bath is set at 650 degrees Fahrenheit, which produces a perfect temper and a perfect blue.

The mounting of the bases on a rifle should be done with the drill jig, illustrated in Chapter XVII, Volume I—one of the most reliable methods for all types of rifles. The mounting of telescope blocks to rifles that can be set upon parallels on the under surface of a receiver is easy, but when it comes to cheaper arms without a flat under surface or a side which can be squared, it often happens that blocks placed thereon are on one side after the

arm is assembled. With the drill jig, however, perfect alinement can be had with the rifle assembled in the stock and the jig clamped in place. For this reason, such a jig should be employed if a number of telescope blocks are to be mounted on rifles in the course of time.

Shields and Ovals—The construction of shields or ovals calls for a blanking and forming die; the metal used is gold or silver. With gold, nine carat is the usual hardness required, as pure gold is too soft. Their principal purpose is for a monogram, and they should be artistically formed. Figure 95 illustrates a number of these in Chapter XIII, Volume I; choose the one which appeals to you most.

Shields or ovals may be filed out by hand when only a few are required. A templet is made first and laid out very accurately upon a piece of sheet brass. If the form is pleasing, lay it on a $\frac{1}{32}$ -inch sheet of gold or silver, cut it out and form it to the contour of the stock in the desired location, which is usually on the under side of the butt stock between the pistol-grip cap and toe of the butt plate. After it is formed, two copper tacks are soldered to the under surface close to the top and bottom ends.

When you have cut out a templet which is exceptionally pleasing in design, it would pay to make a blanking and forming die to reproduce it for your own use, thus perhaps creating a demand for this attractive monogram plate.

Gun Slings—We shall be obliged to vary our work from metal to leather for the leather sling. The military gun sling Model 1907 is one of the best to use on a target rifle, and all gun slings should be remodeled from this type of sling. There are a number of different makes on the mar-

ket; some are very good and others are made of poor leather. If it is not possible to combine all the principles of the government sling in various widths, a sling of simple construction, the Whelen sling, can be made. This sling consists of one piece of $\frac{7}{8}$ latago leather, 60 to 72 inches in length. Two holes are punched opposite each other along its entire length, $1\frac{3}{4}$ to 2 inches apart. It is laced together with leather thongs, or with hooks made as Figure 113 shows, one at the bottom and one at

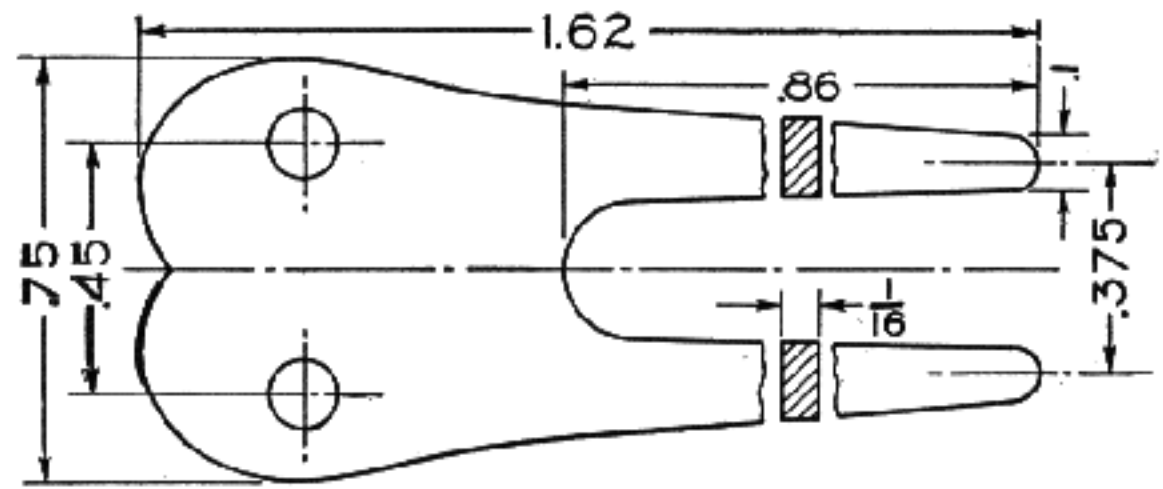


Fig. 113
Die-stamping of a Whelen gun-sling hook

the top. It is used for carrying purposes, but can also be used to steady the hold for offhand shooting. Slings are very reasonable and it hardly pays to make them unless one wishes something different and is willing to spend time making them.

There are probably a great number of simple parts which I have failed to mention in this chapter, but the general outline of special parts will enable you to make others. I have omitted sights of special construction, carrying cases, loading tools, etc., because special chapters are devoted to some of these subjects. At times the construction of special parts taxes the ingenuity of the mechanically inclined person as well as the amateur; but after all, each one turns out something which is just a little different and creates greater possibilities for something better than we have had.

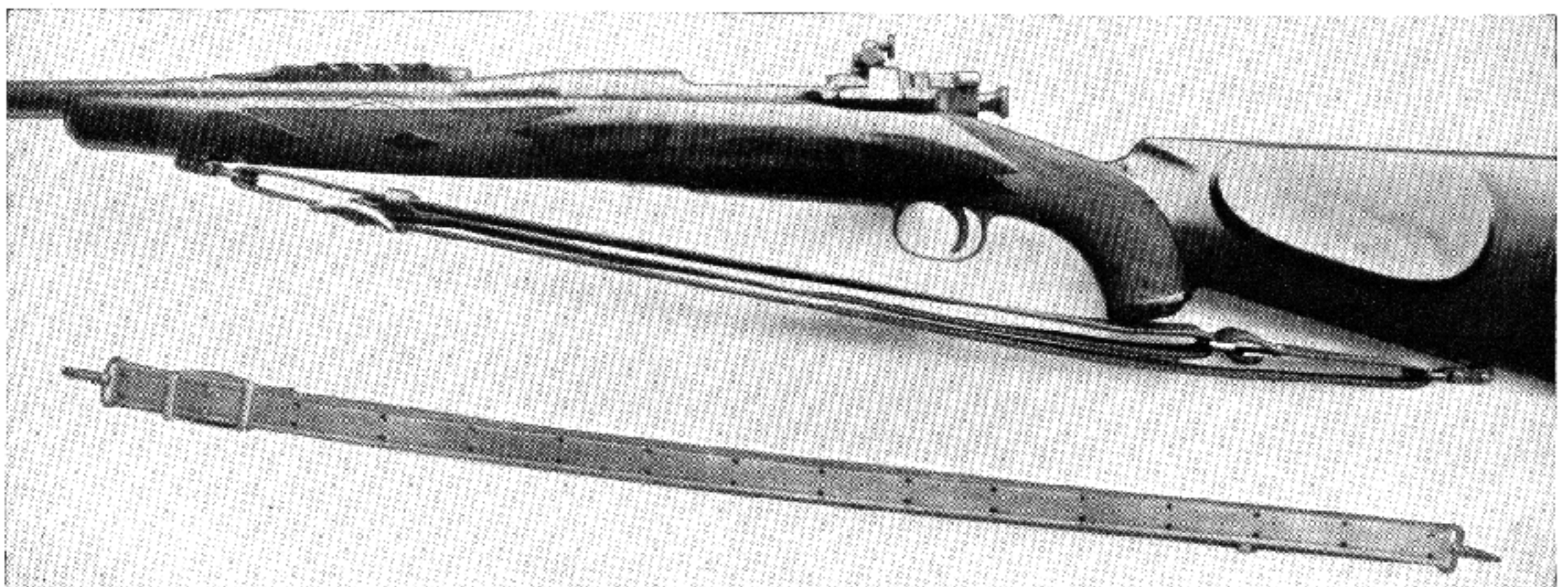
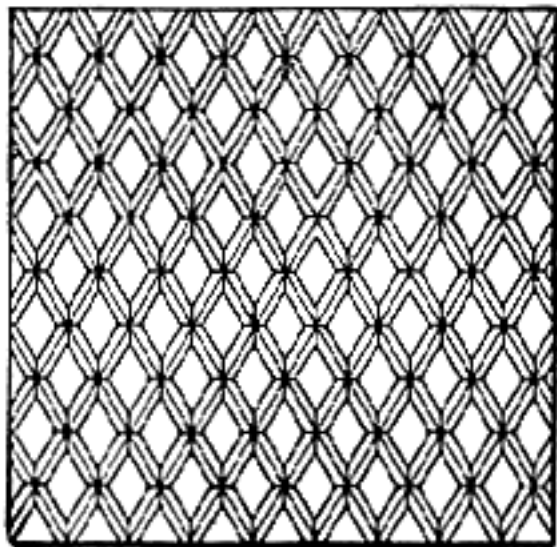


Fig. 114
The Carney gun sling. The sling that meets the needs of the target shooter or hunter

CHAPTER XX

Manufacture of Gun Sights



Manufacture of Gun Sights

THE designing and constructing of new sights requires a considerable amount of tool and die making practise, as well as a knowledge of the principles of optical engineering. When all these interpretations of designs are understood, the study of ballistics is essential, and the understanding of various other controlling factors. Many ingenious, mechanically trained men do not have the courage to construct sights without anticipating some mercenary returns for their efforts, and the only way this can be accomplished, when one has something better than the standard factory sight, is to build these in his own shop. However, when one must compete with large and well-established businesses in such lines, one must have capital as well as a large variety of salable items.

Putting aside the values in dollars and cents, design sights for your own particular needs and ideas; they may not be new, but you can find endless pleasure in realizing your ideas, providing you have the necessary tool equipment. After you have looked through a number of catalogs of sights, you will see such an endless variety, from simple open sights to the most complex aperture forms, that you may become discouraged. You may think there is no room for improvement. Never hold such thoughts. They are like an old book I once picked up, written by a noted London surgeon in the year 1802; in it he described the various instruments used in his profession at that time, saying: "There can be no further improvement in the instruments shown." (They appeared to represent butchers' knives and saws.) If only it were possible for him to return to earth today and see what has been attained in the medical profession alone, he would be amazed.

The same carries true today, for many think there can never be further improvement on what we have. Eliminate such thoughts from your mind and look upon all that is before us as mere toys, for the evolution of mechanical development is so great that it is impossible to foretell the future.

In designing the various types of sights it is desirable to bear in mind one of the properties of the human eye, since it is only by so doing that the principles underlying the various types of sights can be fully appreciated. The human eye, like the

photographic camera which is exactly similar in principle, is unable to focus simultaneously on objects at different distances from it. From this it follows that in alining two or more objects, such as the open sights about to be described, only one of them can, at any given moment, appear perfectly defined. In tracing the design of rifle sights from the simpler to the more complicated, it will be found, however, that the attention of inventors has been directed first to bringing all objects which have to be seen into as nearly as possible the same focus, and second, to magnifying the image or object so as to make it more readily visible and increase accuracy of aim, whether at the target or in the hunting field.

The only way the active, mechanically trained person can aid the development of sights is to use the present manufactured designs, discover the lacking principles and faulty construction, and then improve upon these deficiencies.

During my years as a maker of special sights I have learned that various persons require a considerable degree of exactitude in order to acquire accuracy in their aiming, while others can take any sight, whether open or aperture, and obtain good results. Yet there is always a certain amount of error that they cannot understand, especially in the use of open sights. We often hear of ridiculous designs, but from just such things a new idea is born which may supersede all expectations.

Look at the long-range target shooter; there has been no improvement in the standard aperture sight for him. The elevation and windage adjustments are not satisfactory by any means. There should be designed a means for quickly figured estimation of windage for any velocity rather than for figuring out the number of clicks on a knurled nut. A special quadrant could be designed which is positive for either right or left windage, and so marked for any given distance and for any wind which may be blowing from five to forty miles an hour. This could be graduated on the quadrant, which is quick and positive, without the shooter figuring this all out on the firing line. This is only a suggestion, but it has to do with an improvement that is badly needed.

Sights should be constructed for the different

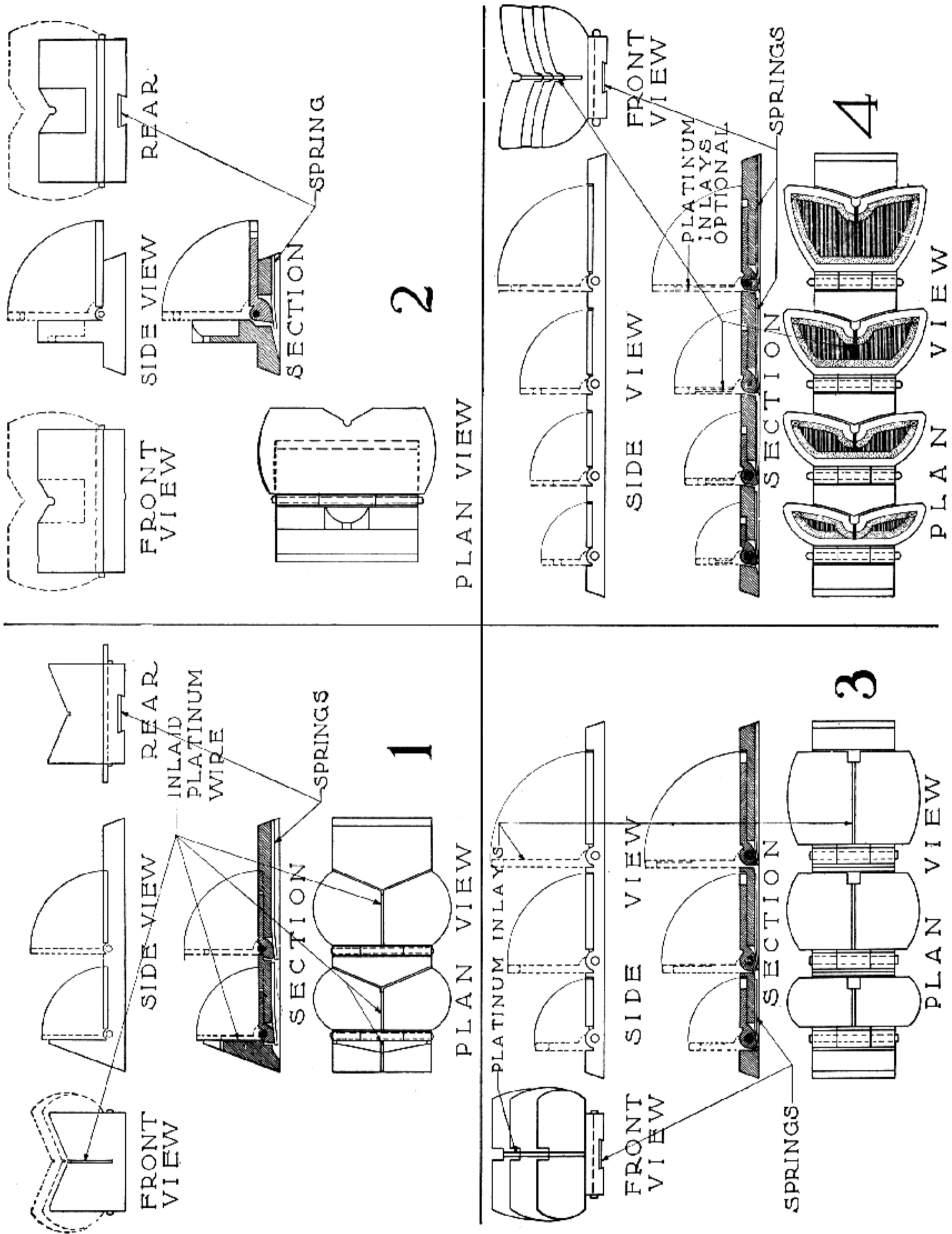


Fig. 115
 Leaf-sight designs. Notched leaves are preferred by most hunters

purposes intended for a hunting arm. They should be made simple with as rigid a design as possible within keeping of the design of the rifle. For target work they can be rigid, but with many complications to suit various conditions found on the rifle range. It will be necessary for a great many sportsmen, knowing the special designs they may wish, even tho they are mechanically trained to select the standard factory sights. In our first part we shall select the open sights for construction, but it will be found necessary to refer to Chapter XVII, Volume I, for certain connective links.

Rear Open Sights — The making of a good leaf sight as shown in No. 1, Figure 115, requires special form cutters as well as special milling-machine fixtures, but once the tools are made it is a very simple matter to turn these out with 1, 2, 3, or 4 leaves. The base is first milled from a piece of cold-drawn steel, with a width selected for twelve bases at once, by allowing the formed milling cutter to mill out the leaf-sight center. After this is milled for the desired number of leaves, it is sawed off to width in the milling machine with a slitting saw. The bases are now clamped in the vise or a fixture and the dovetailed spring pockets milled transversely.

Having completed this part of the milling operation, the small holes are drilled to hold the leaf in position. A No. 60 drill is used, so care must be exercised in the pressure applied in feeding through the stock. Of course you have a drill jig to hold the base; have it set at right angles; the drill must be kept very sharp and the point well lubricated with hard oil. Another drill jig is used to remove the center of the formed section and this is filed out to a square gauge and the leaves fitted.

Next in order comes the form milling of the leaves. These can also be milled in the strip so that it is possible to secure twelve leaves. The strip of material selected is first sweated to an iron or steel block; this is clamped into the milling machine vise and the form cutter allowed to run the full length. This operation not only mills the leaf to the required thickness but to the required form at the bottom. The pieces are now taken off the block and the solder removed; then they are cut to the proper width with a slitting saw in the milling machine. (For such small work as this a bench milling machine is best.) Having cut these off, the next operation is to mill them down to the slot width, which is done in a jig on the drill press, the jig being so constructed that it can be reversed and the opposite side milled before removing from the jig. A special end cutter is made so the correct radius is formed that has been milled in the base,

and when the leaf is raised or lowered it will rise around this part. The leaves are now fitted into the slots and drilled in position.

The next stage of the operation is to make the small flat springs that the slots were milled for. Because the springs are of different lengths and have a slight angle in them, it is best to fit these all in at one time and then set in the leaves. Before the leaves are set in position a small radius is filed on the overhanging ends; this is best done with a hardened form by setting it against the leaf and filing close to the block. A small parallel clamp is used to hold it in position while the ends are being formed. No. 60 drill rod is cut to length and the leaves assembled in the base. This is not a complete description of the manufacturing of a folding leaf sight, but with such information and with a sample before him the student can construct one. The main question is the correct form of sight to use rather than the manufacturing principles involved.

In selecting an open sight it will be well to choose *A* in Figure 116, a plain flat bar possessing no notch. This is one of the best rear sights constructed on the theory that the eye naturally finds its center, particularly when a fine platinum line is placed $\frac{1}{16}$ inch from the top, or to the top, extending to the bottom, or an ivory inlay formed in the shape of a pyramid and the point coming to the top as in *B*. It is surprizing how accurately shots can be placed with a sight like this. Without the lines, the most minute error that the eye might make would vary greatly on the horizontal, but the vertical would always be perfect, for you can estimate very clearly just how much front sight you are holding over the bar. The platinum or ivory lines, together with the proper distance from the eye, will give very clear definitions of the bar and lines. Such arrangements permit exact centering of the front-sight blade by the eye and at the same time have the wonderful advantage of cutting off the exact amount from the top of the front sight on the object, making exact horizontal shots. This is easily done with such a rear-sight bar; the front sight may be cut coarse or fine with great accuracy and extreme clearness of vision on the object aimed at. Sights made on this design are a great aid in open country when aiming at running animals. For wilderness work it is better to have a very shallow V as in *C* with a platinum line running into the V. A U-notch as in *M* is better than the V; this type of cut-out will not confine you in locating the center of the bar and the front sight upon the object. The small U allows the front sight to come flush with the top, permitting the full view of your quarry; with this held in the notch the horizontal is always perfect.

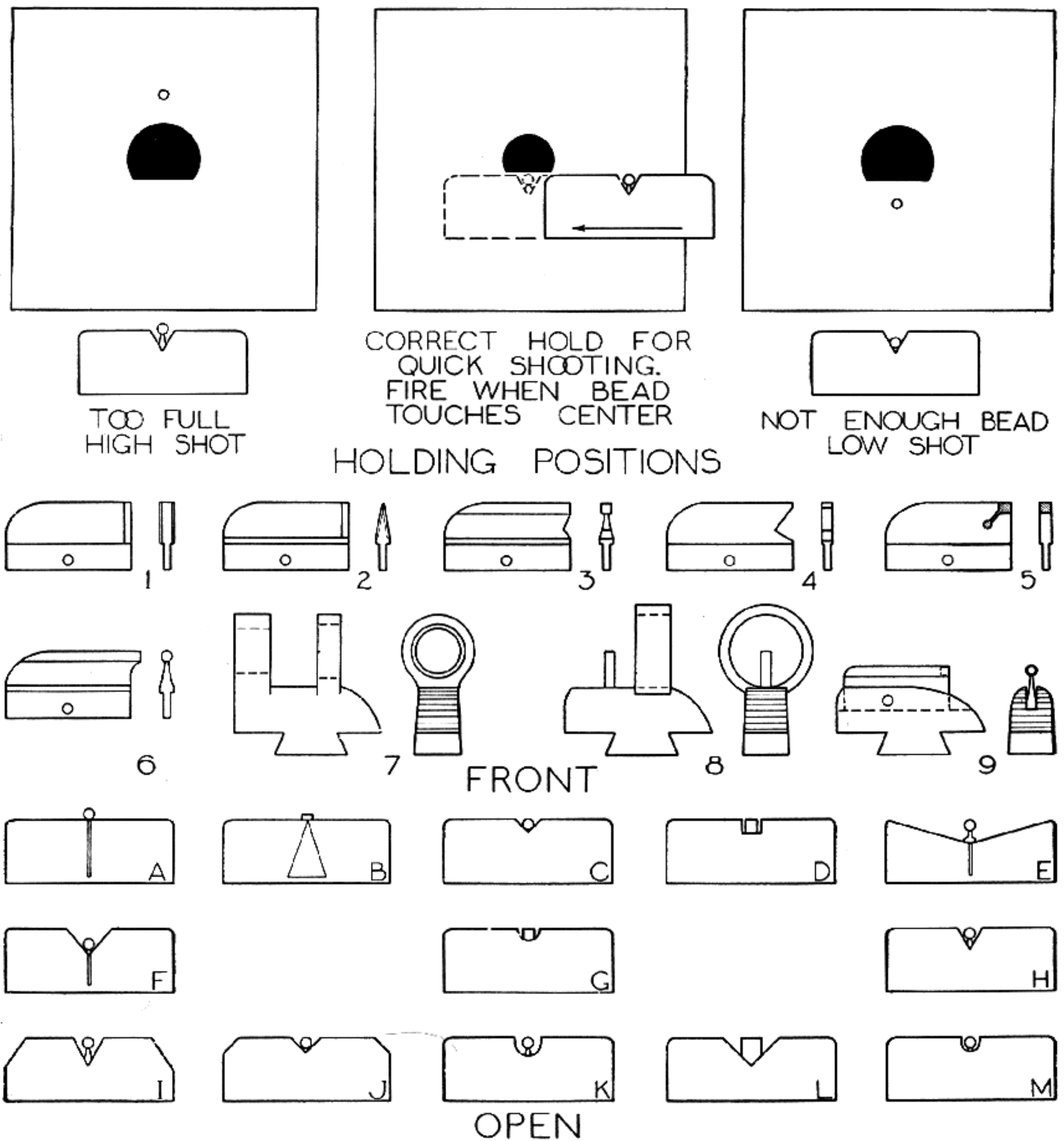


Fig. 116
Front and rear sights. Method of holding on target or object

The same settings are equalized with *D* and a square front sight, but still a number of men will prefer *G*, which has the small *U*. Such a choice can only be determined by experience. A leaf made like *E* is only used on double heavy express rifles for large and dangerous game, as a sight of this design is quick and positive on charging animals but not so satisfactory on a sporting bolt-action rifle.

The correct position of holding an open sight

on the target is rather confusing to some men. Figure 116 illustrates the correct position of holding. It is a temptation to go into a long discussion of this subject, but I shall only treat it briefly. The main object is to draw the front sight down into the notch, and allow the top of the front sight to come flush with the top of the bar or open sight. If it is a flat bar devoid of a notch, the front sight must show over it 0.010 inch. For normal shooting at 100 yards, hold this position and swing the

rifle from left to right or right to left. Always hold the horizontal as shown in the illustration. If you hold only the vertical with an up-and-down movement, the shots are sure to be scattered over the target. Hold at six o'clock on the horizontal position and fire the instant the sight cuts the black and white of the bull's-eye, and the groups will find a perfect center. All hunting arms are sighted in at the point of aim.

In the same drawing two targets are shown, and the position of holding the sights at the time of firing; the front sight is in the two extreme positions in the notches. With a deep notch as in *F*, Figure 116, the bead must be drawn well down, but when the notch is rather shallow the bead should come flush with the top of the bar, except on the wide and shallow bars, for then the bead must show in the center.

in the correct position each time, except on long-range shots; then you must estimate the distance and proper amount of bead to take. When a combination is made with a flat open sight and a straight front sight, it will permit very accurate cutting-off of the correct amount of front sight if one knows his rifle.

The making of the sights shown in Figure 116 requires rather extensive toolmaking experience, so I would advise the novice to purchase the completed but unfinished sights and file out the notches. They also come with platinum lines; a fine line is milled in the center; to hammer in the platinum wire requires a small bench miller and small slitting saws. The ivory lines are made in two ways if you use pure ivory. For the first, a small hole is drilled into the center of the sight so that the hole breaks out along the edge of the face. A piece of ivory is turned on a bench lathe, driven into the drilled hole,

Figure 117 illustrates three different styles of tar-

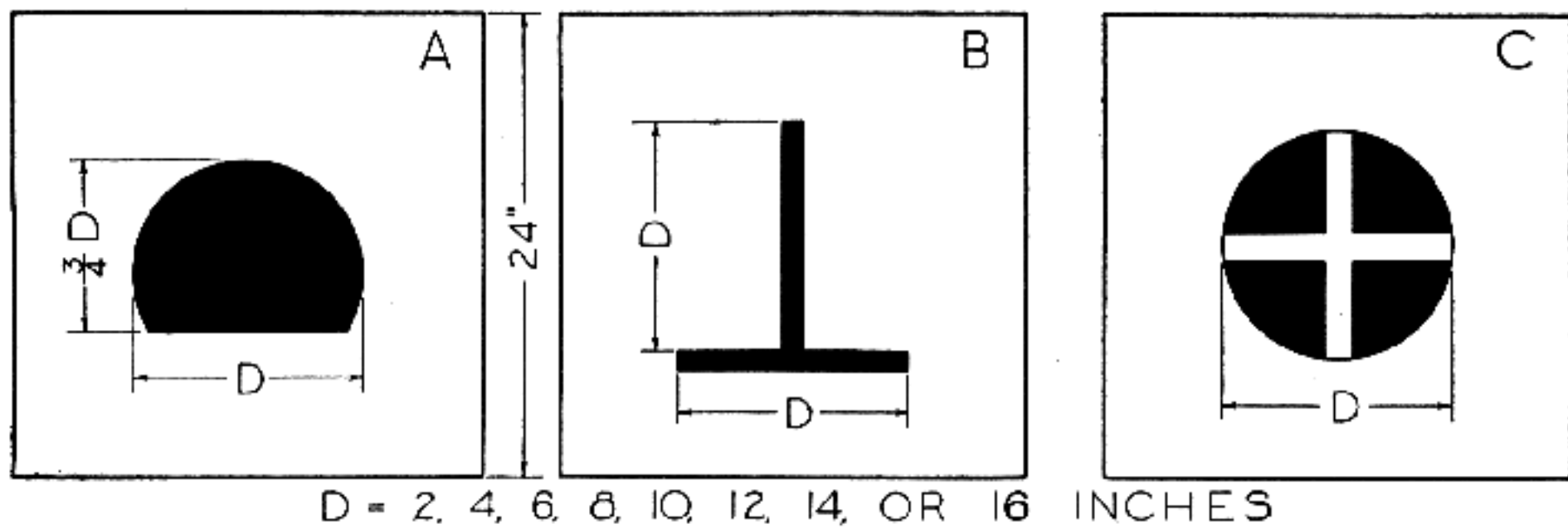


Fig. 117
Design suggestions for targets

gets used for testing or sighting-in purposes when setting on new sights or for targeting rifles. *A* has the under side of the circle cut off straight across and is one of the best targets to use for either open or aperture sights. *B* is the inverted T which is very good for off-hand work, while *C* is the cross inside the black circle. This form of target will always keep the bead well centered and at the same time give good practise in getting the shots off quickly in offhand work.

These targets can be made very easily by cutting a stencil out of the center of one of the cardboards or heavy paper. Different sizes have been given so you can select the one most suitable for your requirements. I generally use the 4-inch size for 100 yards and 6-inch for 200 yards.

After choosing the right open sight, the next important consideration is the ranges—and knowing how to hold the bead in the rear notch. A coarser bead will give you a high shot and a fine bead a low shot. It will be well for the beginner to practise these holds so that he can have the bead come

and the face is filed off, exposing a clear white line. This operation requires time and patience, but when completed makes a perfect white line which has no equal. The second method, used for either the white line or the pyramid, is to mill out the line with an end mill and fill the slot with white lacquer. The pyramid is inserted the same as *B* is laid out; first it is milled out half-way through the leaf with a very small end mill and then a punch is made of the same shape and driven into the milled outer section to remove the corners. The impressions made with this broach in the corners are then chipped out with very fine chisels, made from small worn needle files. After the corners are finished clearly and distinctly, the impression is filled in with white lacquer. Before the lacquer is placed in this insertion, take a fine chisel and chip up little burrs on the bottom so that the lacquer will adhere and never come out from recoil. The same must be done with the straight line milled for the center. After the lacquer becomes dry and hard, it is filed off and polished with very fine No.

7/0 sandpaper; the white will appear clear and distinct.

Aperture Sight — As the name implies, this is a rear sight consisting essentially of a small or large circular aperture through which aim is taken. Any rear sight of this nature is best situated just in front of the eye—as near it, in fact, as is consistent with the caliber of the arm, its safety and recoil. When aim is taken, no attempt is made to focus the edge of the aperture, but since it is circular, it is very easy to put the front sight and object sufficiently near the center. Any error involved will be negligible. Since the nearest object which needs to be focused is the front sight, it follows that the lack of definition is much less than when using the open design of sights. This lack of definition is further reduced by what is known as the orthoptic effect of the rear aperture. This acts by blotting out the more peripheral of the rays which would otherwise pass into the eye so that the blurring of any object out of focus is reduced. This principle is exactly similar to that of reducing the lens of a camera in order to obtain what is known as depth of focus, *i.e.*, reasonably good simultaneous definition of objects at various distances. The orthoptic effect of the aperture is similar to that of the pupil of the eye and is of greater relative benefit to the man who normally has a large pupil and very little pigment in the eye. The optical advantages of aperture sights are particularly marked in the case of elderly men who may find shooting with open sights more or less difficult. Age results in very little diminution in the desired accuracy of the aim when aperture sights are employed. The size of the aperture is of the greatest importance; too small an aperture unduly reduces the light and makes the object difficult to distinguish; too large an aperture reduces the orthoptic effect and makes centering of the front sight and object more difficult. No one size can be established as a standard for all individuals under any circumstances. Some arrangement for changing the size of the aperture would be theoretically desirable. The average size for shooting is 0.0625 ($\frac{1}{16}$ inch). For shooting in the field $\frac{1}{10}$ inch at least is required.

It will be evident that the aperture sight permits of much more accurate aim being taken than does the open sight. It has, indeed, one disadvantage; it is more difficult to find the object quickly when aiming; tho if the exact position of the object or target is known (as when firing at a known target) it is possible to aim more quickly than with open sights. This defect of the aperture sight is due to the blotting out of a part of the field of view by the

circular disc or the turret in which it is held. The closer the aperture is to the eye, the larger is the field of view, and hence the less noticeable is such a defect. The better modern aperture rear sights are made adjustable vertically by means of a screw with a knurled head. Clicks are provided by means of a spring and plunger, engaging depressions on the under side of the head. A similar lateral adjustment is also provided for windage.

Improvements are made on all styles of aperture sights year by year, but there is still room for more, not only on hunting rifles, but on modern target arms. Vernier scales can be provided to give the approximate degree a sight should be set for different velocities of wind to read the correct amount of movement required. Another scale graduated in terms of range could easily be worked out, but these are experimental factors, and the various types of ammunition involved must be considered.

Open Sight — This is the type used on most military arms as well as sporting rifles of various calibers. As is well known, it consists of a front sight near the muzzle of the rifle, and a rear sight the essential part of which is, as a rule, a notch of some special shape, a U, V, or square notch. The front sight generally has some bold upstanding blade which can easily be seen against the object. Various shapes of rear and front sights have been tried with the object of securing their more accurate alinement with one another, but it has been an endless experiment. No shape seems to have any special advantage, and certainly none can give anything approaching perfect alinement owing to the impossibility of focusing more than one of the three objects, one of which, the rear sight, is naturally near the eyes. The position of the rear sight is of the greatest importance. If it is too near the eye errors of alinement from lack of definition will be increased. On the contrary, the effect on the aim of a given error of alinement between the front sight and rear sight is increased in inverse proportion to the sight radius, or the distance between the front and rear sight. This must not be unduly decreased by moving the rear sight too far from the eye. The proper distance for those with normal eyesight is to have the rear sight about 15 inches from the eye. Possibly a greater distance may be an advantage for those who have advanced in age.

Front Sights — The sights used on the fore-end of a rifle barrel are made in a variety of shapes, but for general purposes the one object is to have a piece of thin steel as a blade or an aperture in order to place the shots accurately upon an object.

For practicability the sights illustrated in Figure

116 are of good substantial construction; these often cannot be purchased. From the number of designs shown, you can make up any combination you wish. As an instance, No. 5 can be made round on top instead of flat, and the same idea of inserting gold at the tip can be applied to either No. 3, 2, or 6. The most essential points to consider in constructing front sights are strength, shape, and clear definition. Accordingly, tool or alloy steel should be used to give these the strength required. Front sights made of cold-drawn steel are apt to bend from the slightest fall or tap, and at times even break off. Front sights should be securely fastened to either the barrel or sight bases by various means—dovetailed slots, pins, or suitable screws, the latter being the most practical method. The sights illustrated in Figure 116 are to be placed in a milled slot so that when other bases are in evidence on specially made arms which require a dovetailed base these can be made accordingly.

Make the sight shown in No. 5, Figure 116, of steel; insert the gold in the slot and drilled hole, and hammer it in. First, drill a hole $\frac{1}{16}$ inch in diameter on a 45-degree angle from the corner of the square seat. The hole to be centered should be about $\frac{5}{32}$ inch down from the corner on the angle; countersink this hole on both sides. With a jeweler's hack-saw, the blade measuring between .020 and .025 inch, saw from the corner on the angle into the hole. File an angle on both sides of the saw slot so that the gold will have an anchorage when hammered in. To file this angle, use a fine knife-edge needle file. Use $\frac{3}{32}$ -inch gold wire between 16 and 22 carat, and flatten the end so that it will just drive into the slot. If it is impossible to purchase gold wire of this diameter, have your dentist cast an ingot of gold this size and about 1 inch in length, enough for a number of insertions.

Before hammering the gold in place, drill a small hole into the center of the blade from the top just so a part of the drilled hole will break through, the depth to be about down to the corner of the saw slot. This also gives a better support to the gold after it is hammered into place. Drive the hammered gold into the slot and cut it off just long enough so that a good heavy bead will be formed. Hammer the gold into the saw slot from both sides; first on one side and then on the other. The blade must be reversed often and a good hardened piece of steel should be fastened in the vise. With the end piece which forms the bead, hammer this down well into the small drilled hole in the face. To do so, the blade should be held in a small vise or between lead jaws in the bench vise. File all the surplus gold from the sides and file the bead to any desired shape. You may either file a radius on the

top, making the gold and steel round, or even square; file it to any desired width or diameter which suits your requirements best. Leave the point square and flat, and then polish with fine emery cloth. Remember that a dull appearance on the gold will not reflect light as much as if the surface is given a high luster or is polished with rouge.

To convert this perfect gold-bead front sight into an ivory bead, all that is necessary is to coat the surface of the face with white lacquer which can be applied with a common toothpick. A small vial should be carried in the recess of the butt stock under the butt plate, and when you find it necessary to convert the gold bead, the toothpick should be dipped into the lacquer and just a drop placed on the face. This produces a perfect white front sight, for it dries a few minutes after application. Then, if you wish to change back to the gold bead, all that is necessary is to remove the hard white substance with a penknife. Thus you have two sights in one; it is never necessary to remove the sight after it is once set in place.

The removal of sights in the field or at camp often ends rather disastrously, because of losing the pins or screws by which the sights are held in place. If held in place by screws, it very often happens that they are rusted and it is impossible to remove them. In many instances you do not have the proper screw-driver to remove them. If pins are used, you do not have the right size of drift punches, and besides you never possess the proper facilities to hold the rifle barrel to make such changes. But with the white lacquer in your kit the change can be instantaneous and you have an ivory bead which can never be broken as in the use of real ivory.

Next to the gold-bead sight is No. 1, or 2, used for a hunting rifle. This is the straight square steel blade known as the marine type of front sight with flat top. These are made in various widths up to $\frac{1}{8}$ inch, as No. 4 shows, which is the revolver type of front sight. I never make No. 1 any wider than 0.090 for hunting purposes, as this is the extreme width. No. 2 is the tapered front sight made when one wishes a bead of $\frac{1}{32}$ inch and is the type I often recommend, because of the fact that it is impossible to make a small bead and have strength in the blade. By tapering it to a sharp point, the rest of the blade is well supported and will never be bent by hitting it against an object. This front sight is very satisfactory to use in connection with an aperture sight, but when used with an open sight in bad lights it is rather hard to pick up.

Many men design a sight as in No. 3 with a square top. This sight is rather difficult to make

and more difficult to keep straight because of the frail support it has. The center must be milled out so that the thickness will be no greater than .020 inch in order to get the correct effect of the square bar. When greater widths than 0.060 inch are made it is possible to increase the web thickness, making the sight more substantial. No. 6 is a sight similar to No. 3, except that it has the round body held only by a thin web; however, you will be flirting with the same trouble pointed out on No. 3. Many factory sights are constructed like No. 6, except that they have the full support of a substantial web and not the overhanging round circle, but are made similar to No. 5 with the support to the bead. Some manufacturers continue to make the round-pointed gold bead together with the top of the round steel which is gold plated. These sights have been discussed before, from a different angle.

No. 4 in Figure 116 is the hawk-bill sight which is the most practical for target revolvers, because of the clear distinct definition it gives on an indoor target. When used on a rifle, great care must be used in handling, for a sight of this kind will cut or tear the flesh very badly if the barrel is allowed to slip through the hands from force of habit.

Nos. 7 and 8 in Figure 116 are the aperture front sights for target purposes. No. 7 has the two diameter holes, the front one being the largest to allow an optical effect in the smaller hole. The front hole is tapered by using a taper-pin reamer which gives a very clear and distinct outer ring. Various sizes can be made to suit different conditions of eyesight and at the same time give the proper clearance between black and white on the target. The rear face may be bell-mouthed, as this gives a better effect to the front aperture. It is not advisable to use a bright enamel or lacquer on these two rear faces of the aperture, but to have a jet-black enamel baked on, if this substance has been agreed upon to blacken the sight with.

No. 8 has the aperture and post integral with the base. The post may be filed to any width desired for various requirements. The aperture produces a shaded effect on the post and even in brilliant light the post will appear well defined against the target. This sight is a wonderful help to those with failing eyesight or to those who at times find the front sight fading out. It is also a great aid on a target rifle used for long-range work.

An ordinary globe sight with interchangeable disc and post has a straight tunnel effect. Such sights are very good and meet with the approval of many target shooters; however, they are made upon the wrong principle. In designing this type of sight there must be an optical effect to break lights in any direction they may be coming from, and the

post must be clear, even tho the sun is shining toward the shooter. This sight is only a simple improvement over the old Winchester spirit-level sight that we see on some of their old single-shot rifles. Some of the finest work was done with this sight in many of the Schützen matches over thirty years ago. The improved aperture front sight will be discussed later.

No. 9 in Figure 116 is a standard factory sight fitted low in a Springfield front-sight movable stud when using open sights or a low aperture of special construction. By mounting this sight low in the stud, there is very little danger of bending it in a bad fall or any other way. When setting it in low, it is necessary to cut off the bottom and drill a new hole for this pin or screw if one is used.

If a front sight is to be changed very often, no matter what make of arm you are using, replace the pins with small fillister-head screws. An extra sight may be carried for emergencies and easily changed with a small screw-driver.

You will notice that I have constructed these specially-designed front sights on the principle of strength and stability together with a practical understanding of the requirements of front sights. At the arsenal, all work when completed and accepted must be sturdy and capable of enduring hard service in the field. If the beginner intends to carry out certain ideas he should study the possibilities of extreme conditions under which it will be used. A pessimistic but wise plan will be to anticipate the very worst conditions; it often changes our methods of construction.

Most of the front sights illustrated in Figure 116 are made sturdy, but there are those of a frail design which are used mostly on target arms. The most delicate sights are sometimes ordered, so I have designed these to give the student an idea for making them. I would advise making everything which happens to come into your mind; nine ideas may be wrong and one may be right, but this is the way success is arrived at in all experimental work. It is easy to make a thing, but it takes a wise man to criticize his own work, profit by his errors, and build another and another until something is arrived at which will prove successful. Through such persistency you will gain experience invaluable to yourself and others.

Aperture Front Sights — The improved target and hunting type of front aperture sight is designed on the optical principle of a telescope, being constructed to break light and give a clear and distinct definition as it is brought upon an object. Many men have their front sight fade out because of defective vision or the impossibility of holding the

front sight on an object for any length of time. With a front sight of such a design it is possible to secure any combination of rings to accommodate defective eyesight. The rear retaining rings can be used to place any desired form of post or small aperture by using a watch hand or reversing it and using the point.

The apertures can be made to any size and these used in place of the sight-retaining rings to convert the sight into a standard aperture sight pure and simple. The reticules or light-breaking rings can also be made to a diameter which will produce the desired effects of light upon the front or rear rings. Naturally, defective eyesight is not the same in all men, so different sizes must be made to find a perfect combination that will allow clear and distinct aim and reduce errors to a minimum. The error of aim with the best sights now used is about 1 inch at 100 yards. This is based on perfect vision; therefore, this error is increased at greater distances. The greatest trouble experienced is the fading out

of the front sight, but with a sight that will break lights, the eye is able to hold the front sight on the object longer and consequently get the shot off much more quickly. One type is made for target work and one for hunting, by removing a section of the top in order to allow a greater flow of light in this opening.

It is very evident that in the manufacture of aperture front sights none have been made with the idea of using the principles of certain machine refinement. Most of the aperture front sights have been constructed with a view to satisfying the target shooter, but not the man with defective vision. His choice is limited to a telescope.

No dimensions have been placed on the parts shown in Figure 118, but the outside diameter of the tube is $\frac{5}{8}$ inch and the length is governed by the apertures, reticules, and retaining rings. The front locking screw is held in place by a thin spring fastened in two different ways, as the drawing shows. The inside of such an aperture sight must

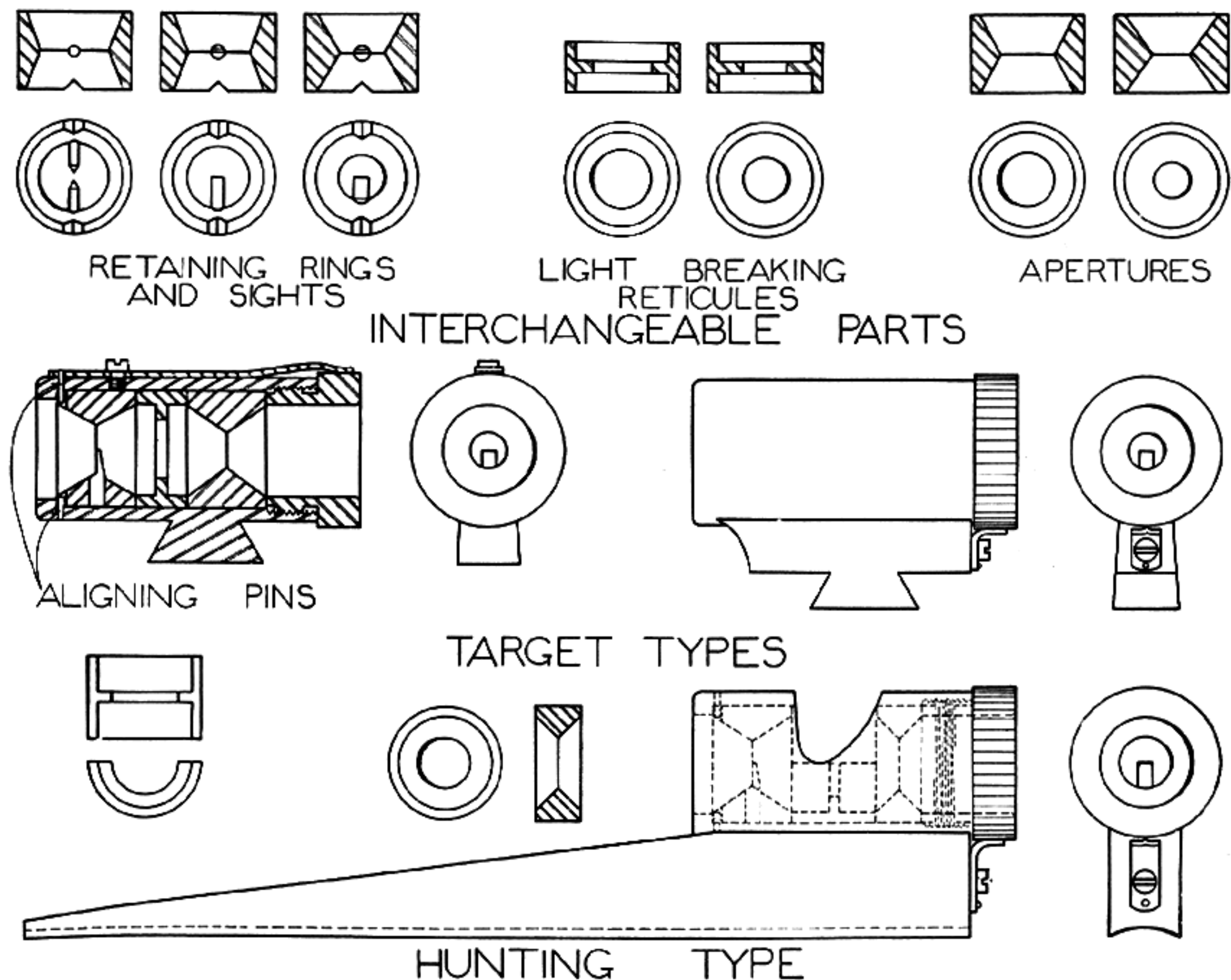


Fig. 118
Improved design of aperture front sight

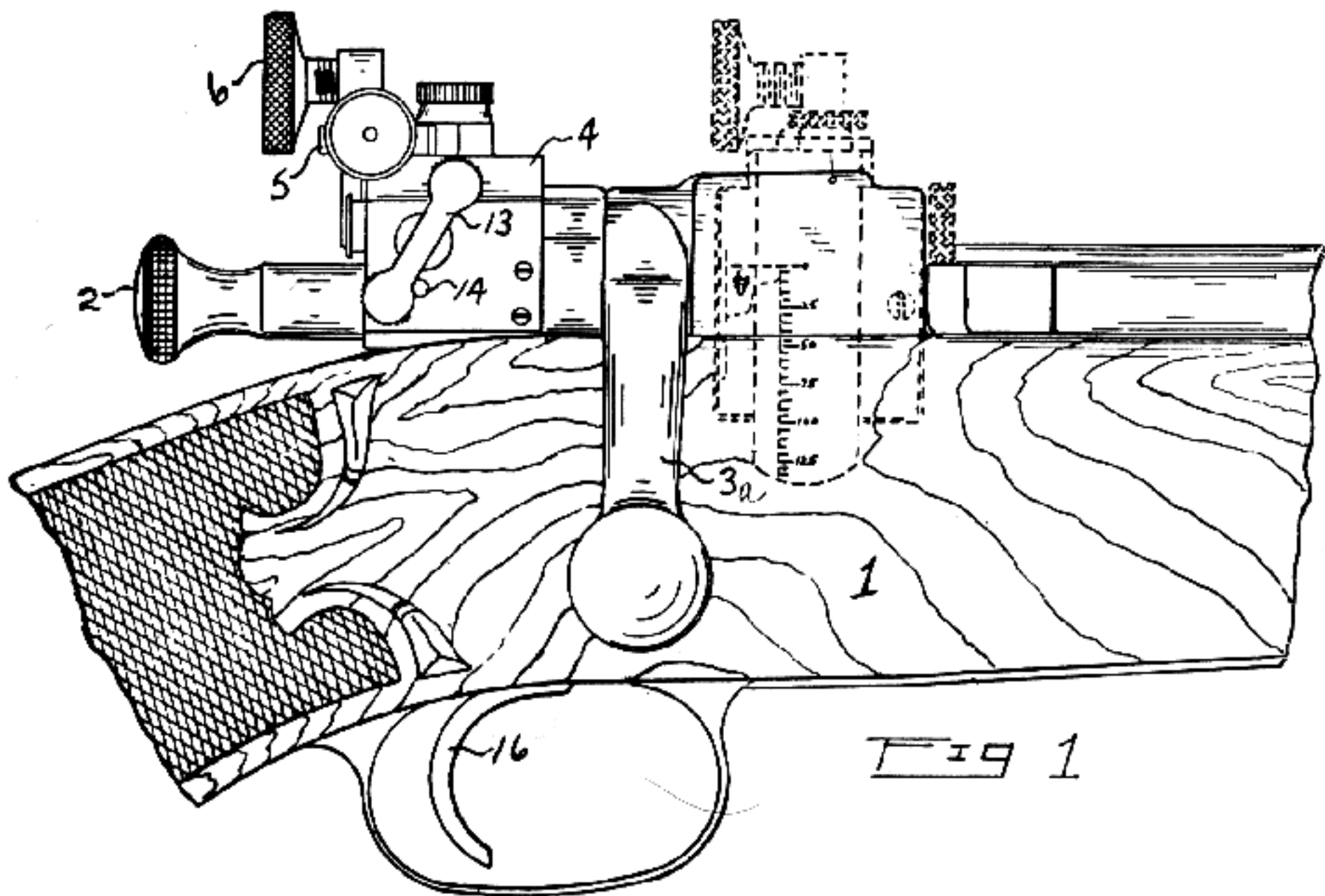


FIG 1

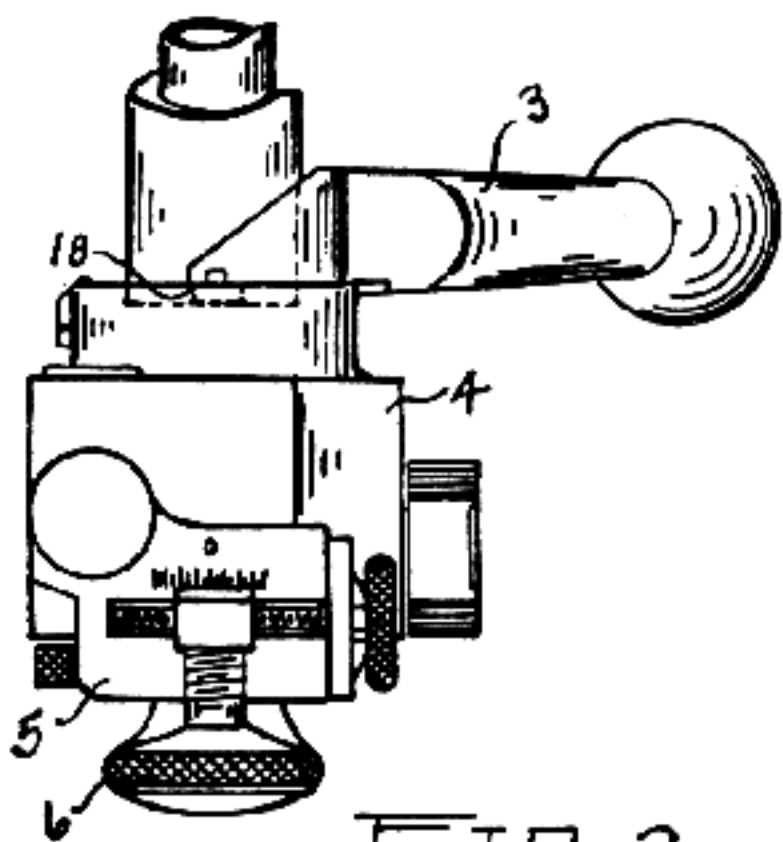


FIG 2

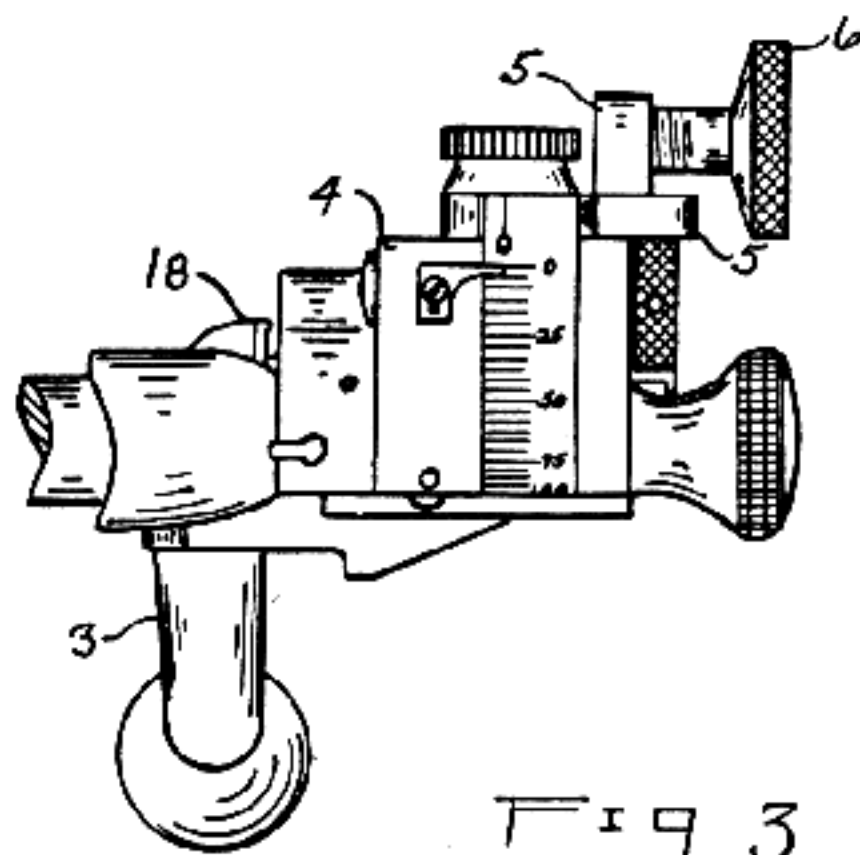


FIG 3

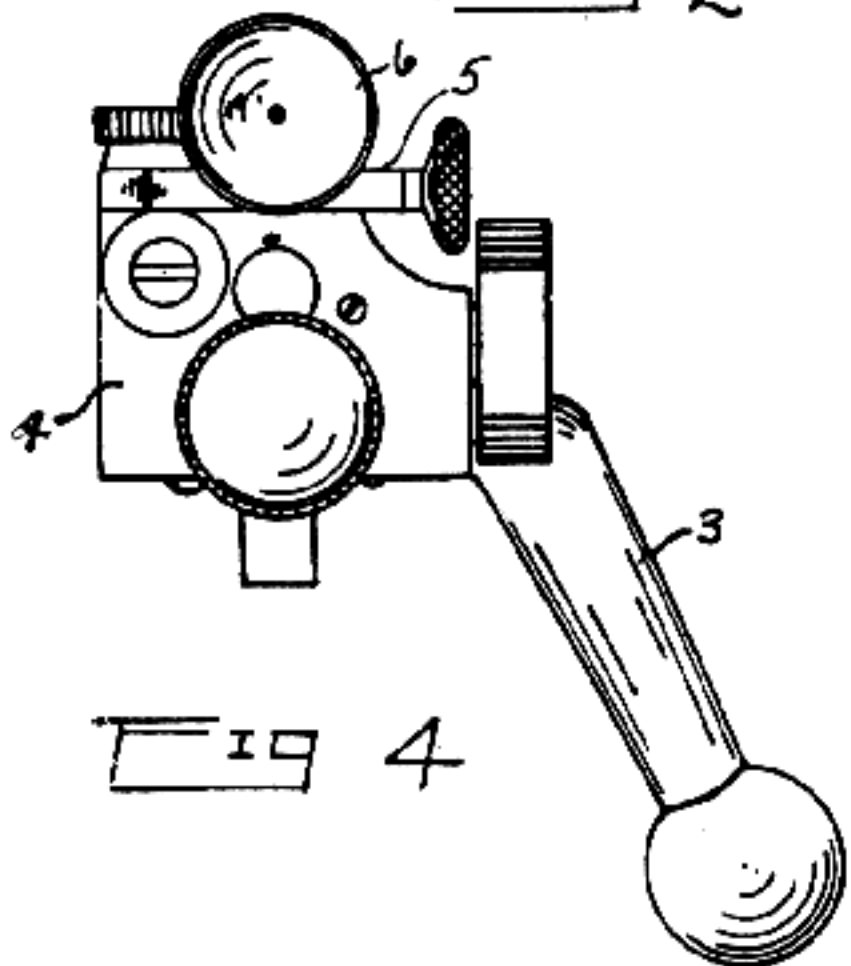


FIG 4

Fig. 119
Howe-Whelen aperture sight in
position on rifle

have these parts turned and bored perfectly true and the back rings cut so that the alining pins will bring the pieces in the exact center. All these parts have their optical centers, and these may or may not be true, or correspond to or be in alinement with the axis of the tube; it is essential to have these parts all in perfect alinement. Since the Springfield front-sight base is the most popular, one is designed for that while the other shows a standard ramp with the sight brazed to the top in the correct position.

It is an easy matter to design such a sight for any type of rifle, and those with eyesight difficulty will find it a great aid in their sighting arrangements. Its rigid construction is one of the most desirable features, because it will stand the hard knocks of real service. With such a sight the rifleman can throw his rifle to his shoulder and as he catches the object the true aim will be clearer and even brighter than could be had with any standard sight of

similar construction. In fact the ideal front sight has at last been designed.

Bolt-sleeve Sights — When Colonel Whelen and I designed and made the bolt-sleeve sight, our object was to eliminate all this by designing a new sleeve and have the sight slide work in it, together with the safety which was placed on the right side in a location so that the thumb could operate it with ease at the instant of firing. A hardened pin was placed on the one side, with a strong spring back of it, which would always keep the sight solid and in position. Figure 119 shows this sight on a Springfield Model 1903 remodeled rifle.

The same idea was applied to a Mauser action by designing a new bolt sleeve. A sight like the Howe-Whelen is rather expensive to make because of the precision work required for its perfection. A number of these sights were made and sold to the public but were of rather poor construction, since the

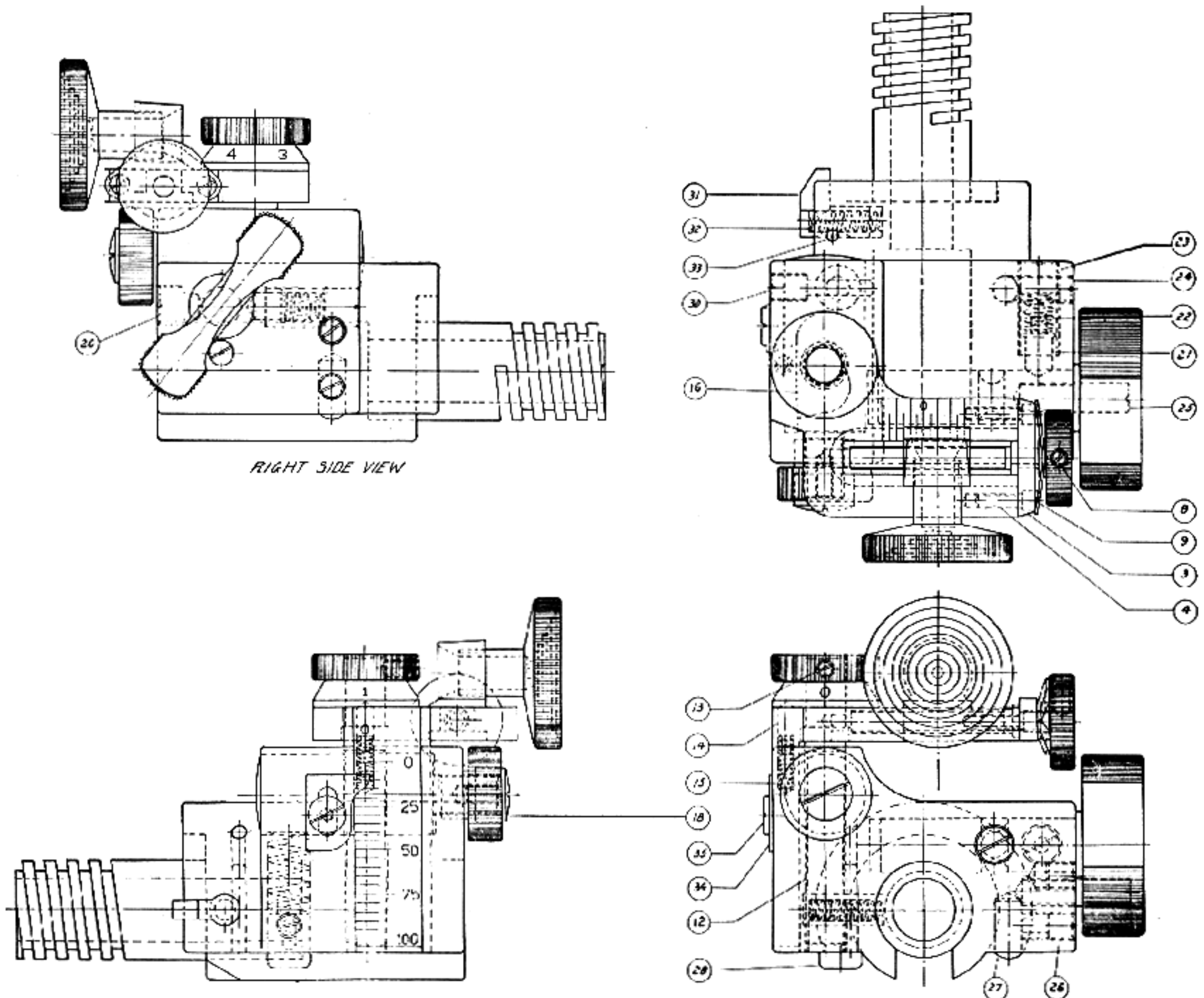


Fig. 120
Assembled view of Howe-Whelen aperture sight

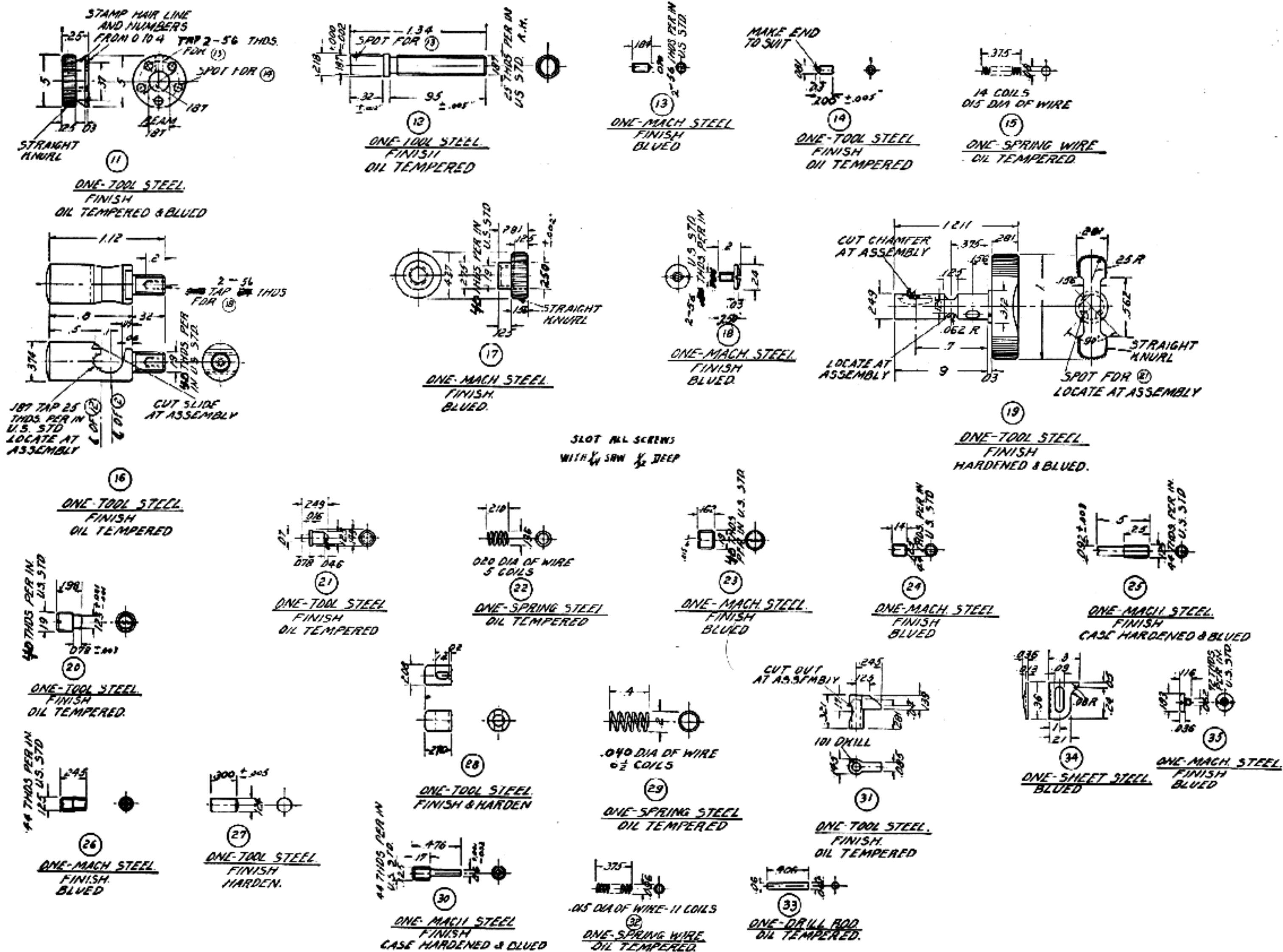


Fig. 121
 Detailed parts of Howe-Whelen aperture sight

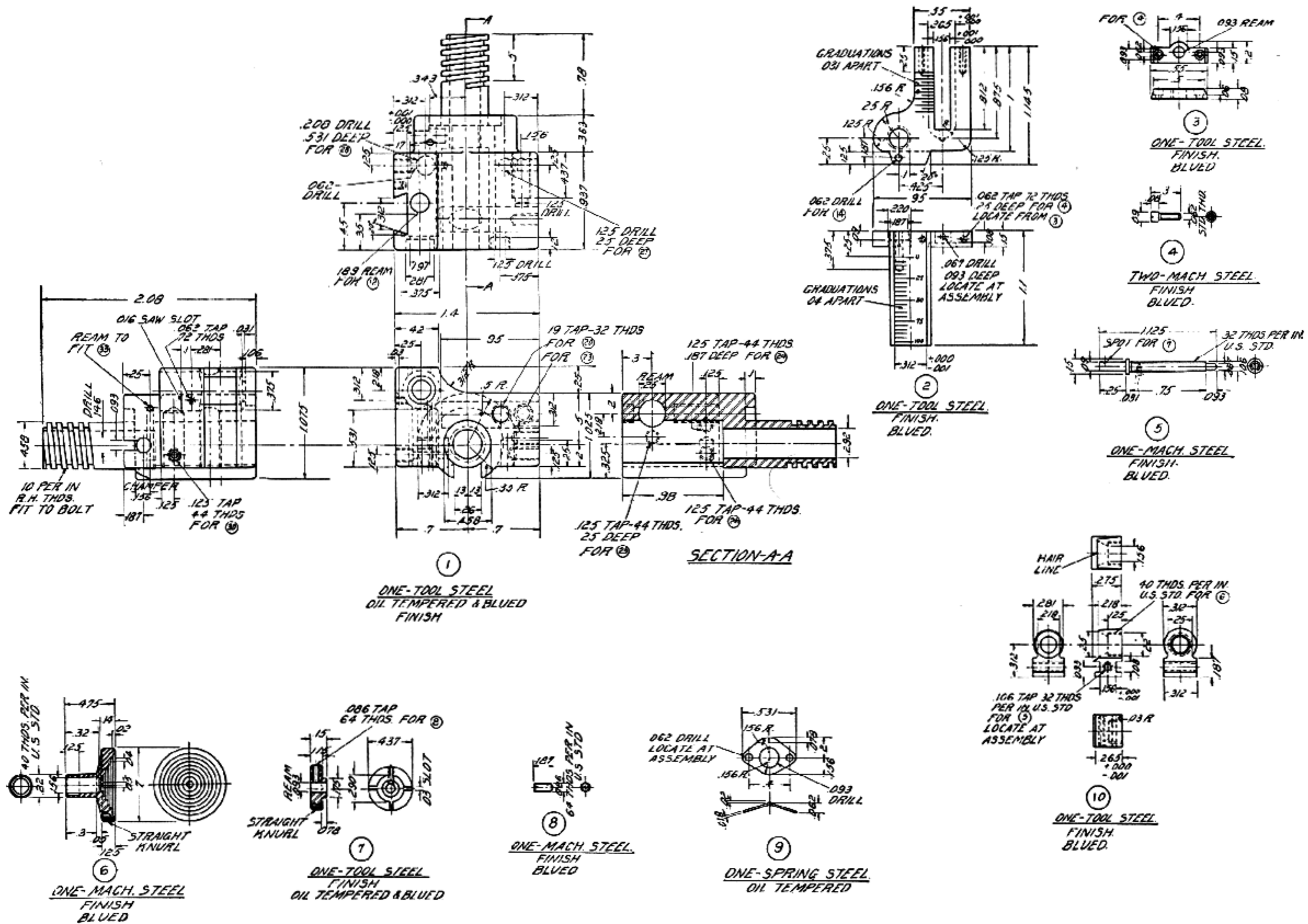


Fig. 122
Detailed parts of Howe-Whelen aperture sight

manufacturers did not have the necessary experience to produce an article of such delicate design and precision. However, if they were made in quantity and made right, they would be one of the best bolt-sleeve sights on the market today, because of their simple application and the fact that they are better than 2 inches closer to the eye. The sight did not require any screws to fasten it in place; all that was necessary was to remove the regular sleeve and assemble the sight as tho assembling the entire bolt mechanism, or as tho it were the sleeve itself. The entire new sleeve and all sighting mechanical arrangements were in the block. The safety feature of this sight was one of the best, and I believe there was never a better feature incorporated into a sleeve that locked as this did and in a position so accessible in quick release as the rifle was brought to the shoulder. Another advantage of having the safety in such a position was that it made it possible to mount a hunting telescope very low without the interference of a safety as on the Springfield or Mauser actions. There have been many sights made since Colonel Whelen and I designed this one; some have been good and others just mediocre. This, however, has opened the way for subsequent ideas and experiments.

Figure 120 shows the assembly of the Howe-Whelen sight and Figures 121 and 122 the details of the component parts. The mechanically inclined person or engineer will see that one of these is rather complicated to construct. The necessity for a substantial sight of this nature led to this design. It made it possible to have the aperture closer to the eye and at the same time it was advantageous for the arrangement of windage and elevation on the Lyman principle. As one progresses in making these he will develop decided ideas regarding sights; this will lead to some that are alone in their class.

Since the drawings of these sights are self-explanatory we shall proceed to examine and discuss the possibilities of manufacture. The body must be made from heat-treated alloy steel to give the desired toughness; the body acts as a sleeve for the bolt, at the same time housing all the essential parts of the sight. The first operation on the body is to drill and ream the hole that the cocking piece rides through; also to counterbore the rear end to the desired depth. A special mandrel is made and the front end turned and undercut, and square threads are cut to have it fit in the rear end of the bolt. After this operation the bottom is milled to form. The body is then laid out for all holes and drilled. The drilling operations on the body really require different drill jigs, but as only one or two will be made by the student for some of his Springfield rifles it is not necessary to make these but to drill

from all the laid-out holes. After completing the drilling operations, the elevation slide slot is milled to the correct width. Holes are to be tapped, the sleeve catch to be fitted, and various other odds and ends done before the pack-hardening process takes place as described in Chapter VII.

Next in order is making all the component parts as given in the detailed drawings. There is quite a bit of work on the slide which should also be made from alloy steel to give it strength. The safety is made from flat tool steel, milled out to the required form, and the ends serrated for a thumb hold, so that the thumb will not slip off when operating it. A locking plunger can also be made to operate with the safety, but this part does not show on these drawings, as it is very simple in construction.

These sights call for graduations in minutes of angle, but as the standard sights are marked a certain distance apart both for windage and elevation we must place marks of some kind to set the sights by; therefore a graduation on the elevation slide should be equal to one turn of the thumb nut. The Lyman standard thread which is used on their aperture sights is 25 threads per inch; therefore one revolution of the screw means 0.040 inch that the slide is raised, which is one-twenty-fifth of the thread on the screw. Each mark on the elevation slide is marked 0.040 inch apart the full length and the nut graduated in five divisions or five equal parts so that it is possible to raise the sight 0.008 inch on every one of the graduation marks on the nut. In line with each one of the lines on the nut is a depression spotted on the under side so that a plunger will snap in place. The plunger has a small spring underneath it so that every time it is snapped into one of the small depressions a click sounds. The windage adjustment is made similarly, except that a flat spring is provided which has a small notch. This engages a similar notch in the face of the nut which has greater power of holding the nut in a given position and keeps it from being turned when rubbed against an object.

Obviously it would be impossible to construct a screw to take care of the trajectory of a bullet at longer ranges. To do this an angle would have to be made to slide the aperture forward by a screw to take care of the fall of any bullet, but that is another problem and must be worked out by the interested person.

The construction of the hole in the cup disc together with the correct form is a matter of choice. The size of the hole in the disc is a matter of proper application. You cannot expect to use one made for fine target work in the brush, nor can you expect to do your best work with a cup disc on a sight for hunting purposes; therefore, these must

be made in two different designs so that when viewing an object, whether target or game, there will be no interference with the view of the object or the surrounding country or shelter. At all times in shooting at an object, regardless of how near or how far away, your vision is taking in the rear sight, front sight, and the object, so do not make the mistake of using the same size of opening for game as you do for target work.

Sight Setting Gauge — Figure 98 illustrates a gauge which is a necessary addition to a gunmaker's

is inserted into the receiver, which has a graduated scale or slide and can be set to correspond to the front sight only 0.050 higher than each of the sides on the front gauge. This gauge is also used to lay off the height of comb and heel when making a new stock, for it is possible to place a straight-edge over the top of it.

The rear gauge can be made to fit any receiver and still hold the same height at the rear, except on some rifles with small receivers. A gauge of this nature should be in the possession of every stock maker to secure the correct drop of stock by using



Fig. 123

Remodeled Springfield Model 1903 designed for Dr. A. J. Ries. Howe-Whelen sight attached

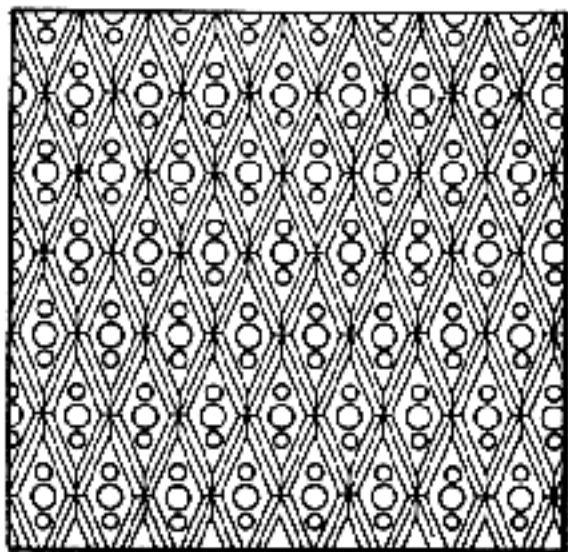
tool lay-out. The gauge for height of sights is only used when making and setting new sights in position. The front gauge is inserted into the muzzle, which has been turned out of a 2½-inch bar of steel. I have placed four flat sides on it, measuring from center of bore; one for 1.100-inch height, for 1.05-inch, for 0.925-inch, and for 0.800-inch. The highest side is for long-range target rifles using heavy barrels. The 1.05-inch is the standard height for Springfield, using any form of receiver sight. The 0.925- and 0.800-inch heights are for special low mounting on Springfield and other bolt-action arms where low sights are required. The rear gauge

the straight-edge illustrated in Chapter II, Volume I. By the use of the gauge and the straight-edge an exact duplicate is possible when making two stocks; otherwise mistakes are apt to happen by the "guess and try" method.

Those who attempt making sights which will be an improvement over those we have today will confer upon themselves a lot of hard study and research work to be able to arrive at a point where it is possible to apply the correct principles, putting telescopic ones aside, and departing from ideas of iron sights.

CHAPTER XXI

Spring Making



Spring Making

THE main principle underlying a spring is necessarily the elastic property of the steel of which the spring is made. The analysis of spring steel used in gun work should be:

Carbon	0.45—0.55	per cent
Manganese	0.50—0.80	" "
Phosphorus	0.03—0.04	" "
Sulfur	0.03—0.04	" "
Chromium	0.80—1.10	" "
Vanadium	0.15—0.18	" "

The process of fitting springs includes hand-forging, filing, polishing, heat-treatment, a tempering bath, and a final polishing before the spring is assembled. These treatments are applied to numerous flat springs used in shotguns, single-shot rifles, automatics, etc. The round, helical or compression springs made of music wire are untempered, except in very rare cases of larger, heavier springs where the wire runs above $\frac{3}{32}$ inch; these are the square wire springs.

The amateur should be thoroughly familiar with spring making, for much of this work will be brought to his attention. To acquire a fundamental knowledge, make a few sample springs; not necessarily for any particular gun, but merely as a means of gaining experience. Conduct your test in an experimental manner with various heat-treatments in the tempering stages of the potassium-nitrate bath. First, test a spring tempered to 700 degrees Fahrenheit, and continue the treatments, increasing the temperature each time until you reach 850 degrees. When you have acquired knowledge of tempers in the test for compression you will be able to guide future spring requirements accordingly.

The finest spring steel for gun work is made in Sheffield, England; the second best is of Swedish manufacture. American spring steel has been brought to a high standard of late years, but it is wiser to use only the best for complicated springs on a high-grade arm. You will find after considering the work involved, that it does not pay to economize when buying spring steel.

Forging — Quite as essential as good steel in making a satisfactory spring is proper forging. In forging, do not work the steel too cold under the hammer, but heat it at an even and uniform temperature. The bending of the spring requires three

heats; one or two heats are not sufficient for the proper forms.

As an illustration of forging a spring, we shall select a main spring from an Anson and Deeley action where the forward end controls the automatic ejector levers. This spring has two actions to perform; operating the hammers and operating the small lever for the ejector cocking arm. When compression takes place, the slight sliding motion on the flat part must be made to the exact length to have the arm perform properly. We must be very particular when it is finished, so that the spring will function this part when compression is at its extreme limit.

Your forging equipment may consist of only a regular forge or blow torch, or you may have a standard gas furnace in which you can control the heat within a few degrees of temperature. Whatever your equipment may be, here are the correct details. The heat of the furnace must be about 1450 degrees Fahrenheit, and no higher than 1550 degrees. If the piece of steel you are using has been cut from a bar, place it in the front of the furnace and allow it to heat slowly before moving it into the direct heat of the flames. While waiting to have the steel rise to the proper heat, set three calipers to the broken spring; one for width, one for thickness at the heaviest part, and one for thickness at the thinnest part, allowing enough for filing. When the steel has reached the correct even color, withdraw it from the furnace and forge it. Never allow the color to run below the cherry-red heat. Continue until the spring is forged to the required width and thickness. Cool in lime and then file to the required width and thickness, allowing enough for length to finish. Polish the inside where it cannot be finished and then turn it over.

Place it back in the furnace and gradually heat to the same temperature. In forging it to shape, before putting the spring into the furnace, chalk a cross-mark where the bend will go. When it is heated to the required temperature, remove it from the furnace and proceed to bend. Since the spring is now very thin at the end, it cools rapidly, and you may be able only to turn it half way. If so, reheat it and completely turn the bend, allowing enough so that it will be possible to insert a $\frac{1}{32}$ -

inch blade between the bend. Reheat again, remove from the fire, insert the blade between the bend and completely finish, hammering it well into shape. Because you have used three heats on the spring to turn it over, the molecules in the steel will not be injured and fractures will not appear later.

Uneven heating is the cause of most of the defects in forging a spring; later on we shall study the defects in the hardening operation. Great care and a thorough knowledge of the characteristics of steel are essential throughout the heating operation. It may be accomplished satisfactorily if the student will use good judgment and be certain that everything is carried out with precision.

The next operation is to place the correct curvature in the spring and also to have the bend parallel to each curve so that the compression will be distributed evenly when the spring is compressed. It may require three heats to secure the proper curves and to have it square. Placing curves in the spring is a simple operation and I presume that you will be able to do this without further instruction. After forging the spring to this point, hold it with the tongs while you turn the leaf to the proper curve, first one end and then the other. Maintain the same heat in the spring during the operation. Bend the spring a little more than necessary so that if the least compression takes place, due to a faulty tempering, the spring will not become so weak that it ceases to function.

After the spring is cool, the finishing takes place. In this operation, the spring is fitted into the slot and about 0.002 inch more is allowed than the spring pocket, so that it will enter freely. When filing the length, measure it with a micrometer to prevent any mistake. The rounded ends must be absolutely square and have a true radius. All file marks must be removed and polished so that when the final finishes are given the slightest scratch will not be detected.

Hardening and Tempering—A lead bath is employed to harden the spring. If the student does not have a crucible, a common ladle will serve as well. Place a sufficient amount of charcoal on the top so that it will not oxidize too readily. It will be necessary to coat the spring with common alcohol and chalk to prevent the lead from sticking to the steel and thus retard cooling of the spots where it adheres. Pre-heat the spring to between 800 and 900 degrees Fahrenheit, and then place in the molten lead, which should be at a temperature between 1350 and 1400 degrees. When the spring is placed in the lead it will float to the top, for lead has a specific gravity greater than steel; therefore, it will be necessary to hold the spring under the

lead with tongs, the ends of the spring being heated to secure the proper temperature throughout. When the required temperature is reached, remove and dip it in the oil bath as described in Chapter VII. When cool, remove and place in a bath of potassium nitrate (saltpeter) heated between 700 and 725 degrees. A low-reading pyrometer should be used to keep the bath at this temperature, or better still a high-grade mercury thermometer having a range above 750 degrees Fahrenheit. With a thermometer of this kind the bath may be always controlled and kept at the correct temperature. Allow the spring to remain submerged between ten and fifteen minutes or even longer—alho ten minutes is usually sufficient.

If the beginner is unable to employ such elaborate equipment, I would suggest the "stick method" for both purposes; heating of the potassium nitrate and testing for the proper temper. This consists of judging by the "feel" or appearance of a wooden stick on the surface of a spring. This is a crude method, but in experienced hands is very reliable. The first indication is the greasy feeling of the stick as the temperature of the spring increases, owing to its greater heat. The first sign of this feeling occurs when the temperature has reached about 575 degrees. After the smoke, a spark may be obtained with hard rubbing, and as the heat increases, numerous sparks are obtained with light rubbing. The next definite indication is the "flare" of the stick which occurs at about 795 degrees. At this point the steel has just reached luminosity, as judged in absence of external light. The "stick" employed is usually an old hammer handle of either ash or hickory, shaved down to a flat edge. You may use softer woods such as birch or hazel, but these are not as good as the former. The charred point of the wood is used continually. It should be noted that resinous woods are not suitable for gauging such temperatures. After you become accustomed to gauging heat in this manner, you can judge the rate of heat within 50 degrees Fahrenheit, which is a practical working range when tempering springs. The temperature of the potassium nitrate bath may also be judged by this method.

After the spring is carried through the above-mentioned operations, it is ready to be polished. Before any polishing is done, examine the spring thoroughly with a magnifying glass to detect any flaws. Cracks of a circular form on the corners or edges of the spring indicate uneven heating in hardening. Cracks of a vertical nature and dark-colored fissures indicate that the steel has been burned and should be scrapped and a new spring made. Springs which have hard and soft places have been either unevenly heated, unevenly cooled,

or "soaked"—a term used to indicate prolonged heating. A spring not thoroughly moved about in the hardening bath will show hard and soft places, and have a tendency to crack. Springs which are hardened by simply dropping them to the bottom of the oil tank sometimes have soft places, owing to contact with the bottom or sides of the tank. They should be thoroughly quenched, before dropping, by moving them back and forth in the oil. If a spring appears soft and will not harden, it has probably been decarbonized on the surface by too much heat or by soaking it too long. The surface must be removed before the spring will harden properly, but this can not be done with some springs after thickness has been established. Sometimes springs are soft because the cooling bath is not large enough. I refer to those who try to harden a spring in a can cover and expect to see good results.

When the spring is perfect in every respect you may polish it to a high finish and place it under test. For this operation refer to Chapter XV. This is an important factor in governing its life, for if it is not tested it is likely that inherent defects will not be detected. If overtested, a crippled effect is produced which is equivalent to several years' use. The proper method is first to measure the spring with a micrometer and place it under an arbor press, using suitable steel blocks which have been hardened and the surfaces oiled so that the spring will ride free when pressure is applied. Bring the ram down and compress the spring to its full compression; repeat from eight to twelve times and then check with the measurement previously made. A well tempered spring should not lose any compression except the normal set, which should not be more than 0.01. If the beginner does not have an arbor press with which to do such testing, the bench vise may be used instead.

A spring made according to the methods outlined should last the life of the arm; it should even stay compressed when not in use and hold its elasticity. The test will show that the spring is practically constant and independent whether compressed or uncompressed. There is such a variety of flat springs used in firearms that it would be difficult to describe all the shapes and sizes. All such springs must be hand-forged and given the treatments described.

Helical Springs—Altho these are often called "spiral springs," the proper term is "helical," denoting a spring which shortens in action. There are several methods used to coil wire for springs, but the most successful is by means of a lathe with suitable arbors and one small hole drilled through it to hold the wire during the winding operation. These in turn are fastened in the lathe chuck. Wind

it on the mandrel while a tool is used in the tool post. This tool has two rollers fastened to the side of the holder. The coil of the spring is determined by the pitch of the number of threads per inch, and for the size music wire used. A tool of this nature is generally used with heavy wire, and if employed on either heavy or light wire, an even and well-formed spring is the result.

A quick method is to anneal an old flat mill file measuring either 6 or 8 inches and drill a series of holes, small in diameter, such as Figure 124 illustrates. The end of the spring wire is inserted in the drilled hole and at the same time into one of the holes of the winder or mandrel. If such a tool is used on top of the mandrel with the wire running through one of the holes to determine the space required between the spring coils, a true and even spring will be formed.

Let us assume that you wish to make a coil spring to go into a $\frac{3}{8}$ -inch hole; the size of music wire used is 0.045 inch. The double diameter of the wire would be 0.090 inch; because of expansion when the wire is released, you must deduct $\frac{1}{16}$ inch and an additional 0.01 inch so that the spring will be free in the hole. On the other hand, if you should wish the same spring to be free on a spindle or shaft which measures $\frac{3}{8}$ inch, you would use a piece of $\frac{5}{16}$ -inch drill rod for the mandrel. This rule only applies when the spring winder, which fits into the tool post, is used; the proper friction may be had to keep the wire tightly wound with all possible tension.

If a long spring is required, a mandrel of a corresponding length is used with a center placed in one end and the dead center in the tail stock used for a support. When a very small mandrel is used, the end of it is supported between the jaws of the drill chuck placed in the tail stock. The wire is placed in a boring-tool holder or a V-holder in the tool post. A piece of brass about $\frac{1}{8}$ x $\frac{1}{2}$ x 3 inches is placed between the wire and tool-post screw and a V-shaped groove is filed in the brass to hold the wire in place. The groove is filed lengthwise in the brass plate and is made of the proper depth for the size of wire to be used. This clamping arrangement is tightened with the tool-post wrench, just enough tension being applied on the wrench to keep the wire from slipping.

There are several simple methods of winding wire for springs. One of these is to clamp a rod or bolt in the vise and wind the wire around it by hand. This is a very unsatisfactory method, however, for it is rather difficult to wind the wire evenly and with the proper tension.

A very simple hand tool for winding springs can be made. A piece of $\frac{1}{16}$ -inch flat metal is filed

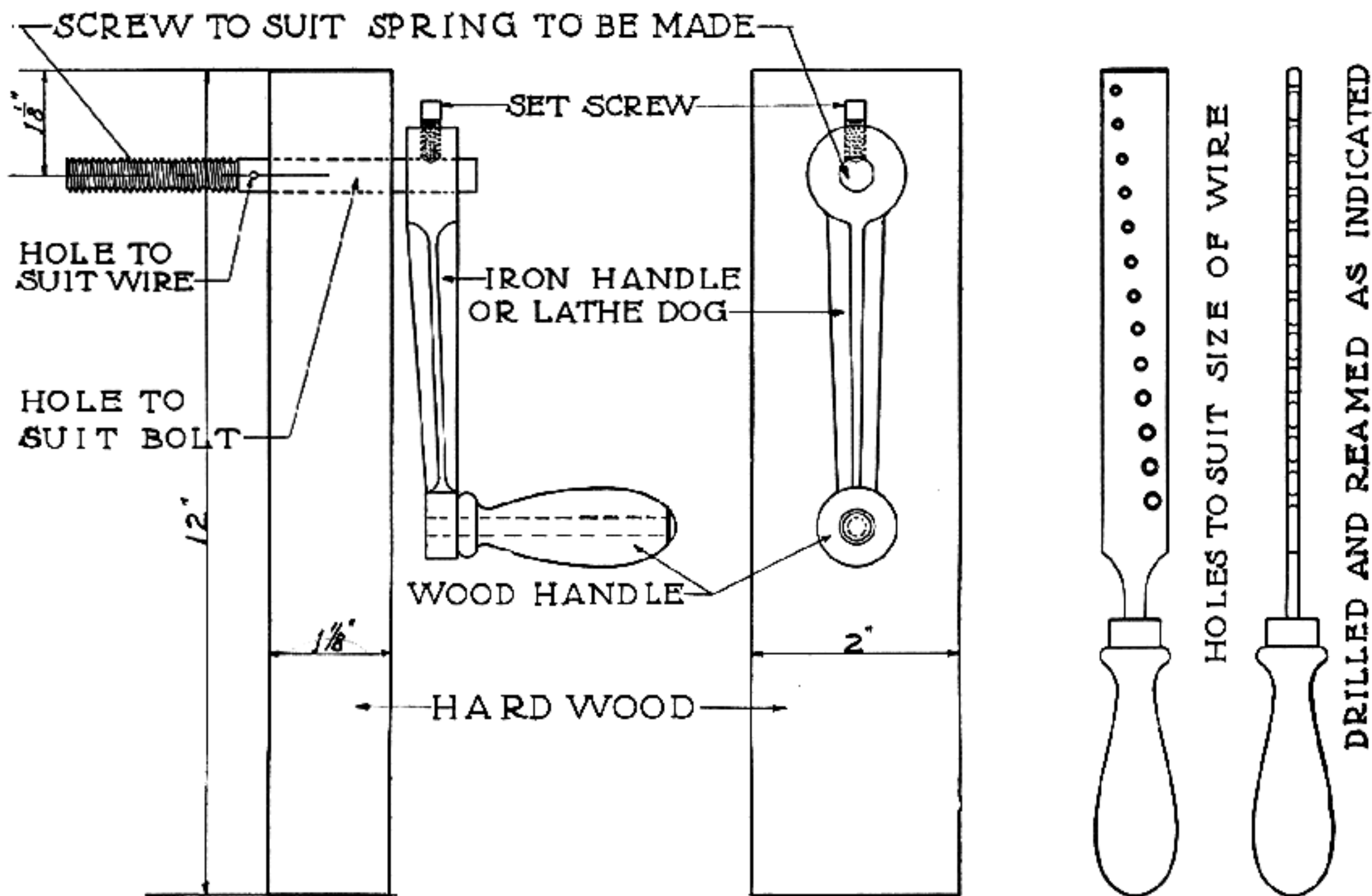


Fig. 124
Spring winding tools

out, and on the left-hand side this tool is made to clasp the rod on which the wire is being formed. This is a handy tool and in the same class as the drilled file used for forming an evenly spaced spring. With such a tool, long coil springs can be wound.

Another method of making a spring of an even coil is to hold a long threaded bolt in the vise. First, drill a small hole in the end of the bolt and then screw on the nut to such a distance that the hooked tool can be placed over the bolt. Place the wire in the hole, and with the tool in place, screw up on the nut, allowing it to follow the thread on the bolt. When enough is wound, file off the end of the wire in the hole and release the spring, which can be screwed off the bolt. Springs of almost any coil, but not of "almost any diameter," may be made in this way.

In the absence of a lathe, a wire-winding tool can be made either by bending a rod into the form of a crank or by using bolts or lag screws with a handle, or a lathe dog fastened to one end. Insert these into a piece of hard wood as shown in Figure 124. This can be held in the vise or fastened to the bench by two or three screws in convenient places. A hole is drilled into the end of the rod or bolt and in this hole the wire is placed and wound toward

the crank. Of course, the spring can be made no longer than this projecting end. To make different-sized springs, different-sized rods or screws must be used, and holes to fit must be made through the piece of wood.

A tool of this kind will prove more serviceable and at the same time look like something. Providing you expect to have much of this work to do, you may procure a casting similar to the tail stock to a lathe and put in a hole where the movable spindle is placed. A similar spindle, but with the end where the wire is to be wound, is large enough to form a shoulder to keep it in place. On the other end place a wheel 8 or 10 inches in diameter. A steering wheel from an automobile will answer, if a handle is provided to turn it with.

The end where the shoulder is may be made with a screw to fit a drill-press chuck, and this can be used for various purposes. The spindles may also be in the chuck. Such a tool can be fastened to the bench, and if more elaborate extensions are wished, a small motor and pulley may be connected. This tool would be a very convenient one with which to lap shotgun barrels at the muzzle. It can also be used for reaming holes, and in emergency for drilling purposes. As a tool for holding taps to tap threads in holes it has no equal—the work is

held in the left hand and the wheel turned with the right.

The flat springs used in cheap revolvers and arms, which do not require much tension, can be made from the sheet spring steel. Always cut the strip of sheet spring steel in the direction of the grain, which is lengthwise, for the grain of the steel must not be across the spring. After the spring is cut to shape, grind down to size, or taper-grind it, for on all the cheap revolvers the operating end must be a taper and the stationary end which fastens in the frame must be heavy. When finished to correct width and taper, heat it and place the required bends in the proper places, then harden and temper as described.

The straight tapered springs used on Colt and Smith & Wesson revolvers are very simple to make, as the ends have a slot for the hammer stirrup. After the spring is slotted, heat the end and form it over a piece of drill rod fastened in the vise. When formed to the correct shape, harden and temper.

The student may not be able to secure the fine British steel, nor perhaps any suitable spring steel, through his local source of supply. Let us suppose that he must have a spring in a hurry, say for a Ballard rifle. Since this is rather a large spring it must be made as nearly correct as possible and at the same time it must be very resilient. The best steel to use in such an emergency would be from an old automobile spring. Anneal one of the leaves by placing 6 or 8 inches of the spring in a pipe and closing both ends. Pack lime all around the spring, heat to about 1400 degrees Fahrenheit, and allow to remain at this heat for one hour. Then let the furnace or forge cool off with the pipe and its contents therein, which will require from four to six hours. When the piece is thoroughly annealed, saw lengthwise a piece of the bar long enough for the intended spring. Forge it to shape, allowing enough for finishing, as instructed in the first part of the chapter. If you are doing this work on a regular forge, using bituminous coal, make sure that you have freed the fire of sulfur and only use coke which has been prepared as described in Chapter XIX, Volume I. Complete the spring according to

the sample and fit it well into the slot with the correct taper from lug to contact point on the hammer end. It is now ready to harden.

The taper is an essential element in making a good spring for a firearm. When a spring is compressed and has the gradual taper, it must be constant from the large end to the smallest thickness. This tends to give a spring a gradual freedom of elasticity and a greater range of compression. The weakening of a spring due to an uneven taper is obviously a very serious factor and one of the prime causes of failure in most springs made for firearms; which points to the possibilities of unequal stress set up in steel structure, regardless of the correct forging, hardening, and tempering. If you will examine a number of broken springs which have been removed from firearms, you will find nearly all causes of fractures about the same—improper heating, uneven taper, or improper hardening and tempering. The last cause is the most common.

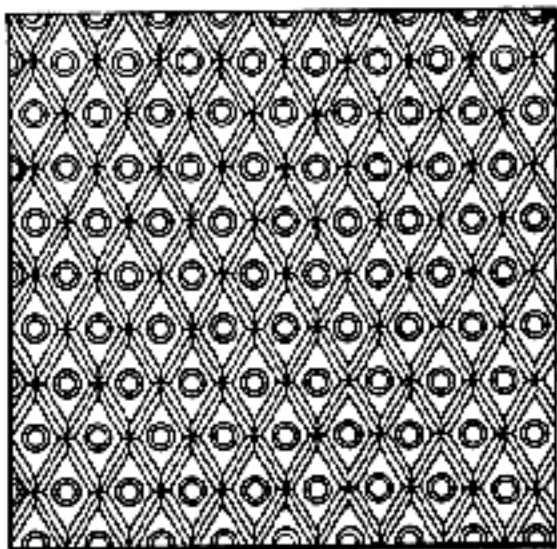
If I were to extend this chapter any further it would be necessary to carry it into technicalities involving a number of experiments to determine different points, such as stress and strain, development of formulæ for deflection, practical consideration of the theoretical aspect, remarks on spring steel, etc. This study alone would require a good deal of time and would fill several chapters; but for the average student this would be of no value.

Remember that to obtain good results when making springs, it is necessary to have the means of heating the steel uniformly and to the proper temperature. Forging should be done according to the correct method and cooled at the required degree. The medium of oil should be employed, and the temperature and heat kept reasonably constant.

It is well for either the amateur or professional, when making springs, to discard such old ideas as "burning oil" off a hardened spring, and instead apply the modern and more practical method. If this were practised more, much spring trouble would be eliminated. Perhaps you deem it difficult to give up practises clung to so tenaciously these past two hundred years, but modern methods demand flexibility.

CHAPTER XXII

Bullet Swages and Case-resizing Dies



Bullet Swages and Case-resizing Dies

IN THE lean years such as we are experiencing during this world-wide depression, it becomes a necessity to economise at every turn; the loading of ammunition is a means of reducing expenses to fit the times. The hand-loading of one's own ammunition is a source of great enjoyment, and those who have a small shop where it is possible to make their own reloading tools, as described in this chapter, are in a fortunate position. They can not only make loading tools but bullet swages and bullet moulds.

It is surprizing to see the ingenuity shown by men who construct their own reloading tools. A man whom I know made one from a bottle capper; it cost him the sum of \$1.35. He was able to load not only one caliber of cartridge, but many, starting from the Hornet and ending with the 45-70. We can not consider points of extreme precision with a tool of this nature, but when we draw aside the curtain and analyze Captain Woody's information, we can not help but understand that he has striven for accuracy, eliminating every cause that would tend to make bad groups on the target. We can also see from the information given that he has accomplished the results he has striven for in the complete construction of his dies; those who have a small lathe in their home workshop can achieve the same results. After a start is made you will construct not only one straight-line tool for a certain caliber of cartridge, but many, or at least enough for the number you may have on hand.

For the major portion of the ensuing material in this chapter I am deeply indebted to Captain G. A. Woody. Captain Woody has needed no introduction since the development of the .22-caliber Hornet cartridge.

Resizing Dies—Getting a bullet started right is one of the secrets of good accuracy. A good bullet—one which has its rotational center of gravity directly within its axis—can be made to shoot inaccurately by canting it in the neck of the case. In this canted position it gets started incorrectly, and the upset it is forced to take leaves it distorted, resulting in an inaccurate flight.

To be assured that the bullet will at least get the benefit of a good start, the neck resizing die must

be accurate. By all means, a full-size resizing die should be used, as this arrangement alone insures that the neck will be concentric with the body, especially that portion of the body just in front of the head or rim. It is this portion of the body which should, in accurately-made chambers, support the case and line the bullet up with its seat. Obviously, if the neck and the rear portion of the body are not in line, the bullet will be canted in its seat, and inaccuracy will result. All cases which are to be reloaded should be resized, especially at the neck. In no case should a chamber be made in which the neck is so tight that the cartridge neck after being fired will be small enough to hold a bullet. This is one of the surest ways to assure inaccuracy. It is seldom that a cartridge case has a neck which is exactly the same thickness all around. Such a case, fitting into a chamber the neck of which holds the case too snugly, will surely start the bullet incorrectly. In addition to this, there is always the danger of excessive pressure arising from too-tight chambers.

With this explanation, it is seen how necessary it is to have the neck concentric with the body; this can be obtained only through the use of a full-length resizing die. This should not be construed to mean that the full length of the body should be resized, but that the die should fit the full length and resize the neck. A full-length resizing die is simple in construction. All that is required is a piece of steel sufficiently long to take the case. Its diameter should be large enough to give it some weight, since the operator will often find it convenient to hold the die in one hand and strike the knock-out pin with a hammer. A good heavy die works very nicely this way.

Before proceeding to worry much about the die, one should provide himself with a reamer of proper size. He will find that the dimensions of a fired case, excepting the neck, will be just about what he wants if he is to fire the resized cases in the same gun from which he has taken the fired case. There is no advantage in unduly resizing a case if the same gun is to be used with his reloads. Having selected a good sample of fired case, he should use it as a guide from which to make his reamer. A reamer for this job is easily made by turning down

a piece of drill rod to the exact dimensions of the fired case minus about .003 inch at each point. This is necessary because a reamer of the type he will make will cut one to two thousandths large. The neck of the steel plug or reamer blank should be about .005 inch smaller than the diameter of the neck of an unfired case with the bullet inserted and should be at least .050 inch longer than the longest neck of a case you are able to find. Always make the reamer small in diameter, since the die can be lapped out if the first trial indicates it to be too small. Leave enough on the forward end for a pilot which should have a diameter about .005 inch—or more—smaller than the neck diameter. Select a diameter which will enter a hole drilled with a convenient-sized drill which you may have or be able to get. Use care to see that the length of the neck section is sufficiently long to keep the end of the case from buckling or becoming closed in. The rear end of the reamer blank should be turned to a size to fit a convenient chuck.

Having gotten the blank finished to size and smoothed down, it should be caught in a vise and slabbed off to one-half its former thickness from a point just in the rear of the pilot to a point in the rear of the section which would form the body adjacent to the head. If a good grinder is available, this slabbing off can be done after hardening, and it is preferable in all cases to leave a little thickness to be stoned down after hardening. Such points on the reamer as the cone and front of the neck should be given a slight clearance. In fact, this type of reamer should always be given a slight clearance just back of the cutting edge, and this clearance should increase as the cutting edges approach the nature of leading edges, as in the case of cones and crosswise cutting edges as in the end forming the neck. It is necessary to carry this clearance all the way around to the opposite side.

You are now ready to proceed with the die proper, and having selected a suitable piece of low-carbon steel, chuck it up and face off the end. Center drill and then drill completely through with a drill somewhat smaller than the one you have selected for your reamer pilot size. Follow this with the finishing drill, which should be about .001 inch larger than the pilot you have provided on the reamer. Without moving the piece from the chuck, insert the reamer and proceed to enlarge the drilled hole. Use a slow speed and plenty of oil. You need a smoother finish. Ream to a depth which you have gauged to be satisfactory. Remove the die, and after relieving the sharp edge, try forcing in a fired case—with a vise. Having forced the case out, analyze the results by measuring the salient points on it as compared with an unfired

case. Try inserting a bullet in the neck. If the bullet fits too tight, you are all right so far. Now, try the case in your gun, noting if there is any binding anywhere, especially in length. If there is no binding, you are still all right. Watch the length to see that you have not unduly shortened the case. A very nice way to determine the length is to try several cases in the die pushed in to various distances. For instance, if you allow the head to extend away .050 inch from its seat on the die, and the shell fails to seat in the rifle by .050 inch, you are a little too deep; that is, you have no clearance at the shoulder and should face the die off about .003 inch for clearance. The same analysis will indicate when the die is not deep enough by allowing the case to enter the chamber to a point less than .050 inch minus the .003-inch clearance. In this case, the die should be reamed slightly deeper.

After you have measured the resized case and compared it with an unfired case and pondered over it for some time, decide whether or not you can afford to do much lapping on the interior, and if so, how much. If the neck or any other part of the body needs lapping, a stick to about the proper size and driven into the die and then removed will give very good results. When the stick is removed, trim down the section you do not want disturbed, and with valve-grinding compound lap out the surfaces you want increased. Try the die several times until you get exactly what you want. If you find that the reamer has cut too large, the only thing left is to stone it down at the large portions and start over again. Remember not to decrease your case too much. The neck should not be so small that undue pressure is necessary to insert the bullet. An unsightly bulge at the neck after the bullet is seated is unnecessary and a detriment to accuracy, since you will note that when the bullet expands the case it will invariably go in unevenly. Just enough pressure to hold the bullet in securely is sufficient.

After you have gotten the proper size of case, it is well to case-harden the interior of the die. An effective way of doing this is to heat it up to a good red and insert into its interior a small piece of sodium cyanid. Remember that sodium cyanid is poisonous and should be handled accordingly. Allow the piece to remain so heated a few minutes and quench in water. The inside will have a thin but hard surface, and a slight lapping will make it smooth. A knock-out pin should be provided. This is simple, yet many do not think of the effectiveness of providing a decapper with the knock-out pin. This can be arranged by selecting a short rod which fits loosely in the mouth of the case and shouldering down one end, leaving a tip the diameter of which will enter the primer vent and be of sufficient length

to decap the primer. In using such a rod to knock out the case, the primer is detached at the same time the cone is knocked out of the die, making two operations in one. Figure 125 shows a resizing die and knock-out pin as described above.

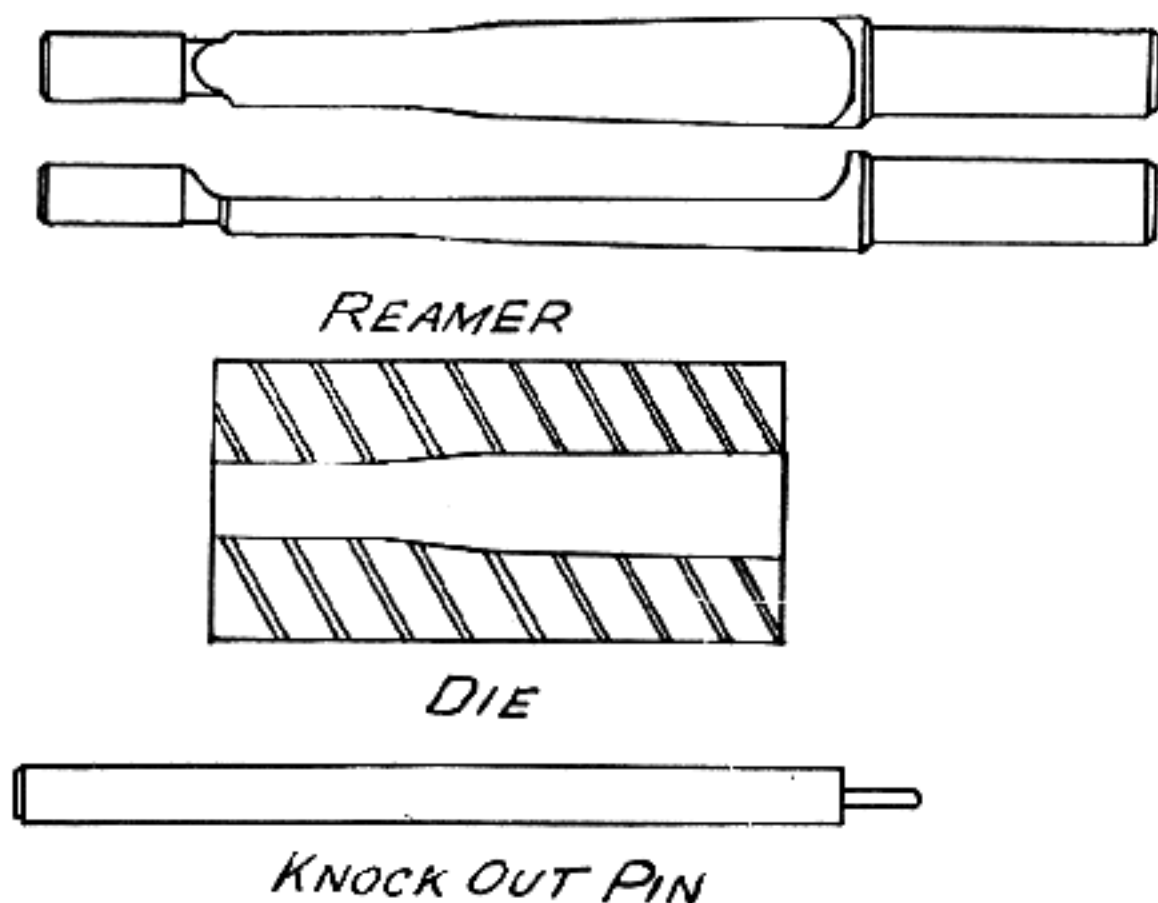


Fig. 125

Swedging die. Reamers used for making die. Half reamers may be used as expedient when only one die is required

To use this full-length resizing die, first wipe off the exterior of the cases that are to be resized with a slightly oily rag, so as to have just a very thin smear of oil on the case. If a heavy coating of oil be on the case, it will be distorted. Place the case in the body of the die. Have a large vise with brass jaw covers. Place the die with the case in it in the vise, and close the vise up until the head of the case is just even and flush with the head of the die. Then remove the die from the vise, and holding it in the left hand, insert the knock-out pin in the mouth of the die, and with a hammer knock the case out of the die. This will remove the case from the die and also remove the fired primer from the case. Before driving the case out, be sure that the primer decapping pin has entered the flash hole in the case.

Bullet Swages — Making one's own bullets, to a few, is a very interesting pastime. There is something about the game, when once you have mastered it, that is hard to get away from; one finds himself making bullets of various components and getting from this a wonderful picture of the action of bullets.

Before undertaking the manufacture of a bullet swage, one should know that he is capable of fine and accurate tool work and should have a good knowledge of the behavior of metal when being drawn. It is useless to attempt to make bullets

with a swage that is not accurate and capable of maintaining its accuracy. There are bullets and bullets—not all shoot accurately.

One of the most important features of a bullet is that its center of gravity be exactly in line with its center of rotation. This fact is more obvious when it is considered that the rotational speed of a modern .30-caliber bullet is approximately 200,000 R. P. M. At this rotational speed, it is readily seen what will happen if the bullet is in the least out of rotational balance. It is impossible to attain any degree of accuracy with an unbalanced bullet.

Our modern method of manufacturing bullets is simply to have a die with a recess in it the shape of the bullet. That portion of the die which forms the point of the bullet is drilled, reamed, and lapped to take a push-out pin, which is recessed on one end to form the extreme point of the bullet. The operation consists of forcing—with a punch—a bullet jacket and core into the die by the aid of a crank press, the return stroke of which pushes out the bullet by the aid of the push-out pin. To design a die following out this principle is simple enough, yet the maintenance of the push-out pin when making long pointed bullets is difficult. For this reason, commercial manufacturers dislike undertaking soft-point, long pointed bullets.

One simple yet effective design of bullet die is shown in Figure 126. It should be noted that the die is supported at the junction of the body of the bullet and its point. The base which forms the point is inserted into the main body of the die, and

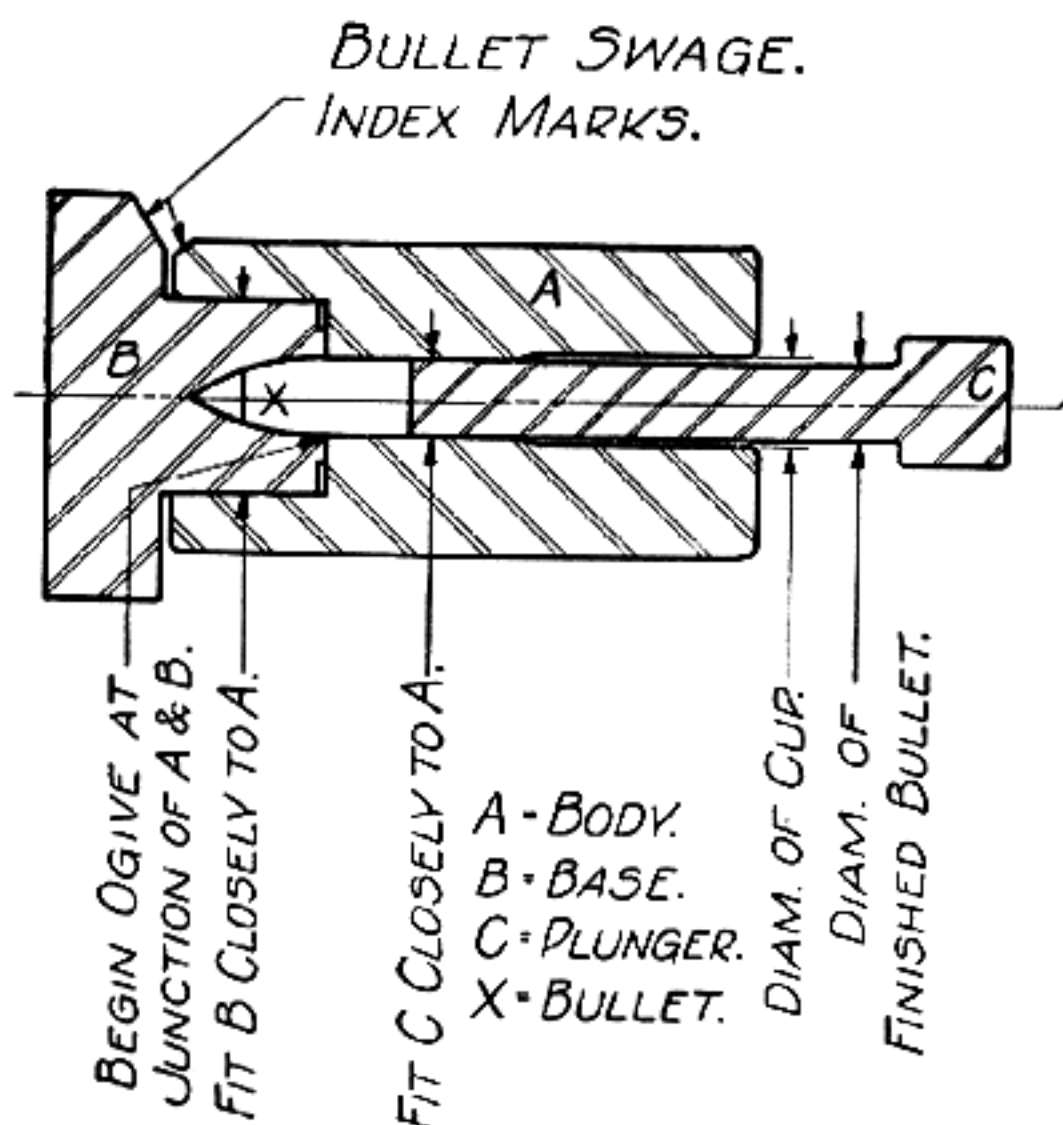


Fig. 126
Bullet swedging die

in this position a jacket and core are swaged to shape. To remove the bullet, the base is pulled out of its recess, and the bullet is forced out by pressure on the punch in the same direction that the bullet was swaged. A swage so designed must be made accurately or it is useless, yet when made accurately it is much more easily maintained than one with a push-out pin.

For a bullet the size of a .22 caliber, the first consideration is to provide a reamer of the shape you desire. While practically any shape can be used, it is best not to select one of a radius greater than five calibers. That is to say, the arc of the bullet point should not have a radius greater than five diameters of the bullet. It has been thoroughly demonstrated that long-pointed bullets have a greater sustained velocity than blunt-pointed bullets, and that they strike higher on a 200-meter target. Obviously, this phenomenon can be partially attributed to other conditions, such as jump; yet, all in all, the long point produces a flatter trajectory even at short ranges. This statement can be verified by taking a blunt .22-caliber Velo Dog bullet and reversing it to a long-pointed bullet in a swage which will be hereafter described. The results will be astonishing.

Proceeding with the reamer and having determined the point and diameter, which should be about .002 inch smaller than the finished diameter of the bullet you have determined upon, slab off one side to almost one-half the thickness of the reamer to a length not greater than the length of the bullet. Be sure that the section in the rear of the cutting edge will run free in the hole produced. This section should not be larger than the diameter of the cutting edge nor very much smaller, as it will subsequently act as a guide for the cutting edge, keeping it straight and preventing it from digging in. Having slabbed off one side, be sure that the cutting edge is backed off slightly and that the extreme point will be free to cut. If the slabbing operation does not go to the exact center, the reamer will bind, and if it is cut beyond the exact center, it will leave a small projection at the point. The latter, however, is a better condition than the former. The reamer should be shouldered back to a length of 2 or 3 inches, depending on the length of the bullet you are to swage. See Figure 125 for a reamer used for this purpose. Harden and draw the reamer, leaving it sufficiently hard at the cutting edge.

For a caliber .22 bullet, select a piece of tool steel about 1.125 inch diameter and 1.750 inch long and chuck it up. Face off one end and center drill. Drill through the entire length with a drill a few thousandths smaller than the reamer. Now replace

the drill with the reamer, and with plenty of oil and slow speed, proceed to ream through the entire length of the blank. With the blank still chucked, counterbore the end with a diameter of about $\frac{5}{8}$ inch to a depth of perhaps $\frac{1}{2}$ inch, leaving a good radius at the bottom of the counterbore. Be sure that the counterbore is a perfectly cylindrical cut at least not greater in diameter at the bottom than at the outer edge. Break down the sharp edge of the counterbore. Now remove the blank and again catch it in the reversed position in the chuck. Face off the end and break down the edge of the bored hole. The hole on this end must be slightly enlarged to a depth leaving a length of the original reamed hole equal to the length of the cylindrical section of the bullet plus about $\frac{1}{4}$ inch. This enlargement is necessary in order to get the bullet started, but it should not be more than .010 inch larger than the finished bullet. Having completed this operation, it is well to force a lead slug through the die to see that it is neither too small nor too large. It should be about .001 inch smaller than the finished bullet. On one side adjacent to the counterbore, file off a small angular cut; across this, file a line which will later be used as an index to line up your base. You are now ready to harden this portion of the swage. Hardening a thick, hollow cylinder is quite an art. If it is immersed in the cooling medium, it is liable to shrink in the diameter of the hole through it. The best way is to have a jet of water flowing upward through a tank, and by placing the heated die over the jet, the interior surface will harden almost as soon as the outer surface, leaving the hole about the same diameter as it was before hardening. It should be drawn to a light straw color with the counterbored section slightly deeper.

After the die is hardened, it should be lapped out to the desired diameter. A metal lap is perhaps the best, as the hole should be a perfect cylinder at the section which forms the body of the bullet. The desired diameter is best determined by forcing through the lapped hole a bullet of the type you intend to make. Lap out the counterbore slightly. After this operation you are ready to proceed with the base.

The base should be of tool steel. The first operation is to chuck up a piece of steel about $\frac{1}{4}$ inch larger in diameter than the body of the swage. Shoulder back a section to a length equal to the depth of the counterbore of the body plus about .050 inch. Leave a good radius at the corner. Make the diameter a force-fit to the counterbore. This operation requires very close fitting; a nice smooth-cut file will serve very well. The accuracy you will get with the swage depends a great deal on

how accurately you fit the base to the body. Before you remove the base from your chuck, remove a portion of the metal which your reamer will later remove to form the point. This can best be accomplished by drilling in with a center drill. Do not go beyond a point where your reamer will not clean up. The small point is what you should remove, since a reamer of the type you have made usually does not cut well on the point. Don't go too deep. Make a line on the base to coincide with the line on the body.

You can now remove the base and gently force it into the body, but be careful that you do not break the body in doing so. Have the two index lines pointing to each other. If the two pieces are too tight, and there is danger of breaking the body, drive the base out with a soft rod and dress it down slightly at the points where it bears hardest. The base can best be seated by tapping it slightly with a light hammer. When it is seated, be sure that it is seated close to the bottom of the counterbore. It is best always to shoulder back the end of the base about .020 inch, leaving a small rim $\frac{1}{16}$ inch wide around the edge of the hole so that the two edges of the base and body come together firmly. Having seated the base firmly in the body, and the two index lines coinciding, you can now proceed to ream the base to the limit you desire. It is best to lay out your bullet beforehand on a 10-to-1 scale and determine just where you want your junction line. Drive out your base and measure the depth you have gone and try again until you have gotten the right depth. Always keep the counterbore free of chips. You should have no difficulty holding the base and body together while reaming, as the force-fit should be sufficient to keep them together. Always keep the index lines together. Reaming is best accomplished by using a hand drill and holding the body and base in one hand while you operate the drill with your other.

Having completed the reaming, you can now proceed to harden the base. The section forming the point of the bullet should be drawn to a light straw color; the base proper can be drawn much darker. Provide yourself with a stick with a point shaped like the bullet and lightly lap out the bullet recess. Do not round off the edges too much. Fit the base again to the body by dressing it down with a piece of fine emery cloth. Never try to fit the two by running them together with an abrasive. The two pieces will probably fit together after the black from the heat is taken off. Be careful not to take off too much and thus make the parts sloppy. Do everything you can to keep the recess in the base in line with the hole of the body. With a

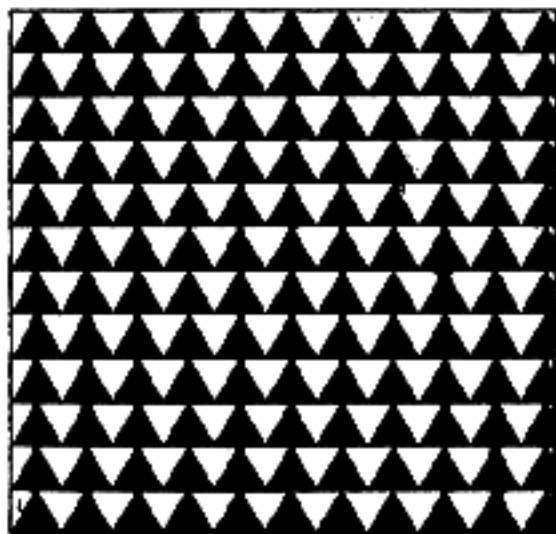
small hardened rod which just fits the hole in the body by a slide fit—the rod to have a perfectly flat end at right angles to the axis—proceed to force the components of a bullet into the assembled swage. Tap the base until you can remove it, then force out the bullet. If there is a slight burr thrown up all around the bullet, you have done well. You can now lap out the bullet seat again and try another bullet. If you have been accurate in your work, you will have a bullet with only a slight ring showing at the junction point. Even a ring .001 inch greater than the bullet diameter at this point does not seem to hurt. Bullets made from such a swage as above described have given an extreme spread of not more than $2\frac{1}{2}$ inches at 200 meters. The essential features are that the bullets should have a flat base—not canted—a point that is concentric to the base, and not too short a bearing surface.

When once the body is made, various bases can be used with it to give you many variously shaped bullets.

This bullet swage is used by assembling the base *B* with the body *A*, bringing the index marks on each to coincide, and using care that the base and body are snugly together. Then insert the assembled components of the bullet in the rear hole in the body, followed by plunger *C*. Then, holding the swage so assembled, place it in vise or arbor press and close the vise or press with a firm, heavy pressure, which will form the bullet perfectly to the die. A little experience will show how much pressure to use. Then remove the swage from vise or press, remove the base, and force the bullet out forward with the plunger.

Such a swage may be used to resize a jacketed bullet which is slightly under or over size, such as reforming a .30-30 bullet that measures .306 inch so as to give a different form and a diameter of .308 inch, or to resize .311 bullets down to .3085 inch. Or in certain cases it may be used to make complete jacketed bullets. For example, take the 45-grain .22 Hornet bullet. Cartridge cases for the .22-short rim-fire cartridge can be obtained before they have been headed; they make excellent jackets. A lead core weighing 40 grains and small enough in diameter to enter the .22-short case can be used, or the ordinary .22-long rifle bullet sized down so that it will enter the case may be used for the core. This lead core must fit very snugly into the .22-short case which is to become the jacket of the bullet; otherwise the jacket will be corrugated in the die. Assemble the core and case (jacket), swage up, and there will result an excellent soft-point bullet.

CHAPTER XXIII
Bullet Moulds



Bullet Moulds

BULLET moulds will be of interest, not to those who can purchase them ready-made from the manufacturers, but to the man who experiments with different forms of bullets. The necessary equipment to make the mould and cherries consists of a lathe, a milling machine, and a drill press; the lathe to turn the cherries, etc.; the milling machine to cut the flutes in the cherries and to form the mould blanks; and the drill press to cut the impression in the moulds with the finished cherries. All the operations require a certain degree of knowledge pertaining to tool making so that all the work will be done with precision and so that when the moulds are completely perfected good results will be the reward on the target. It will be an easy matter for you to make all such tools without very detailed instruction, providing you use extraordinary care in the construction of the cherries.

I always found great pleasure in going over some of the old tools in the loft of the small-arms department at the Frankford Arsenal. There were a number of old cherries, bullet moulds, tools and gauges, dating from the Civil War period to the present time. My chief interest centered on some of the old cherries made from time to time for different bullets, particularly on the accurate way the flutes were cut. Most of these had been cut by hand with a file after the flutes were gashed with a milling-machine cutter and were spaced very accurately. See Figure 127. This was the first method used after the cutter was formed ready to be fluted. The gashing of the teeth was done in a milling machine by catching the cherry in the dividing head chuck and indexing the head to the number of required flutes. Each time this was done, the cutter was brought against the top of the cherry to make the impression for the location of the flute.

The small-arms department made all the shrapnel balls for the shell shop; these were turned out on a special shrapnel ball machine with two half-dies which came together, forming a true sphere. This machine had a number of these dies set in a row, and as the lead wire was fed through from a roll at the back of the machine, an automatic feed carried the wire a certain distance directly over the dies; when the two halves came together a ball was

formed. Figure 128 will show the reader how these dies were made. Altho you may never have occasion to use them, you may be able to apply the idea to other work. Different-sized balls required different-diameter cherries, and these were in cabinets and also boxes in the loft, never to be used again, as shrapnel is an obsolete item on the list, the high explosive shells replacing these in modern warfare.

You will find very little use for the round balls today, as these are also on the list of obsolete bullets, except for muzzle-loading rifles and in shotguns for deer in certain States. The shotgun spherical balls may be secured from the ammunition companies already loaded in the shells, but for the old muzzle loaders or flint-lock arms you must make new ones. Their usefulness has passed, and they are in the discard, more or less; however, it is well worth knowing how they were made.

Ball Cherry — The term "cherry" applies to the ball-reamer used to make the mould for a spherical ball or bullet; so named, no doubt, after the fruit. This is an old term; in fact, I have seen mention of it in a book printed in 1814. To the average mechanic nor anyone not familiar with this process, to produce that perfect sphere in metal in the form of a solid steel ball seems a very difficult operation. It is very simple, however. The majority of tool makers would make a templet and turn and file one to form. This may be perfectly satisfactory for the average job, but when a perfect sphere is required, it is just as easy and simple and does not require any more time than the templet. It only requires a little instruction to make one of the correct size to any given diameter, and for any caliber of rifle or gauge of shotgun.

The first stage of the work is to make a forming tool to fasten in the tool-post holder of the lathe. As an illustration, suppose we wish to make a cherry 0.500 inch in diameter, which when finished will cut a true spherical hole. Take a piece of steel between $\frac{5}{16}$ inch and $\frac{3}{8}$ inch in thickness which can be fastened to a suitable holder. When set in the tool-post holder in the lathe it must come on the exact center. A piece of an old file of good quality of the above given thickness, properly annealed and the teeth ground away, may answer the

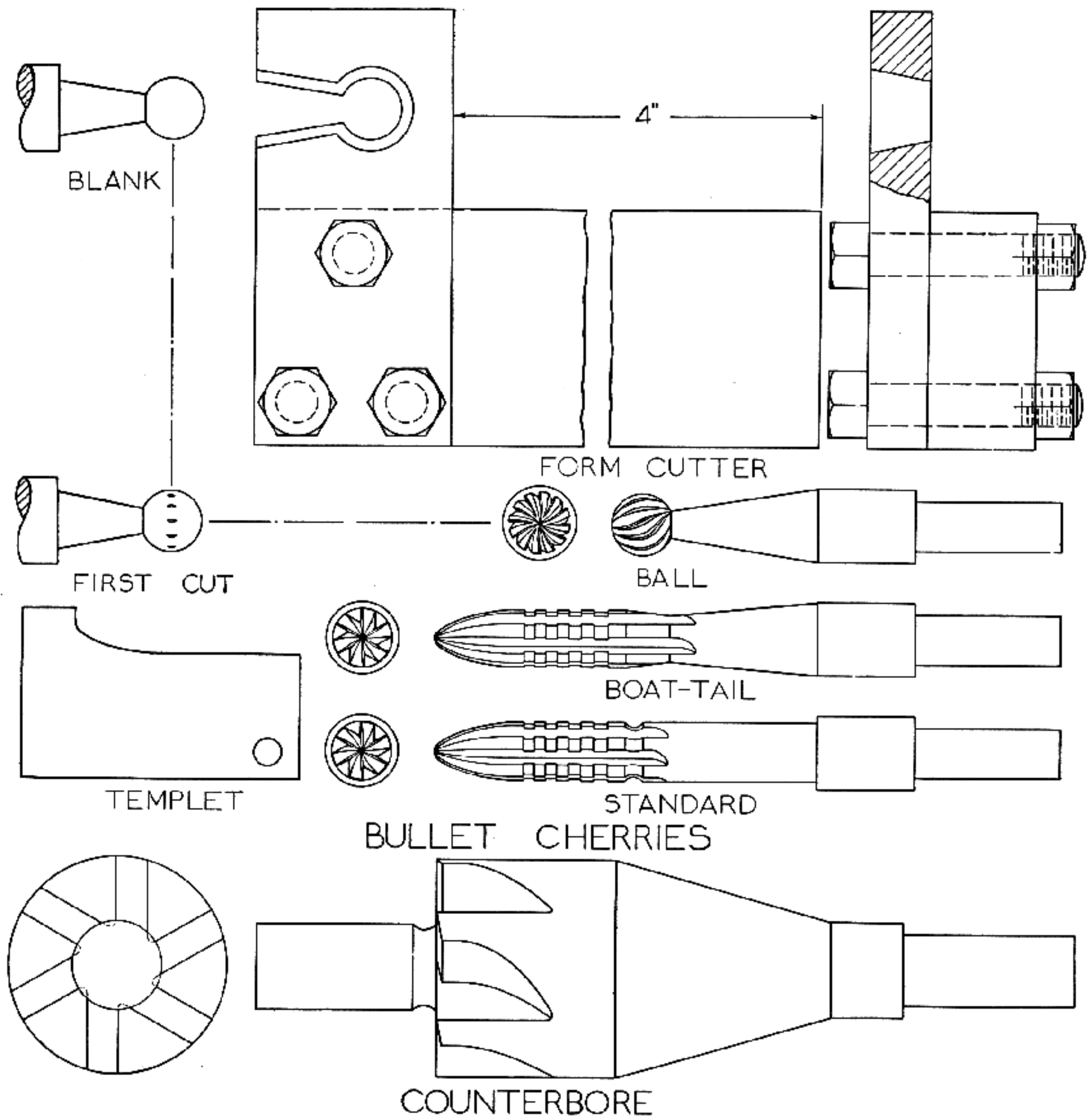


Fig. 127

Bullet-mould cherries. Mould counterbore and form tool for cherry

purpose. It should be annealed to as soft a degree as possible. A piece of non-shrinkable steel such as "Paragon" or "Ketos" is preferable. Drill a hole near one end, but a little smaller than the given diameter. With a No. 8 or No. 9 taper-pin reamer, ream the hole until the cutting edge measures 0.501 inch, which is 0.001 over the desired size to allow for the finishing and stoning operation, and which will bring out a ball to measure exactly 0.500 inch.

The advantage of using the taper-pin reamer is that the hole is made perfectly round, and at the

same time the taper of the reamer gives an angle to the hole allowing for clearance and a good, strong, effective cutting edge. With a file, cut out a portion of the tool to a V shape, and at the same time file back the clearance the same as the reamed tapered hole. Figure 127 illustrates the forming tool and work produced from same. The V may be cut either on the side or on the end, and it is then possible to center it much better. When it is completed, harden and temper for use.

For the cherry, turn a piece of steel in the lathe $\frac{5}{8}$ inch in diameter. "Stentor," an oil-hardened

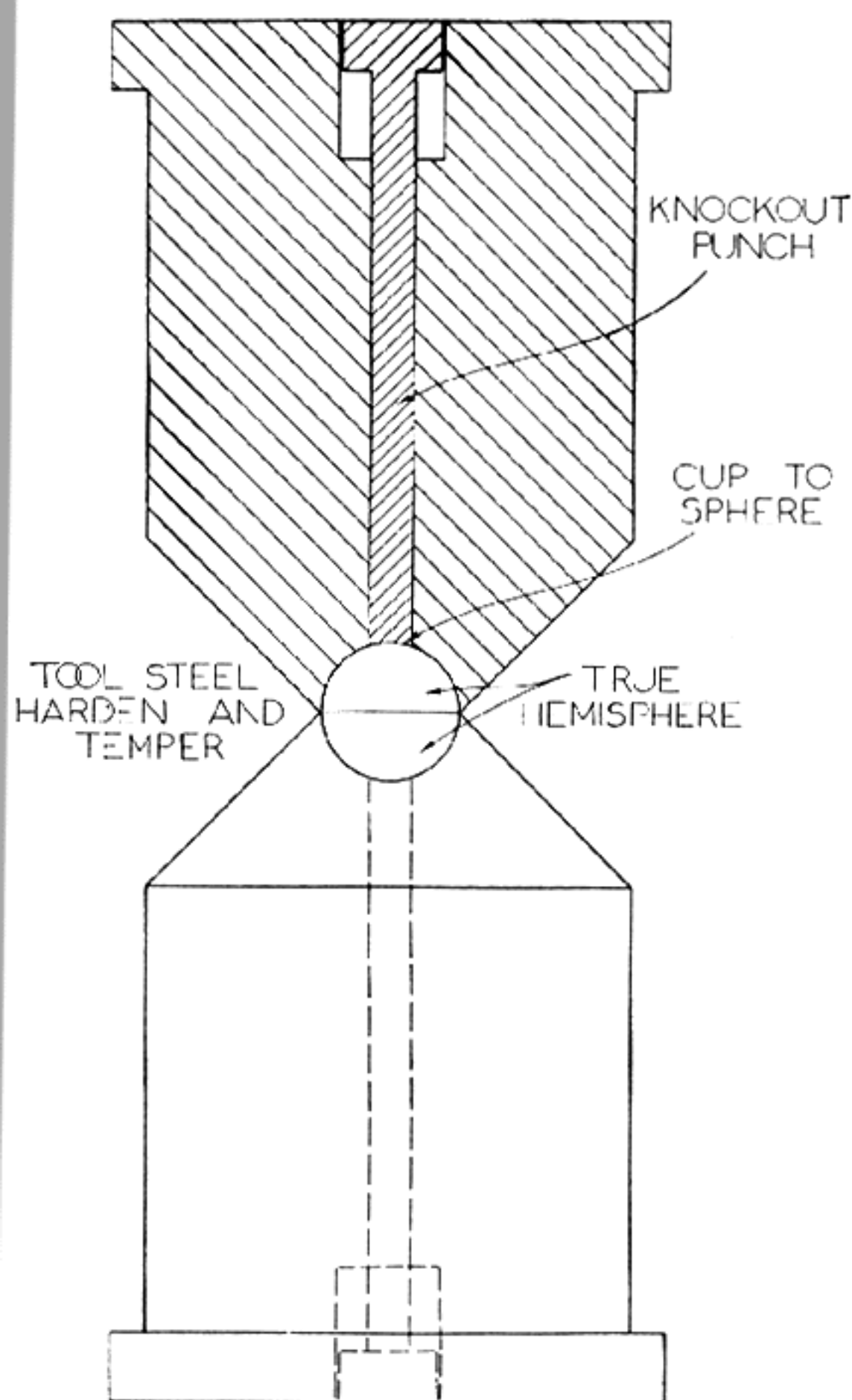


Fig. 128

Shrapnel-ball dies. Form of die used to make the lead balls encased in shrapnel shells

holder and resting it on a rest attached by the tool post. Plenty of oil must be supplied to prevent scratching or tearing the sphere. The tools should be kept well stoned on the face so that the metal will not pick up on the cutting edge of the tool. Naturally the former is the most efficient way to cut one of these cherries, but the latter may be used when one is in a hurry.

The flutes in a cherry must be cut in the milling machine; first by gashing the flutes on the highest rounded point of the sphere. Cherries must have a greater number of flutes than a reamer because of the end and because of cutting two halves at once in the mould and also in order to produce a finely finished surface. Most cherries have between twelve and sixteen flutes. You will notice in Figure 127 that the flutes do not terminate in the shank but are off at an angle clearing it. This is done to insure a perfectly spherical form by having a cutting side operate at the bottom of the hole while it is being formed. Such a flute is rather difficult to file, but as the flutes are all equally spaced, the first one is filed so that the bottom one is continued clear around the bottom. This is the one and only flute which is cutting and all other flutes terminate near this one, so patience and care must be applied or the blank may be spoiled. In using the three-square file to cut the flutes to make a fine cutting edge and at the same time a sharp V cut, grind away the teeth on one side. This will only allow the bottom side to work, and the ground side will always keep to the cutting edge without removing any metal. By grinding a file in this manner, two acute cutting angles can be had from one file. When the file becomes a little dull on the sharp cutting edge, a little grinding will restore the edge and make it sharp again. Very narrow lands must be left on the flutes, which should not be any more than $\frac{1}{64}$ inch; even less is better. When filing the flutes from the gashed lay-out, first file one and allow it to terminate on an angle clearing the shank. Continue with the next, and so on until all come out at an equal angle, are equally spaced, and are deep enough in the flutes to give good chip room.

In tempering a cherry do not allow it to become too hard above the spherical portion. Draw the shank to a very dark blue up to the ball, and it will be less likely to break. It is better to leave the sphere a dark straw if using carbon tool steel. If oil-tempered steel is being used, the cherry part can only be drawn to a light straw and the shank to a blue. It will be well to stamp the sizes of the cherries on the tool or in any conspicuous place on the shank, with the size in decimals of an inch, so that it will not be necessary to check it with the micrometers before using.

tool steel, is perhaps the best; all reamers are made from it. The length is governed by the requirements. The shorter they are, the better, for there will not be so much spring. The end on which the cherry is to be made is roughed out into a ball. The end which the center supports is roughed out with the lathe tool, leaving only enough metal to finish with the form cutter in the V and then turned back in proportion.

When forming the rough-filed sphere, the blank should be held firmly in the lathe chuck, and the lathe run at a slow speed. Set the compound rest so that the tool will be in a parallel line with the work and on the absolute center. Move the cross slide in against the work. Let it gradually scrape its way through the circular form and V-shaped opening in the side, receiving the stem to which the cherry is attached. You can also do this operation by hand by attaching the forming tool to a suitable

Bullet cherries are stoned after the temper is drawn to a sharp cutting edge; you will find that this operation demands patience, for it requires the use of a square or three-cornered oilstone. As the lands were left very narrow and 0.001 inch over-size, you will find that with care and patience you will have each flute stoned to a perfect cutting edge. The stoning of any reamer or cherry does not require much clearance; only enough so that the cutting edge will clear, which gives the tool a better support and does away with saw edges on the flutes causing the metal to pick up and produce a bad finish in the mould.

Bullet Cherry — If you will send to the Lyman Gun Sight Corporation for *The Ideal Hand-Book*, which costs fifty cents, you will find such a great number of different bullets that it will be almost impossible to construct a new one; still you may have your own invention of some particular type of bullet not listed, or you may wish to carry out some special experimental bullets to prove certain ideas. Then this chapter and subject will be of interest to you.

Figure 127 illustrates two bullet cherries, and if further experiments are to be made on any type of bullet, the principle is based upon the same construction except that you will change diameter, width, length of grease grooves, and ogive at the point. You may wish to make a one, two, three, or four caliber radius, or you may wish a certain design of point which has never been suggested before to prove some of your theories. You may also wish to experiment on the base, placing different angles and lengths, or giving it a boat-tail effect to reduce trajectories in flight; or you may cherish other ideas which have possibilities of working out some theory to your own satisfaction. There is too much work connected with making these reamers, so it will be much better to turn the bullets first from copper, making up ten on a lathe and then testing them on the range for accuracy. Consider the specific gravity of the two metals in the mould. You will use lead and tin, and for the sample bullets, copper; copper has a specific gravity of 8.9; lead, 11.37; tin, 7.29. Mix these to the same specific gravity as copper. Use a great deal more tin than lead, which hardens the bullets considerably. This problem will be worked out to your own satisfaction.

The first operation to be done before the cherry is turned is to make a templet of the bullet's nose. This is made from a piece of $\frac{1}{64}$ sheet steel. All lines and radii can be laid out and then filed to the sharp lines. It is only necessary to use one-half of the templet; this is much easier than to file the

complete form. In making such a gauge the point is made to the exact form wanted, guess work being eliminated. In using the gauge or templet, it is necessary to turn and finish the cherry to the correct diameter of the bullet you are about to make and then turn and file on the ogive so that when you lay the straight portion of the templet over the end it conforms to the exact radii. The finish of the reamer or cherry must be so that all tool and file marks are entirely removed before the grease grooves are turned out; these take up the next operation. It is now necessary to grind parting tools to the exact width that the grooves must be, and each is placed in its correct location along the diameter of the cherry. These must be to a given depth. When the parting tool begins to cut or shows that it is just touching the straight cylindrical part of the blank, set the dial on the cross feed to zero and feed it in until the desired depth is reached, by the graduations on the dial. Continue until all grease grooves are cut into the blank and all to the correct depth.

The question of boat-tailing a moulded bullet is a matter of experiment, as explained before, or a matter of preference. The next stage of the operation after the necessary lathe work is to mill the six flutes in the cherry. Indicate this to make sure that when you place it in the chuck on the dividing head it will not run over two or three thousandths of an inch. A 60-degree angle cutter is used for milling the flutes, and this must be set 0.010 inch ahead of center, which will eliminate chatter on the mould when reaming it out in the drill press. When the cherry has the flutes milled, file off the slight burrs thrown up by the milling-machine cutter, and wash it in clean gasoline to remove the oil. Use the coppering solution as given in Chapter XVI. When reamers are to be stoned or filed, always coat the surface of the flutes with this solution, for it will give you the true cutting edge, which may be readily seen as you are working either the stone or the file to the cutting edge of the flutes. Have a small bottle of this mixed for use in all such work and for laying-out work as well.

It is now necessary to file out the grease grooves on the cutting edges and at the same time relieve the sides of these grooves so that there will be well finished serrations in the mould. A finely cut needle file must be used for this operation. It is somewhat difficult to file these out, so some patience and care must be exercised in order to keep the cutting edges sharp and at the same time not give them too much clearance or place a radius in the corners at the bottom. After the grooves are all filed, the cutter is ready to be hardened. This is done by the usual hardening and tempering methods

previously described for the ball cherry. When these operations are completed, it is ready to be stoned on the outside cylindrical portion of the flutes. Polish the lands and coat them with the coppering solution and stone to a keen cutting edge; also stone the cutting edges in the flutes to remove all cutter marks. It is always well to run a fine needle file along this edge before hardening, to remove the rough edge, and when the stoning of this surface takes place, a much better finish will be secured. When stoning up to the cutting edge, do not allow the oilstone to remove too much material on the back end of the flute. Start to stone on the back and gradually work up to the cutting edge. The stoning of a reamer requires some practise to enable one to stone up to the cutting edge with freedom. This will come with practise and you will know the required amount of pressure to apply on a stone. At the same time work up to the edge of the flute with freedom, holding the exact size of any reamer made in this manner. Continue stoning each flute until it is perfect, down to the extreme end. With a fine stone ground so that it will go into the grease grooves, touch them up so that the cutting edges will be well polished, removing any file marks and also any scale left in the hardening operation.

Simple Form of Cherry — Any one who has used a standard twist drill knows how rapidly one of these will cut into metal. Suppose this form of cutting edge could be applied to a bullet cherry. It would not matter if the cherry were spherical or of a conical form. File two cutting edges like a drill on opposite sides of the blank from the shank to the end of the cherry. It is natural that the two rounded portions be left on each side of the cutting edges to be removed; then the tool is nothing more or less than a peculiar-shaped drill or reamer which may form an internal sphere. But this form could not be used or applied between the sides of the blank bullet moulds, as the full rounded sides permit this, form the cutting edges in a manner similar to that of the ones made at first, only not so large, making three or four on each side according to the size of the cherry. These cuts can easily be made with a fine-cut three-square file or half-round file, as previously described for the fine-fluted spherical cherry.

A tool of this kind can be made very quickly and will answer in a number of instances where a bullet is needed to try out for a certain muzzle-loading rifle or revolver. It may not produce the same results as the tools first described, but you may only want this cherry to enlarge some old bullet moulds which have been found and will answer

the purpose for the time until you are in a position to make the proper tools and moulds fitting for a rifle that would demand the best in this respect.

Bullet Moulds — Simple as it may seem, most mechanics have more or less trouble making the joints of two half-pieces of metal come together, forming a hinged joint, especially on bullet moulds. Examine those produced by a manufacturer who has all the necessary tools at his command, and often you will find the joints not well made. It may be due to the mechanic's not having the proper knowledge of how "to lay out." Such a joint may have been the excuse for an ill-fitted piece of work. However, it is an easy matter when instructions are followed.

Figure 129 illustrates the proper lay-out to make on the joints of a bullet mould. It will be observed that the line *A* is the surface line of the finished half of the male section where the two halves come together. This is *C* on the female half. The lines *B* and *D* are drawn at right angles to these, and in the intersection of these lines is the diametrical center of the round projection that is to form the joint.

At the point of intersection of these two lines, or where they cross each other, make an indentation with a sharp-pointed center punch. Then lay out the diameter of the joint on both halves. Drill a hole $\frac{1}{64}$ less than the finished size of reamer to be used when the joints are finished and both halves are to come together. After the holes are drilled a counterbore must be made to cut down the surfaces at *E* and *F* and at the same time to leave a sharp shoulder and face. Figure 127 gives an idea of how this counterbore is made. To make this tool, select a piece of steel, chuck it in the lathe, and turn the pilot to the size of hole drilled in the male half. Turn the body the required size of the joint to be made, and under-cut the pilot so that when the face is filed it will be possible to finish this below the size of the pilot. Turn the shank the required size to fit the milling-machine collet or drill-press chuck. When all the lathe work is completed, mill teeth on the end and file cutting clearance on the face of the flutes. Harden and temper as usual. Then stone the face of the flutes and the tool is ready for use.

If the counterbore is to be used in the drill press, cut down each half of the joint on the male section to about half its thickness. The outer circle or cut of the counterbore will be a guide to file to, or you can mill the circle of the joint. When stoning the face of the counterbore, if the face is made just a little convex it will form the surface of the joint a little concave, and a better fit will result.

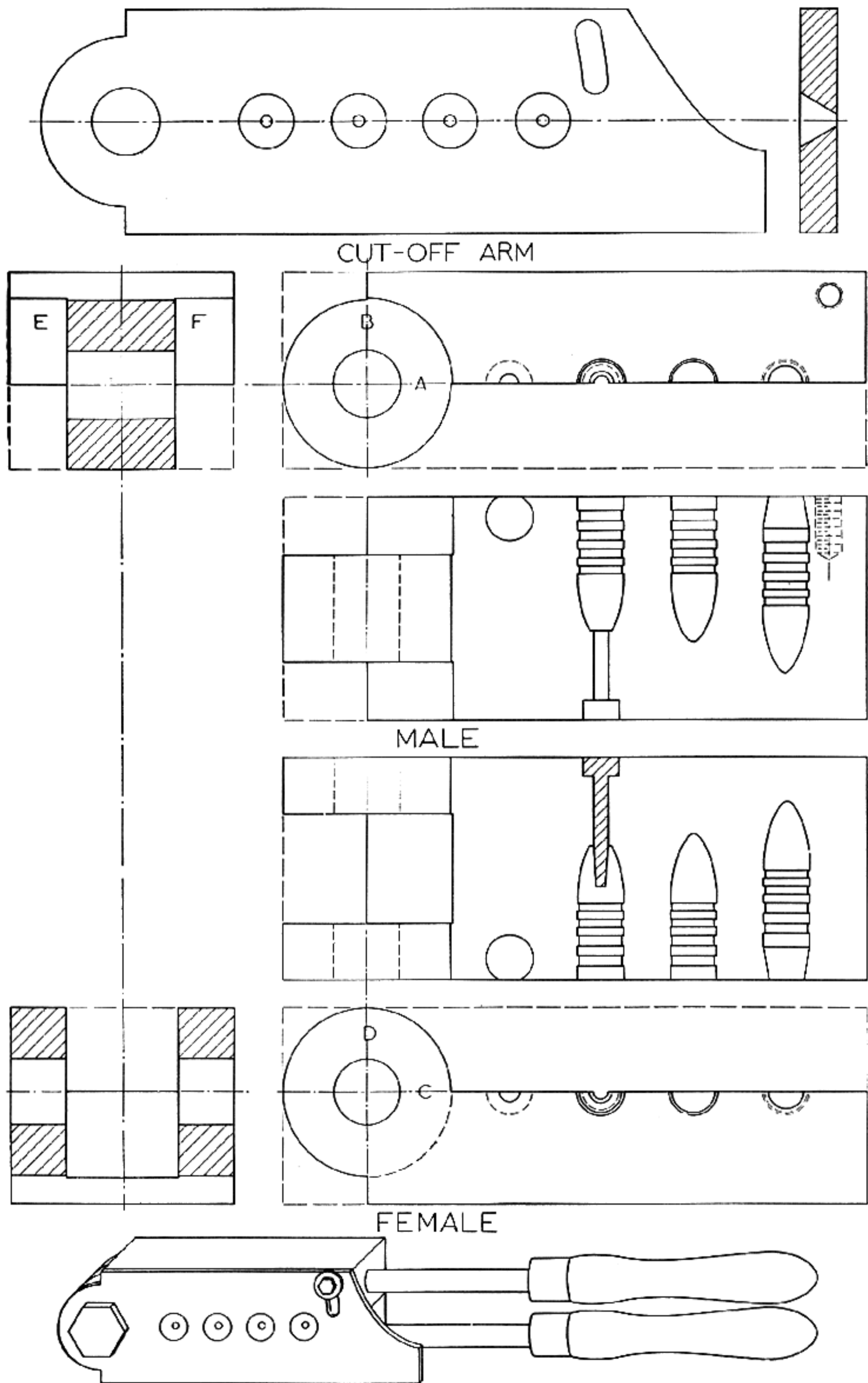


Fig. 129
Lead bullet mould

The female half must be milled out so that the male section will just enter the slot. It is much better to mill this first and counterbore the male part so that a perfect fit can be made. It is also well to mill out the circle as laid out on the female part before the slot is milled, so that a larger amount of the surplus metal is removed before the straddle mill is inserted, as it is difficult to get the inside radius to conform to the male joint. Use a larger straddle mill, which will clear the female joint.

When this is done, place the two halves together, ream the hole, and make a stud to fasten them together, allowing a shoulder for the top cut-off plate, so that when the nuts are pulled tight there will be just enough friction for mould and plate to have a free movement when opening and closing.

Brass is the best material to make a bullet mould from, as it is the easiest metal to work and looks well when finished. Of course, it may be made from cold-drawn steel, but brass is preferable.

The most practical method is to mill the joints on the moulds. The circle is milled by first placing a piece of steel in the milling-machine vise and drilling on one end the same size as the center hole was drilled in the mould. Fit a bolt in this to take one-half of the mould, and hold it friction-tight. By using a 2½ or 3-inch straddle mill a perfect circle can be produced. Fasten one-half of the mould on the holder in the vise and clamp the bolt just so it is possible to turn it. By feeding the mould up to the edge of the cutter the surface or shoulder is cut where the two portions of the joint come in contact when opening. By turning the mould around slowly, a portion of the circle is cut, say about one-half. Remove the mould from the bolt, reverse it, and the remainder of the circle can be cut; the whole "round" and the abutting surfaces are produced by two cuts, enough metal being allowed to smooth the joints with a file. Finish it so that a perfect circle can be seen.

After the stud is fitted you will find that the top and bottom surfaces of the mould do not come together. One is always higher than the other; thus it will be necessary to mill these two sections so that a true and even surface is had on the top and bottom. If the two closing surfaces, *A* and *C*, do not come together, place a light film of Prussian blue on one half. The blue is placed on the surface *A* and the impression left on *C* is removed with a fine file. The perfection of the joint can be ascertained by opening and closing the mould a few times, removing the high spots until the two surfaces show perfect contact and fit the top cut-off plate. This is made from a 1/8-inch Brown & Sharpe ground-gauge stock or from saw steel. You

may wish one, three, or even more bullets moulded at one time in these moulds. Establish a center line when this plate is against the edge of the friction stud. Establish this line between the two halves and lay out the proper distance apart where the reamed holes are to come. Drill a small hole on each one of the laid-out lines. With a No. 52 drill assemble the plate again to the mould and scribe each drilled hole into the body of the mould, which should come exactly between the two halves. With a fine center punch, place indentations between the two halves; and with a small combination center drill, establish these centers. First place a small paper clamp on the mould. If a round ball is to be moulded, select a drill the same diameter as the shank at the small part next to spherical termination, and drill to a depth within 1/8 inch of the bottom; this will leave sufficient metal for the cherry to clean out at the bottom.

When all parts are completed, the mould is ready to ream. A drill press is used for this operation. It will be well to give the spindle a thorough inspection to see that there is no lost motion or play between the bearings on the spindle or the arms which hold the spindle. Satisfactory adjustments must be made, not so tight that the machine cannot be turned over by hand, but there must be a free movement of the bolts without lost motion any place between the arm, spindle, and work.

The most satisfactory method to ream a mould is to hold it between the jaws of a drill-press vise and gradually tighten the vise until the mould is completely closed against the cutter. You use a ball cherry the depth of which should not be any more than .010 inch. Less is better, for then you have a ball without any flat when cast. After the cut-off plate shears the flash, a 1/8-inch opening at this point is sufficient. This diameter is not very large at the connection point of the spherical section, but the smaller the hole the truer the bullet is to a perfect sphere. Be very careful when feeding in the vise jaws not to allow this cutter to remove too much metal and catch and break the cherry. The drill press must be run at a slow speed and the feed must be clamped so there will be no lost motion one way or the other. In other words, it must be clamped solidly. The drill-press vise should not be clamped to the table, as this must be free, so that when you tighten on the screw both sides of the mould will be cut evenly. Stop the machine often and brush the chips free of the cutter. This is one point which must be watched very closely, for if this condition is allowed to exist, the cherry may be broken.

If you are using a regular bullet cherry with grease grooves, a much larger hole can be drilled

that will relieve a considerable amount of metal, and the cherry will not have so much work to perform. Care should be used in the manner described for spherical balls—slow feed on the closing of the vise, freeing the cherry of chips, etc. All this must be watched very closely. Also examine the cherry to see that metal is not clinging to the cutting edges. If so, it must be stoned until you have a highly polished surface in the interior of the reamed hole for a bullet with a conical form and grease grooves. You may find it necessary to enlarge the hole in the shearing plate more than $\frac{1}{8}$ inch, but keep this diameter and try a few test bullets before it is opened any larger.

You may wish to make a hollow-point bullet; if so, it is necessary to drill through the mould with a drill the size you wish to make the opening in the end of the bullet. Then use another drill to remove a large amount of the surplus metal so that the cherry will not have too much to do within $\frac{1}{8}$ inch of the required depth.

Figure 129 illustrates the method used to make a hollow-point bullet. The hole drilled is counter-bored to a standard size; then a pin is made long enough to place a hollow in the bullet at a depth which will be ample to give the desired effect. A taper is placed on the end so that the pin is easily removed from the bullet after casting, and a shoulder is turned on the opposite end to fit the counter-bored portion so that the correct depth can be obtained on every bullet. This must be faced off flush with the bottom of the mould. As each bullet is cast it will remain on one side or the other. All that is necessary is to give the pin a slight tap with a piece of wood and it will fall out together with the bullet. After the mould is closed, pick the pin up with a pair of pliers, insert it into the hole again, and you are ready for the casting of the next bullet.

The moulds must be provided with suitable handles. Thread pieces of cold-drawn steel of sufficient size according to the weight of the mould, and fit common wooden file handles to the ends. Of course, if you wish fancy handles, two can be turned out of ebony or some other attractive wood.

Material for Casting Bullets—Cast bullets consist chiefly of lead and tin, altho other metals are used. Lead-tin alloys are mixed to give a certain hardness, as lead alone is too soft. The Brinell test shows lead to have only 3.9 and tin 4.1. Add 10 per cent of tin to lead, and it raises the hardness of the alloy to 10.1. When you add more tin, this increase of hardness goes on until a certain point is reached, and then the alloy becomes softer. The hardest point is reached when 66 per cent of

tin is added to 34 per cent of lead, which shows a hardness of 16.7 on the Brinell hardness test. The addition of mercury tends to harden a bullet to a little higher degree and at the same time makes it come out of the mould clean and white. A very small percentage of phosphorus renders the bullet alloy very "lively"; that is, the alloy has a tendency to run more freely in the mould. Too much phosphorus is very injurious to a bullet. If any one wishes to use this when making up bullets, it should be in the form of phosphor-tin and then only 300 grains of a 5 per cent phosphor-tin to every 25 pounds of bullet alloy mixed is generally sufficient.

The cores of all commercial bullets are 10 per cent tin and 90 per cent lead, which gives very good results. As lead has the highest specific gravity and tin about four points lower, we increase the tin contents and lower the specific gravity of a bullet, which has more or less effect on accuracy. So to secure the best results a considerable amount of experimentation is required, not only on the alloy used but on the weight of bullet as well, until the correct combination is reached. In mixing an alloy it is best to mix 1 to 10 and first try this, which is 1 per cent of tin to 10 per cent of lead. For example, melt ten pounds of lead and one pound of tin. This gives a hardness of 10.1. If this does not prove satisfactory, add more tin, but keep a record of the amount added so that a check can be referred to when the best results are obtained.

Such work for the man who does his own loading will prove fascinating and a means of reducing his ammunition bills. Having acquired this experience, you may anticipate greater results from jacketed bullets and those using a higher velocity. Casting your own bullets from moulds made by yourself is valuable not only for the experience gained but also for its economy. Today when it is possible to purchase any mould from the manufacturer the majority of men will say that these standards cannot be improved upon. True, but that was how they perfected that standard, and there is still room for improvement. It is to the real rifleman that such information will be of benefit; anyone is capable of becoming one and producing something more accurate than can be bought.

Next in order would be the loading of ammunition, but I shall leave this to those who have gone farther than I. However, some valuable suggestions may be derived by those who have already made their barrels. From the chambering tools, straight-line loading dies can be constructed. These tools are the only satisfactory means of loading ammunition regardless of the number of reloading tools on the market today. The finishing reamer that was

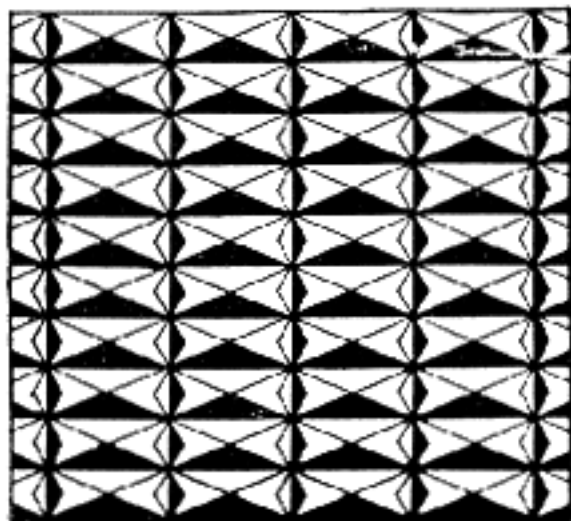
used in the chamber is now used on loading dies to be reamed to a depth which will allow the cartridge to come flush with the bottom.

A special reamer is necessary to ream the clearance for the bullet. After this is done, the die is

hardened according to the usual methods. A bullet seating punch is made to the proper length and also hardened. Then a satisfactory base is made which completes a loading die that is known to place a bullet in the case in perfect alinement.

CHAPTER XXIV

Restoration and Preservation of Antique Firearms



Restoration and Preservation of Antique Firearms

TO THE historian as well as to the antiquary and the sportsman the development of the gun must always be an intriguing subject. It is a truism that gunpowder changed the whole aspect not only of civilization but of society as well. When the defensive armor of the knight ceased to be proof against the weapon of his humblest assailant, it set the bounds of feudalism and inaugurated a new era in which "Jack could be as good as his master." In a book such as this it is not desirable or even possible to trace the development of the shoulder and hand gun except in a very cursory manner, and then only in so far as relates to the restoration and preservation of specimens of such old arms as may be part of one's family inheritance, or those acquired for private and public collections. There are some valuable collections of arms in our country, most notably perhaps the Nunnemaker collection in Milwaukee, which is under the charge of that delightful sportsman, Dr. Paul Jenkins. We mention this particularly because of the great willingness of Dr. Jenkins and his colleagues to identify unknown guns for amateur collectors and gun lovers generally. To our amateur, however, the intimate collection which he dreams of some day possessing holds out the greatest charm, and it is to him that this chapter is really dedicated.

In many a country attic stands an arm that would worthily form the nucleus for one's own collection. It may be grandad's old pioneer rifle, as long as he was tall, and intimately associated with the most stirring legends of the family; or uncle's old squirrel gun which performed so wonderfully when squirrels and forests were just around the corner. Aside from the family interest, these old guns rapidly passing into rust and nothingness have a deep interest all their own. They not only mark a stage in the development of firearms, but made as they generally were by a local mechanic, of the simplest materials and with the crudest of equipment, they stand as a monument to pioneer ingenuity and resourcefulness and are an incentive to all of us who love to express ourselves in our firearms.

Most of the older arms have suffered severely from time and neglect and at first glance may ap-

pear hopeless of restoration. This is not necessarily so. It is true that as active firearms their usefulness has entirely passed, but many can be restored in appearance to their former selves.

The reconditioning of old arms such as these, and putting them into working order—for this should always be done—requires considerable forethought

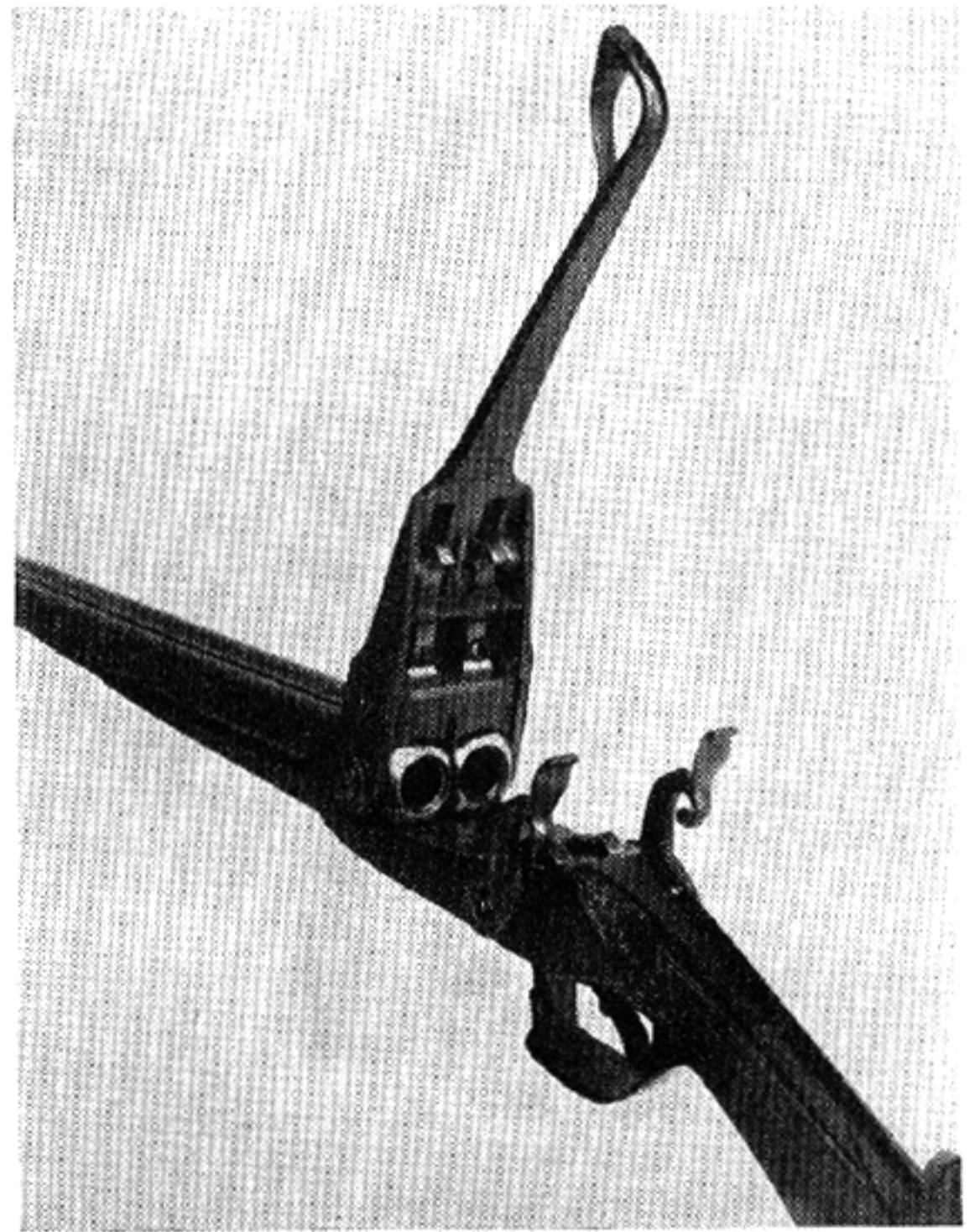


Fig. 130

The Pauly percussion breech-loading gun, made in the year of 1811. Napoleon had the arm tested in his presence: eleven shots per minute were fired by the inventor

and patience, especially when missing and broken parts must be made so that they do not conflict with the ideas of the old forest craftsman and so that they are quite free from any suggestion of newness.

Models running back no further than the Civil War—that period so fruitful of new developments in firearms—are usually restorable to actual use,

providing always that explosives and loads such as they were designed for are used exclusively and no "stepping up" ever attempted. If you shoot any of these old arms you will soon discover how much modern precision in manufacture has done to attain uniformity in shooting. The famous "Kildeer" was not sentiment. It was either the work of some noted craftsman jealously guarding his superior knowledge for his own products, or even more likely the happy accident that unperceived and unintended made some fiddles and some guns strikingly better. So don't be surprized if the discovery of a fine-shooting old gun is an event. Some of them did and do shoot, and grandad might have had such a one. Who knows?

The shoulder guns made or used in America go back to the very beginnings of each gun, for the Spaniards brought their arquebuses with them, and indeed our Puritan forefathers too. Very few of these remain, but an old Puritan arquebus was brought to me some years ago, for reconditioning preparatory to being placed in a museum. It was, strangely, in excellent condition, and when I had finished work on it, could have been put to its original use. It weighed eighteen pounds. With it came the staff upon which it was rested when discharged. This was shod with an iron point where it was thrust into the ground and the upper end fitted with a U-shaped notch in which to rest the barrel. The charge in this old arm was ignited by the end of a coil of smouldering rope which had been treated chemically to render it slow-burning. This was carried in a holder on the right side.

This gun, however, must have been of a very early date, for really the matchlock, which superseded it, was the arm we associate with the first

New England settlers. The matchlock introduced two features into the gun and new words into its nomenclature, the gun lock and the trigger. The gun lock was only the simplest mechanism for holding the slow match. In its earliest and simplest form it only consisted of a curved and pivoted lever, the one end holding the match, the other end passing through the stock and terminating in a trigger. When the trigger was pulled the lever moved about its axis and the burning end was thrust into the priming pan. This was a great improvement, for it released the right hand so that it might assist in the holding and give precision to the discharge.

The next step—the first real lock—was to actuate the fuse holder by a spring so that it jumped back automatically from the pan after ignition. Thus the gun lock was born.

The matchlock was superseded by the so-called "wheel-lock." In this the burning fuse was replaced by a mechanism to originate fire. It consisted of a wheel or disc of steel, serrated on its edge, and attached to the lock plate, so that its periphery was at the edge of the flash pan. It was given a rotating motion by means of a chain and spring similar to the old form of watch drum. This was wound up with a clock key. Standing opposite this disc was a hinged arm, holding in its extremity a piece of pyrites. When ready for firing the wheel was wound up, the lid of the flash pan thrust back, and the drum holding the pyrites brought down in contact with the wheel. When the trigger was pulled the pawl checking the wheel was released, and the revolving wheel brought a shower of sparks into the pan and ignited the charge.

The wheel-lock was superseded about 1650 by

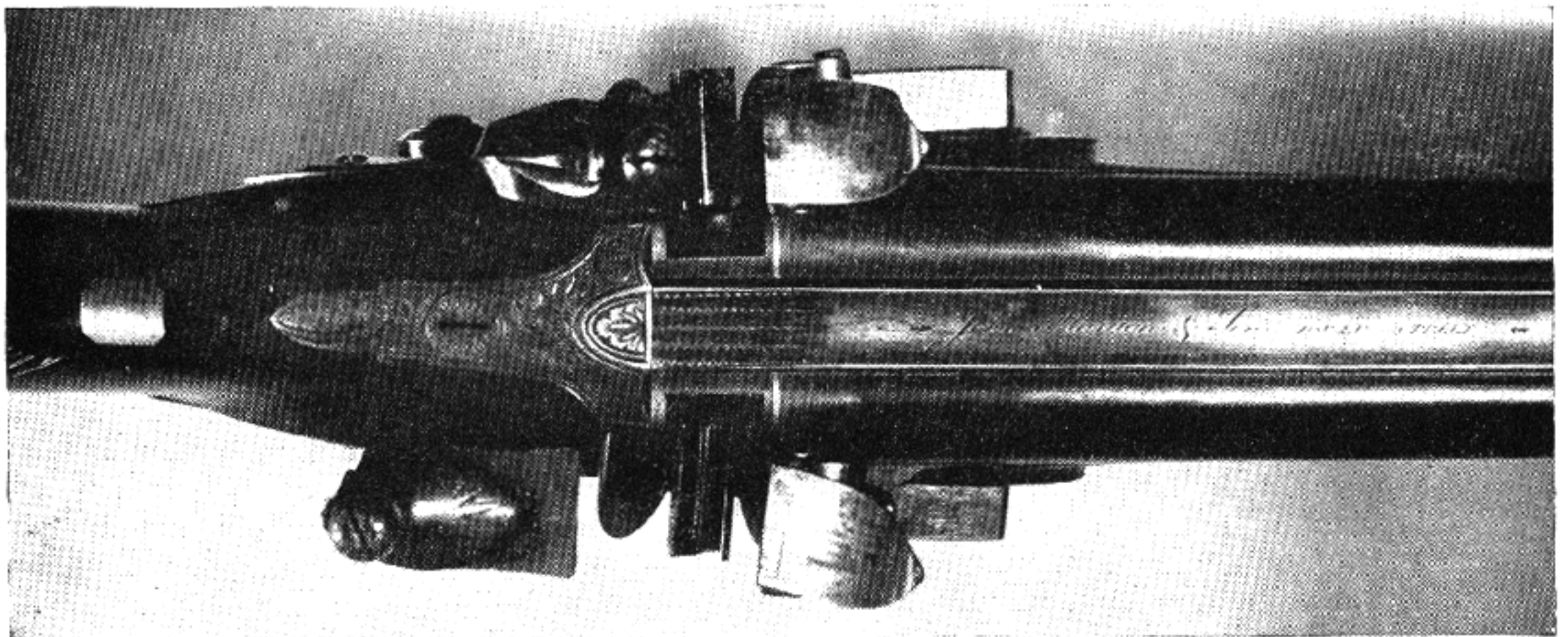


Fig. 131

Flint-lock double gun by Joseph Manton & Son. Note the frizzen connection and the manner in which the barrels are breeched

the flintlock; the great improvement was that the cock, holding a flint, in its falling uncovered the flash pan and thus accomplished two important things—it kept the priming from wind and weather until the moment of firing and automatically exposed it the moment the spark was produced on the frizzen. This arm persisted without marked improvement for two centuries. It is a matter of great interest, however, to know that there were hammerless flintlock guns, the mechanism being housed in the stock and actuated by spiral springs. Some were also breech-loading.

Starting with this gun, the most interesting period in firearms, especially in America, began; little work will come into our hands which antedates this period. We shall therefore confine our remarks and instructions to the flintlock and its successors, the percussion-lock guns and early breech-loaders. The first step in restoration is a critical examination. This is best made in a completely dismantled arm, so strip your gun down to its parts. A reading glass will help you to find

and a tang extending from the breech plug fastened to the stock by a screw running downward into trigger plate. In the later and better sporting arms a hook is formed on the end of the breech plug and this engages in a false breech. In this case only the fore-end fastening is removed and the barrel lifted and withdrawn from its rear fastening. Having taken off the barrel, remove it from the breech pin, nipple and nipple plug, and its sights. You are now in position to see the exact condition of the bore, to clean it and restore it. If the bore is not too badly corroded or the walls too thin it will be a comparatively easy matter to put this back in shape. You will proceed as follows:

Dip a bronze-bristle brush fastened to a steel cleaning rod in a powder solvent (given in Chapter XXV, Volume I) and pass the brush back and forth through the bore, keeping the bore well soaked with the solvent. When the brush is completely worn out, which action will not require a great amount of rubbing, place a small funnel in the breech end, and with the muzzle in a pan on the

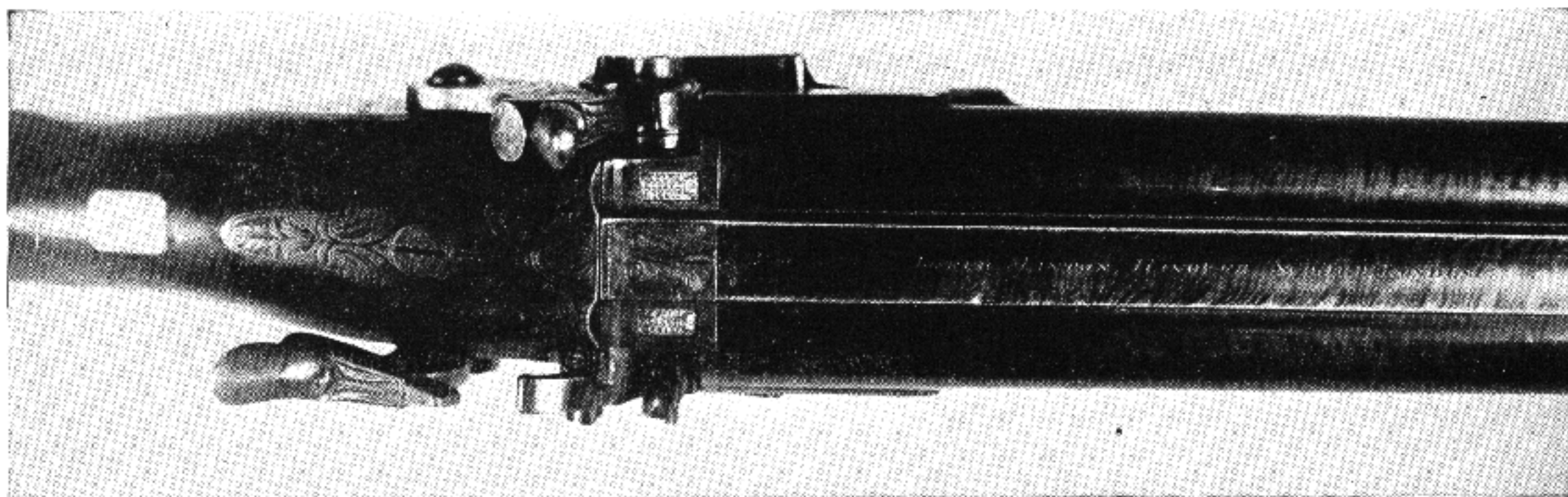


Fig. 132

Joseph Manton percussion-lock double gun. Note Manton's development of Forsyth's principle of ignition

distinguishing marks, if any, such as the maker's name, symbol, and dates, and it will enable you to make a close survey of the arm generally. Before stripping, it is always best to probe the barrel, for it is surprising how many times one will find a charge in the barrel of an old gun. Go quite easily and gently with your stripping and do not apply force irrationally. Rust and grease in time will combine and cause great adhesion, so you must use great care, especially in removing the metal parts from their seatings in the wood. Many of the old stocks are made of maple, and altho this is a strong wood when new, is not a durable one. It becomes "dotey" with age and breaks apart very readily.

You will readily identify the fastenings of guns. The barrel of most of the muzzle-loaders was secured to the stock by a wedge pin in the fore-end

floor, pour gasoline through to remove the rust which had been loosened with the brush. Clean out with one or two patches and inspect the bore to see the true condition. No doubt you will find it very badly pitted; the pits can only be removed by either broaching the bore or reaming and completely recutting the rifling. This will be treated later in the chapter.

When only desiring to clean the inside of the barrel to test, you can follow up the lapping by using the worn bronze-bristle brush with patch wound well into the wire. Soak this completely with #90 emery and oil and proceed to lap the barrel, using the steel cleaning rod. This lapping may continue for several hours, the patch kept well soaked with emery and oil. Every so often, wash the bore out with gasoline and inspect it, first wip-



Fig. 133

Flint-lock double gun made by Tow, of London. Note the graceful outlines of the hammer

ing it out with a clean patch. If you find this treatment has accomplished the desired results, no further lapping is necessary. If not, and you decide to lap the barrel with a lead lap, Chapter XVIII will give full details of this operation, which is the same for this muzzle-loader as it would be for a new barrel. After the bore is enlarged you may find it necessary to make a new bullet mould; Chapter XXIII will give the full details of how to make it.

Rifle Barrels — If it is a rifle you will decide at once whether its shooting days are over, or whether you intend to make further use of it. In the first instance you will only be interested in removing its dirt and rust so that it may be preserved against corrosive action in the future; in the second instance, that of future use, you will have to do more than that in most cases. Some of the old barrels—we allude in this chapter only to such as are really antiques—still have considerable mileage of their own sort, but the majority, being made of soft and poor iron, are pretty well shot out. This, we must remember, was an intermittent disease with all of them that saw much service. Every so often they would be carried back to their makers for a freshening up of the rifling and for fitting with a new mold to cast bullets to the new and larger diameter. The old gunsmiths, even with their home-made equipment, did this very easily and gave

a new lease of accurate life to these barrels. You may wish to experiment in this direction yourself, and if you are patient and persevering there is nothing in this process beyond your capabilities. I am going to describe this operation as it was done in the old days and with different methods. Later I shall further describe how a rifle barrel can be entirely re-rifled in several ways. Let me describe a home-made equipment that I saw some time ago.

The plank was 2 inches thick and 6 inches wide, and about twice as long as any barrel to be rifled. At one end of the narrow side were fixed two bearings, one at each end so as to turn an old rifle barrel freely. At the other end of the frame was fixed a circular plate of iron, like a wheel which was made with divisions on its circumference and had a catch fastened to the wood; when the end of this caught one of the divisions it would firmly hold the barrel in place. When this plate was turned the barrel also turned. Inside of this barrel was placed a rod of iron, around which was cast some soft metal, such as babbitt metal, old type-metal, or even lead. In the center of the rod a square was filed together with barbs on the squares. The rod was then put in the barrel and the soft metal was cast around this section. This was the rifling guide. A handle similar to a large auger handle was fixed transversely to one end, but in such a manner as to turn around freely on the rod. As the rod was pushed and pulled back and forth, the

soft metal followed the rifling grooves; this caused a turn first in one direction and then in another. Because of the rod being loose on the handle, the hands were held in the same position. Chapter XII will give full details of the modern holder for rifling rods.

The rifling head was attached to the opposite end of the rod and carried a cutter let into a narrow groove made in the extreme end and used as a rifling head. It is evident that if a barrel is placed in the clamps which held the new barrel, and the rifling head, bearing a suitable cutter, is entered into the bore of the new barrel and the rod thrust forward by pushing it with the handle, a faint spiral cut will be the result. When the

the cutter put in place and a repetition of the same operation gone over again and then repeated until the rifling was of the desired depth. Oil was supplied to the cutter while going back and forth in its work.

One method of re-boring and rifling is to make broaches as Figure 84 shows; also a rifling head as shown in Figure 134. Of course, these require machinery to make, but when completed, a perfect bore is produced. The broaches are driven through the bore and made so they will remove about 0.0005 of metal. Then the lapping rod is inserted and drawn back and forth until a perfect bore is the result. When using these tools, supply oil freely.

The simple way to re-rifle after the bore is com-

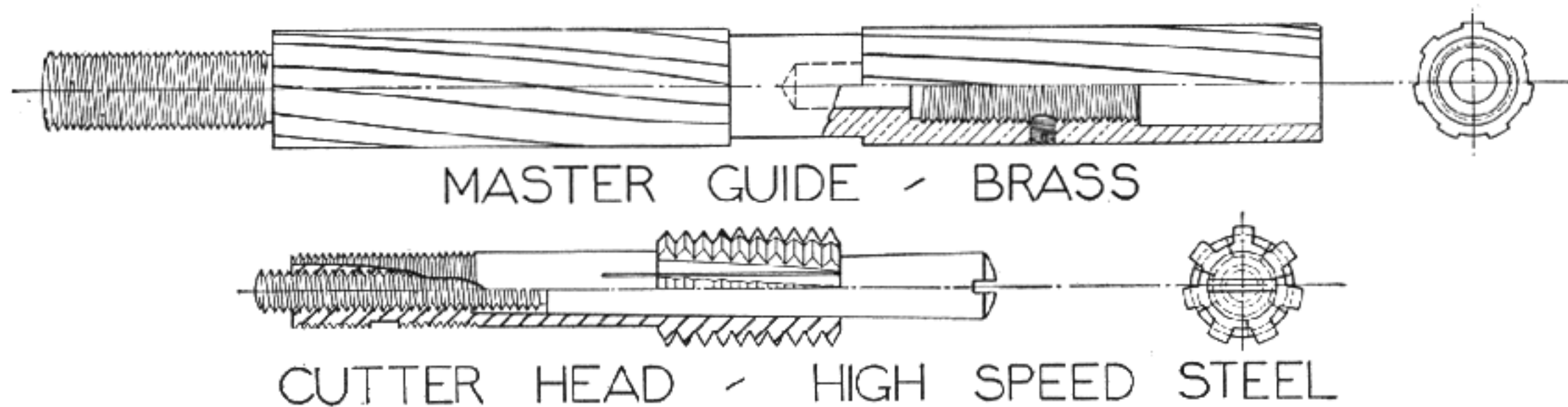


Fig. 134

Rifling-head design for making muzzle-loading barrels

cutter had done its work, or cut all that it would, the plate was turned one division, rotating the old barrel with the rifling head just that amount on the barrel to be rifled. Of course, it being turned, another cutting was done like the first one, then another, until a full revolution was made with the plate; and so on, until the complete circle of the divisions had been made and a certain number of faint riflings were made in the fixed barrel. The cutter was then removed from its slot, a slip of writing paper placed in the bottom of the slot, and

pleted is to make a rod with an elongated slot about $\frac{3}{4}$ inch long in one end to receive a rifling cutter or "saw" (this is the term used for such tools), and to fix at the other end of the rod a handle like an auger handle, but so fixed that the rod will turn freely no matter how the handle may be held. This rod is inserted in the barrel to be re-rifled and the cutter forced into one of the grooves. The end of the rod should be filed square and barbs placed on the ends of the square. Then soft lead is poured around the cutter and the rod is driven in. When the cut-

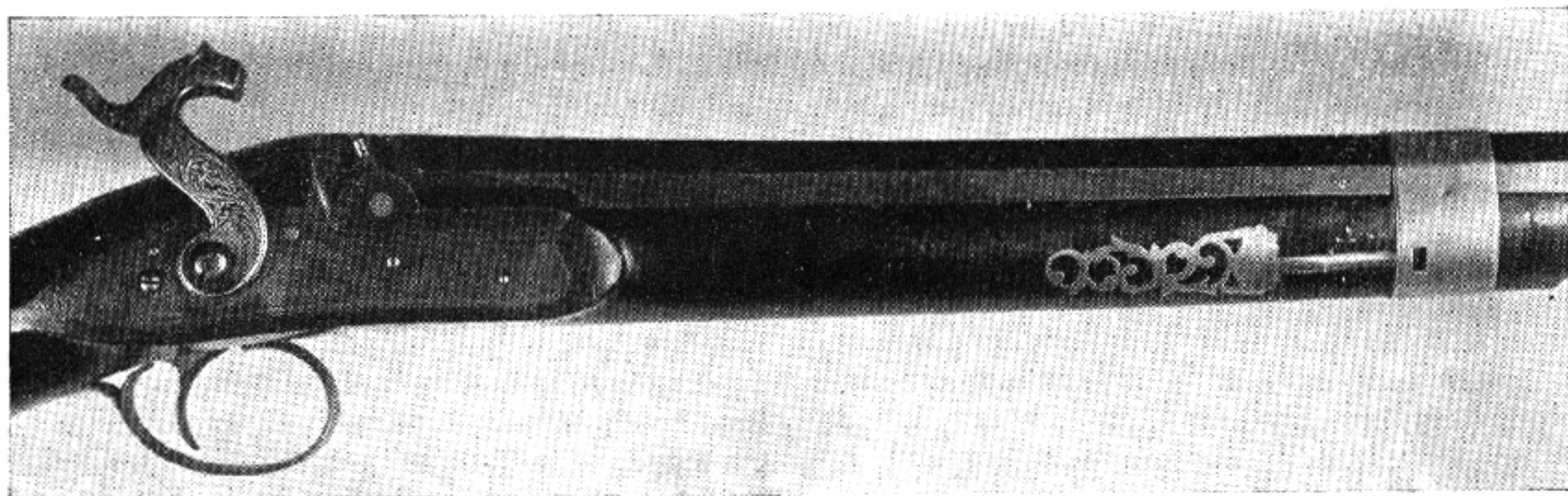


Fig. 135

An early-period percussion-lock rifle. Note the manner in which the nipples are set in the breech



Fig. 136

Side-hammer double gun made by A. Wurffelin. Percussion locks. Note the flush outlines when the hammers are in the fired position

ter is inserted in one of the rifling cuts, it must be deep enough so that the lead will form in the opposite riflings and be free for the cutter to work. This operation is performed from the breech end, but the lead is cast on the rod from the muzzle end. The groove must be marked where the saw first enters. Push the rod free, remove the cutter from the slot, and work the rod through the barrel freely. Now place the saw in position and pull this through. When pushed forward and pulled backward until it will not cut any more, it is placed in another rifled groove and so continued until the circuit of the rifling is made. A slip of paper is then placed under the cutter and a repetition of the process made and continued until the rifles are cut as deeply as desired.

When barrels are so worn that the rifling has not depth enough to hold the tool described for re-rifling, another method must be resorted to. Make a rod of hard wood about 6 or 7 inches long, so as to slide easily through the barrel, and in one end of this fix the cutter. Around the other end cast lead so as to fill the grooves. It is evident that if this short rod is forced through the barrel instead of a longer one, it must turn with the rifling, being forced to do so by the soft metal engaging the several grooves. The operation of working is the same as previously described.

Modern Method of Rifling a Muzzle-loader —

The method which will be used is to drive a short piece of lead, the size of the groove diameter and

about 1 inch long, through the barrel. Then chuck this in the collet of the bench lathe and drill a $\frac{3}{16}$ -inch hole through the center. Take a piece of $\frac{19}{64}$ -inch cold-drawn steel rod 4 feet in length; turn the end to $\frac{3}{16}$ -inch diameter, $1\frac{5}{16}$ inch long, or just so the lead plug will press on. Also thread the end with a 10 x 32 die. Tap a short piece of the $\frac{19}{64}$ -inch rod for a nut, filing two flat sides so it is possible to tighten the lead plug on the rod. The $\frac{19}{64}$ rod must have a straight line marked the full length—this can be done in a lathe by setting a sharp V-tool in the tool holder and drawing the carriage back. Start the rod through the barrel and mark the muzzle where the straight line begins. The length of the barrel is $36\frac{3}{4}$ inches; in that length the straight line will make just a little less than $\frac{3}{4}$ inch of a turn, and as it comes out the breech end, requires the full turn of the rod. There would be 12 inches more of the barrel needed, so the twist must be between 49 and 51 inches. The next stage is to drill and ream a $\frac{3}{16}$ -inch hole into six 2-inch-long brass plugs, for you will need that number to start with. Turn these on an arbor 0.003 inch under the groove diameter. The width of the land is 0.087; this is the proper width of slitting saw to use on the milling machine. All the operations are now done on a Universal milling machine. Procure an American Machinist Handbook, turn to the section on spiral milling to find the proper gears to use to cut a spiral, which will be one turn in 50 inches, and drive this through the barrel. Upon examination you will find the edges of lands turned

too much. Gear up for 52 inches, and if you find that this is too much, give another trial between 50 and 51 inches. A number of trials are made until a plug will go through freely; this determines the proper twist of rifling. In one particular rifle the twist of the rifling was one turn in 50.26 inches. The next operation is to ream the bore, measure the muzzle to determine the proper size of finishing reamer to make, and allow enough to secure a finished bore to the muzzle. Nearly all these muzzle-loading rifles are very badly worn at the muzzle due in most cases to using a steel ramrod; this was the chief reason why they proved so inaccurate as they became older.

The reamers are made spiral, for only the tops of the lands are cut. If there were just a straight hole without any lands, a straight fluted reamer could be used, but when rifling, there are obstructions which the straight fluted reamers would catch, producing a very poor hole. A spiral reamer rids the rifling entirely of chatter and tear on the lands. Chapter IX illustrates the correct method by which to make the reamers used on this rifle barrel. It will be necessary to make three reamers to obtain the proper results: No. 1 roughing, No. 2 roughing, and No. 3 finishing. To secure the finishing

tube as the reamer is in operation.

The next step is to turn a brass barrel plug to fit the bore with a center in the end. A hard maple piece 2 inches long is fitted to the hexagon end of the barrel. Glue this on the barrel, allowing $\frac{1}{4}$ inch of barrel to show, and let the glue harden. Now chuck the barrel in the lathe, inserting the brass barrel plug, and turn the maple piece to a diameter which will clear the inside of the steady rest so the jaws can be adjusted, as these barrels are rather long for the average lathe. The breech end can be set into the hollow spindle a considerable distance away, so that it is possible to have the travel of the carriage at least 12 inches. The barrel is now ready for reaming.

Make a V-block upper and lower to hold the oil tube in the tool-post holder in the exact center. Remove the tail stock and insert No. 1 reamer from the breech end, clamping well between the V-blocks in the tool post and connecting the oil tube. You are now ready to begin the operation. As the reamers are pulled through the bore, use a fine feed on the lathe and let the carriage feed back about 12 inches. Loosen the oil tube, move the carriage ahead again to the muzzle, and tighten continually to make these changes until the full length of the

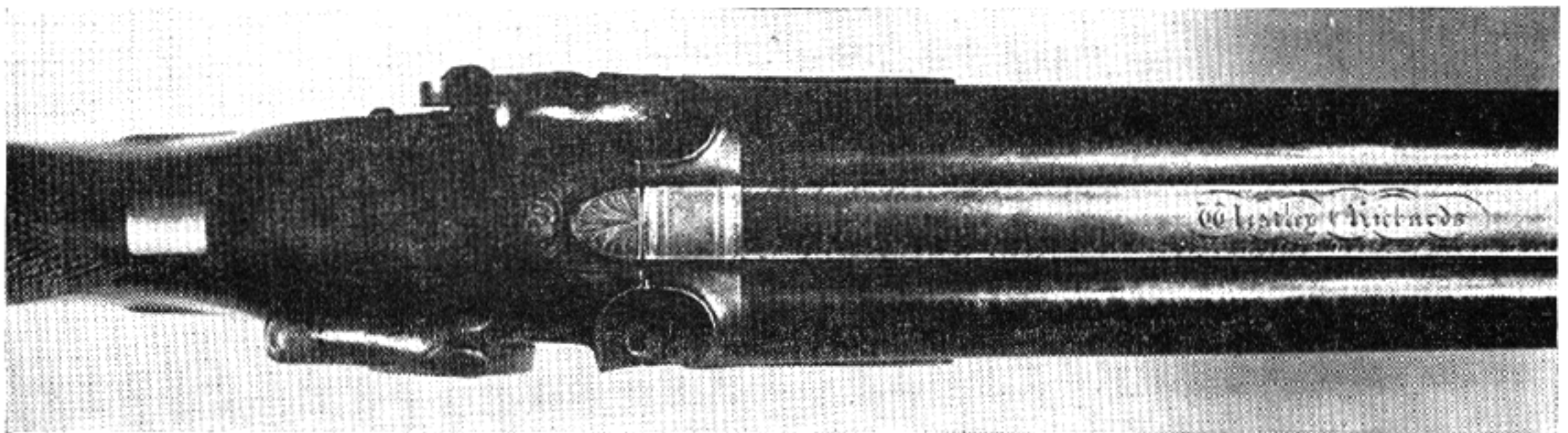


Fig. 137

A fine example of a Westley Richards percussion-lock double gun. Note the graceful cut-outs where the nipples screw into the breech

size of reamer, turn a brass plug which will just enter the bore about $\frac{1}{16}$ inch and allow 0.003 over this size to make the reamer. The reamers are made with pilots on both ends. As these are pulled through the bore the pilot which enters the rifling must be 0.0005 under the cutting size of the reamer. No. 1 reamer can be made to ream out between 0.006 and 0.008, and No. 2 to leave only 0.002 for the finishing reamer to remove; this gives a very highly finished bore. After the reamers are completed they must be soldered to the end of a piece of tubing and oil forced through to the reamer. On the end of the tube, connect a small rubber hose and use a tire pump to force lard oil through the

barrel is reamed. As the tire pump is connected, force a small amount of lard oil into the reamer over 1 inch of travel to the carriage as it feeds back. Having completed reaming with No. 1 reamer, continue with No. 2 and then No. 3, the finishing reamer, which will give a finely finished bore providing the reamers have been stoned to a very keen cutting edge.

After the barrel is reamed the grooves are re-rifled. Figure 134 shows the correct outlines for the rifling cutter. Since the milling machine is still set up, the brass master can be made as well as the rifling cutter. These are then fastened to a $\frac{19}{64}$ -inch piece of cold-drawn steel with wooden handles

and ball bearing for freedom of action when pulling the cutters through the barrel. Figure 85 shows the lapping rod and gives the correct dimensions. This operation is done by hand and is the finest exercise to develop chest and shoulder muscles I know of. Two methods may be used; either leave the barrel in the lathe with the steady rest, or fasten it to a solid upright beam or support in such a position that it is convenient to work your arms free to pull the cutter head through the barrel. You can fasten the barrel to the beam by two straps and four lag screws. When the rifling head is working through the barrel a considerable amount of fine chips will accumulate. These must always be cleaned out each time the head is pulled through, always using the same groove, and marking the barrel and rifling head. Have a pan of lard oil at hand and dip the head in it each time. Also pull an oil-soaked patch through before entering the head so that the barrel will be well lubricated.

The adjustment of the tapered end plug requires but very little to have the cutters take a good clean scraping cut. If it so happens that you cannot go deep enough with the present adjustment of the end plug, make a new one, just a little larger on the taper than the first. You will find that when the cutters are made properly the rifling will come out clean and distinct.

Now make up the lapping rod from $1\frac{9}{64}$ -inch cold-drawn steel and fasten to the handles. First, thoroughly clean the bore. The process on the

barrel will take about an hour. The barrel is lapped from the breech end so that the lapping rod is run through the barrel to the muzzle, allowing it to set below the muzzle about $\frac{1}{4}$ inch when pouring the lead. Run the rod through from the breech end and wind string in the cannelures. This may be done before the rod is inserted in the barrel. The cotton string is only to prevent the melted lead from running down the barrel. Now heat the end of the barrel slightly, so the lead will give a full and perfect lap, the same as when a mould is at the proper temperature. Have the lead hot and pour into the muzzle. It is now ready for lapping. Use flour emery mixed with paraffin oil. The barrel is lapped until highly polished and then finished with 320M optical emery and rouge to secure the highest finish. (See Chapter XVIII.) You will be more than proud of your efforts and will be anxious to give the weapon a trial on the range to see if the stories you have read of these muzzle-loaders are true.

Locks — Gun locks contain all the mechanism there is in a gun, and so, necessarily, they contain most of the complication. However, when the function of each part is closely observed and its relation to its neighbor understood, the gun lock becomes, especially in the old arms, a very simple mechanism. In reconditioning an old gun it is always advisable to take down the locks, clean and polish each part separately, and in reassembling,

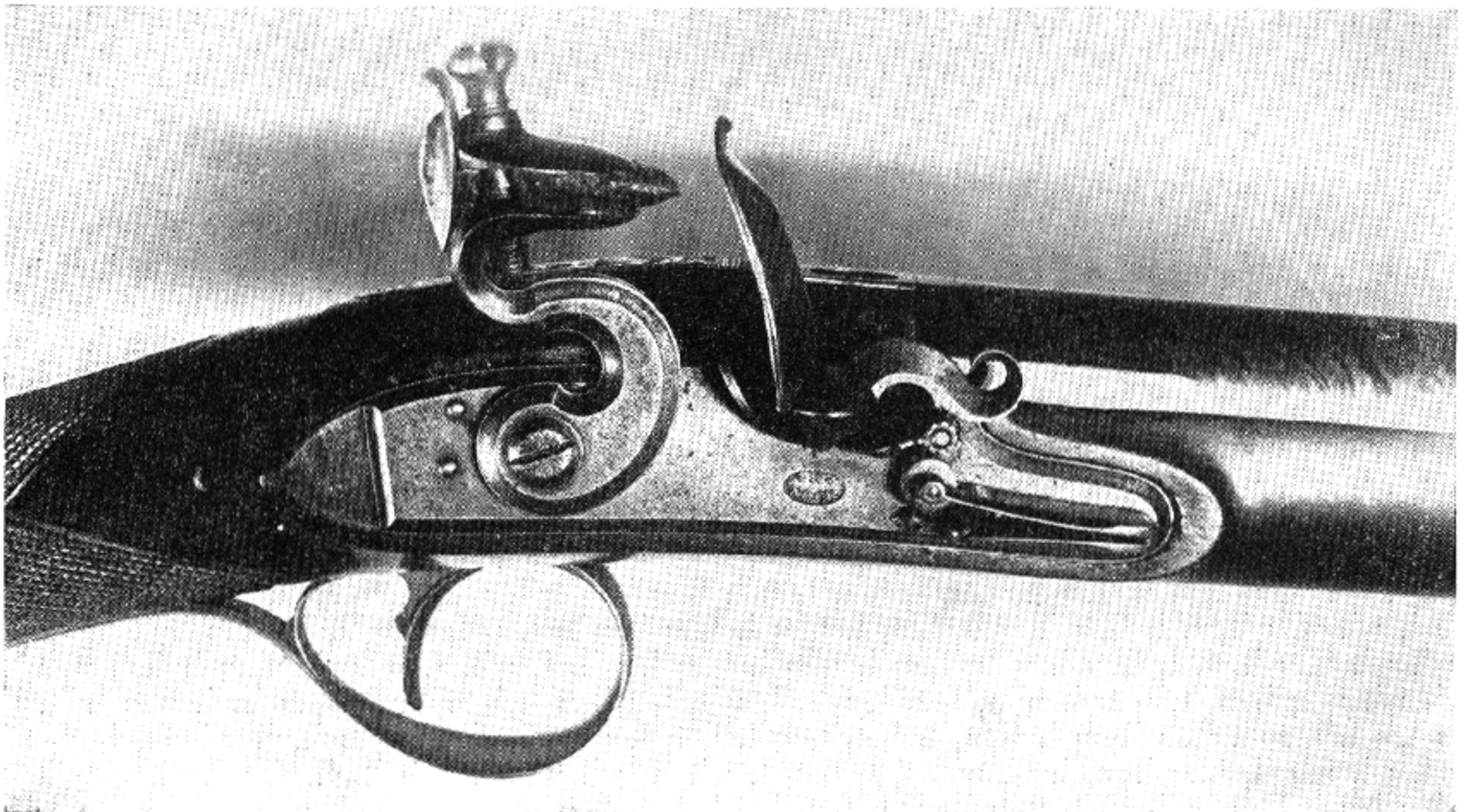


Fig. 138
Flint-lock gun made by H. Nock. Note the outlines of the frizzen

make any adjustment or repair necessary. To take a lock apart it will be necessary first to compress the main spring beyond its normal compression and to hold it in compression while removing it. This is best done, if you do not have the gunmaker's special tool, with a small hand vise. If it is a highly polished spring you will pad your vise jaws with some thin leather; screw up the vise until the hammer is released from the spring's action, then press down the sear spring and let down the hammer. The main spring is now quite loose and you will lift it out still held in the vise. Remember just

Furniture — This term comprises the rest of the pieces that make up the gun: the trigger and trigger guard, patch box, butt plate, fore-end tip, etc. These you have removed and they also are ready for cleaning and reconditioning. These with the barrel and locks comprise all the metal work of the gun; we shall now describe the manner of cleaning and restoring them. First, get rid of the grease and then the rust. To degrease, it will be best to use a metal tank, and if you are equipped with a bluing outfit, use your pickling tank for this purpose. Make a strong solution of lye or caustic

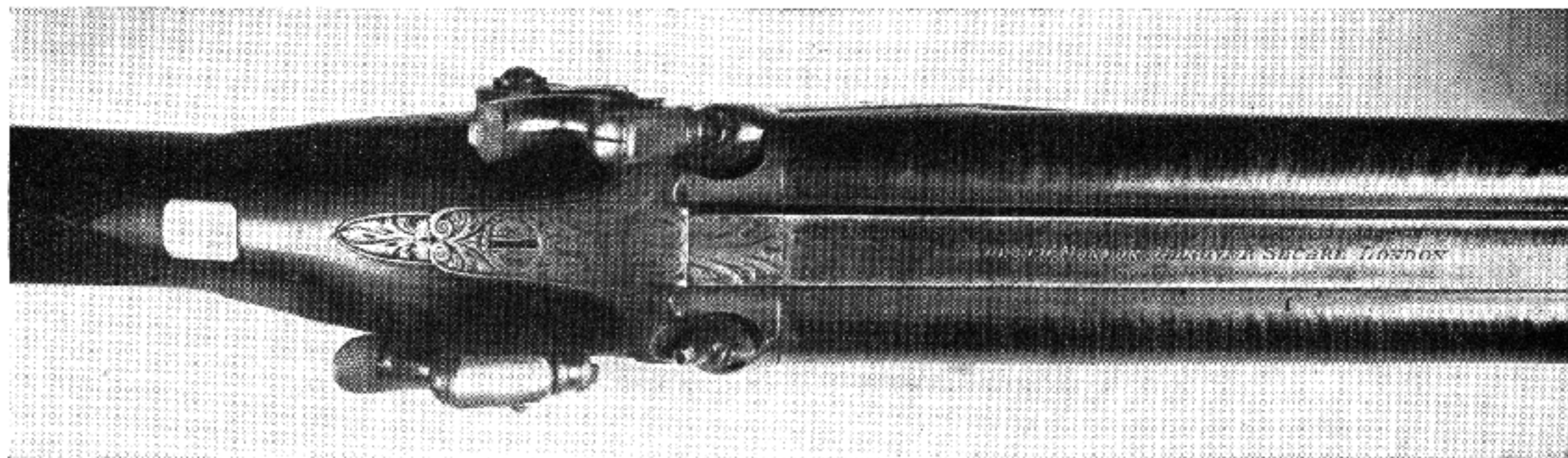


Fig. 139

Early example of Joseph Manton's percussion-lock double gun

how you grasped it in your vise, and where, so that when you assemble you will know just what to do. The rest of the stripping is easy. It is well to have an empty receptacle handy such as a glass jar to place and hold your lock parts, and if you have any fear of "getting things mixed" you may make a rough diagram of the locks before dismounting and place this with the parts before the time of assembling. In this, as in every part of gun work, be sure to use suitable screw-drivers with untapered square points so that your screw slots are not marred. Nothing looks so bad on a gun as chewed-up screws.

In fitting a new outside hammer to a lock you will find that the greatest care is necessary if you are to retain tightness and precision. The usual practise is to drill a hole nearly the diameter of the square of the tumbler axis and file out this hole until it fits the square. Unless you are expert with the file it will be best to file up a square broach, and as you file, drive this into the hole. This will check up on your filing and keep the hole square and straight. Again I repeat, go slowly and carefully in this fitting or a loose hammer will soon result. If you have a loose hammer, your only recourse will be to peen up the metal around the hole with a punch so as to force metal to the hole and then refit again.

soda and boil your parts therein until all grease is removed. To remove the rust, empty your tank, and having made up a solution of binocalate of potassium, put 2 inches of water in the tank, bring it to a boil, and then add the binocalate crystals. The amount of the crystals required will be determined by the condition of the rust. Add a small amount at first, and then more if needed, frequently removing the work and noting its action. This method will answer well unless the arm is very badly rusted; in such case it may be better to boil the parts in a solution of two parts sulfuric acid to eight parts of water, adding more acid if necessary to bring the steel out white. After removing the rust, boil the parts in hot water to kill further action of the acid. As this cleansing will simplify all your subsequent work it is well to do it thoroughly and painstakingly.

The next step is to polish all metal parts. You will do this, if you have power, on a buffing wheel with fine emery paste. If you do not have power, fine emery and crocus paper will do the work; but, of course, they will require more time. Finish all the parts, even those which will be concealed from view, for the cleaning and polishing will halt corrosion and will restore the sweet working that is such a charm in a gun lock. The barrel will probably have to be "struck" or filed longitudinally or

draw-filed in order to get a smooth unblemished surface and then highly polished preparatory to its bluing or browning.

Missing and broken parts must now be made or repaired. There is no part, I think, to be made that is beyond your ability. The steel parts are small and a little forging and more careful filing will produce them. The brass parts, if missing or irreparable, are easily cast, as brass melts at a low temperature and is easily manipulated. Make up a suitable "flask" or wooden frame to hold the sand, constructing it, of course, in two parts so that the pattern can be removed from the moulding sand. You can often patch up the old part with plastic wood or some similar substance to use as a pattern, but if the piece is lost you will have to make a wooden pattern to use in your mould. The more accurate you make this the less subsequent filing will be required. Remember that metal shrinks in cooling, so your patterns must be slightly oversize. Remember also that a slight angle must be given

steel or iron thoroughly, being careful not to touch its finished surface with the hands. Plunge it into molten brass, heated in a crucible. Remove it immediately and let it air-cool. This surface can be polished and burnished and antiqued also if desired.

Now that your metal parts are made and polished, refer to Chapter XVI for the bluing and browning of steel and the antiquing of brass by getting an artificial "patina," as the green oxid is called, upon it. After this is done it will be necessary to varnish or lacquer the exposed metal parts in order to preserve the color and finish. A good varnish for this purpose is made as follows:

2 oz. shellac
4 oz. dragon's blood
960 cc. pure grain alcohol

Dissolve the shellac in the alcohol and add the dragon's blood. Apply evenly with a very soft brush without heat.

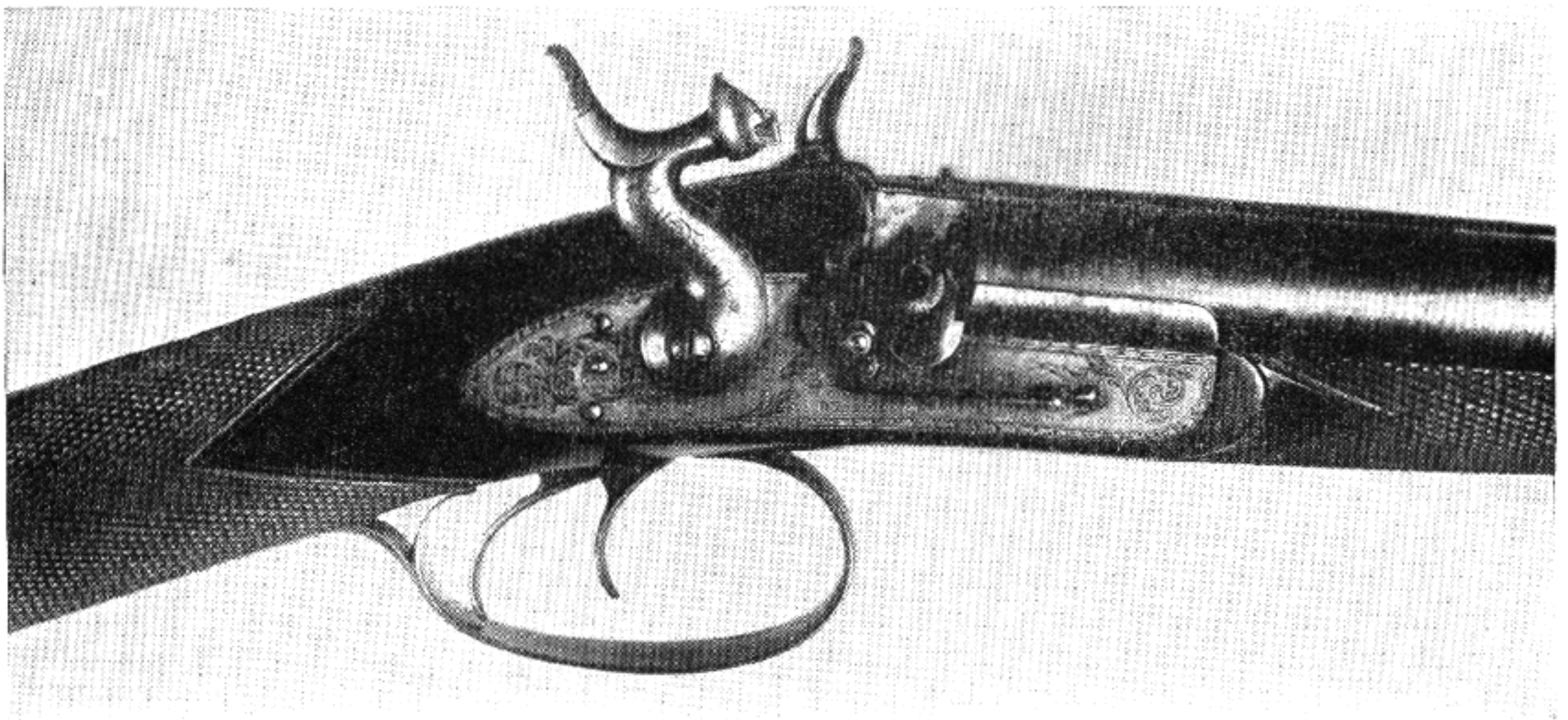


Fig. 140
An early example of William Moore's percussion-lock double gun

to your pattern in all its sides, so that it may be lifted from the sand without disturbance. Vent your mould near the top by inserting a wire when moulding and afterwards withdrawing it; and arrange, whenever possible, to have your opening for pouring so placed that the bottom of the mould will fill first. This prevents air bubbles from forming in the casting. Do not heat your metal beyond the point at which it first flows freely.

Often a piece of steel may be substituted for a brass part and afterwards brassed. The brassing is accomplished as follows: Clean and polish the

When the barrel and all the furniture are finished, the lock-plate, hammer, bridle, screws, sear, and breech plug will be given the cyanid-bath treatment as given in Chapter XVI. When this is completed they will be given a coat of the same varnish.

If an antique appearance is desired on old barrels, it may be secured in this way: After browning, boil in a logwood solution for one-half hour. One-fourth pound of logwood in a bluing tank of water will be about the right strength. The depth of the color may be raised by polishing on a fine wire wheel. Then varnish.

Ramrod Pipes — When ramrod “pipes” or thimbles are to be made it is a very simple operation. These pipes may be made of iron, brass, or silver, but ordinary sheet-iron is generally used. The best thickness is 20 to 22 U. S. sheet-metal gauge. This can be cut into strips and rolled over a steel rod of suitable size, using a wooden mallet to strike them as they are revolved and held in the vise. The upper pipe should be 2 inches in length, the middle pipe $1\frac{1}{2}$ to $1\frac{3}{4}$ inches, and the lower one about 1 inch. For permanence as well as appearance a long pipe is preferable.

To attach pipes to the barrel, the contact points of both the pipe and rib or barrel must be filed smooth and clean. It is then well to test them by inserting the rod and pushing it into place. Mark the place on the rib or barrel where the thimbles are to be fastened, and remove both thimbles and rod from the gun. If they are to be attached to a rib, file a spot the length of the thimbles where it is to go and file it of a depth equal to the thickness of the metal of which the pipe is made. Do not file too deep or you may cut through the rib so that the rod will bind or rub as it is being pushed down in place. Have the joint of the pipe come in the center of the rib as it is soldered in place. Tin the seats on the barrel and the pipe carefully over a Bunsen burner or the charcoal forge fire, and for a flux use No-ko-rode soldering salts. A tinner’s soldering copper is best to apply the solder.

When the barrel is cool enough to handle, put the thimbles on the rod and the rod in place as it is intended to be when finished. Confine the thimbles to the barrels with pieces of binding wire, using two pieces to a thimble, one at each end. By putting the rod in the thimbles and confining them thus, there is danger of their being twisted after being fastened; by putting on two wires there is less danger of their moving while being soldered to the rib or barrel. Remove the rod and hold the barrel and thimble over the fire until the applied

solder melts on both the barrel and thimble. When all are soldered, let the barrel cool, remove the binding wires, and wash with warm water to remove any further action of the soldering salts. Scrape off the superfluous solder, rub the barrel and thimbles bright with emery cloth, and finish with the browning operation. Those who may wish a fancy thimble, will find one illustrated in Figure 141.

Oftentimes ribs are missing on muzzle-loading rifles, or are loose. Upper and lower ribs on shot-guns also may have broken away and must be soldered in place again. To re-solder these parts see Chapter XXV, which gives full information on the subject. We use the same methods today as were used on these arms years ago.

Fore-end Tips — A great number of muzzle-loading rifles with short fore-ends have the fore-end tips either lost or broken, and it is necessary to replace them. They are generally cast right on to the fore-ends to get a perfect fit. After removing the old tip, dress off the wood smoothly and insert the barrel in place. Then put a short piece of wood in the rod groove, the size and shape of the ramrod. Let this piece project 4 or 5 inches, for it serves a double purpose; it prevents the metal from flowing into the hole, and at the same time makes the hole to receive the ramrod. Now, wind thick paper around it—smooth white bond paper is best. Also cover the stock and barrel adjacent to the tip with heavy paper and tie it firmly and closely to protect them against the hot metal. See that the space between the paper and the wood is left large enough so that the metal can be dressed down a little. Cut little notches in the wood to key the metal to it more firmly. Fix the gun in an upright position so that the metal will flow evenly. Always heat more than is actually needed for the tip, so that any dross will float to the top and can be sawed off. File and polish to the finished form.

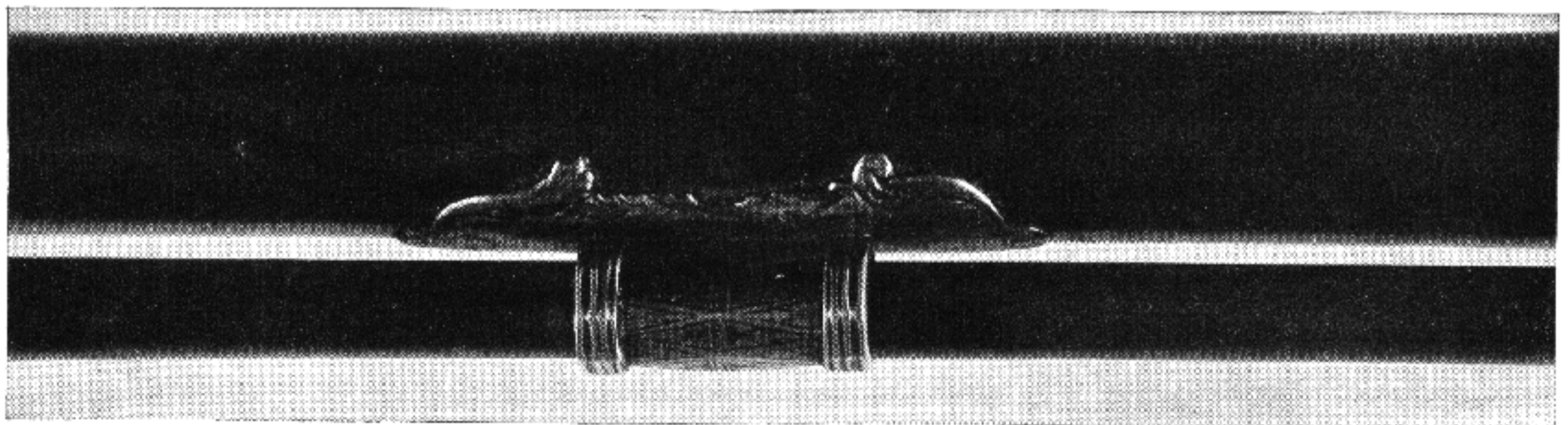


Fig. 141

The silversmith’s art applied to the ramrod thimble of a better-grade muzzle-loading rifle. Made one hundred years ago

The best metal to use for tips is block tin, as it remains white when polished. If you wish the tip harder, add a little antimony.

Nipples — Nipples often are broken or missing, and these have to be taken into consideration in order to make a percussion arm complete. There are a great variety of nipples; they are still made in England. Their forms vary, and there are as many as there are qualities. They may be divided into the musket nipple, the sporting-gun and rifle nipple, and German. The German nipples have coarser threads than the American. The English musket nipple has eighteen threads per inch, also a flat top and a tapered hole, larger at the bottom than at the top. The American musket tube has a screw of 24 threads per inch and has a vent resembling two inverted cones, meeting in a small opening near the center. The top of the nipple consequently resembles a narrow circular ring. Of nipples used in sporting arms of the percussion period, there may be found the broad top, the countersunk top, the taper-bored, the countersunk taper, the reversed taper, the double reverse, etc. All kinds are generally put up with the screw portion made in various sizes. The threads also vary, being as coarse as 18 per inch and as fine as 40 per inch.

It is also necessary to make a nipple wrench, to remove and put these in place. This can be bought in England if one does not wish to go to the trouble of making it up. With an unsuitable wrench one will frequently break a nipple at the square if it should be very hard, and then it is difficult to remove.

Forming Decorative Metals — You will find that most of these arms are highly decorated, and if any embellishments are missing, such as a silver inlay, you will be able to give full scope to your artistic abilities. In shaping silver under the hammer, no heat will be necessary. The metal is so malleable that it may be drawn into any shape by simply hammering it cold. The only difficulty likely to be encountered in this kind of work will be the hardening of the metal under the influence of the hammer, but this may be eliminated by heating the silver to a dull red and letting it cool gradually without quenching. Care must be taken not to heat it too much above the dull red color, as it melts quite easily. After forming silver to its general shape, file it down to the desired shape, and finish with a fine file. Then polish with fine emery and work it over thoroughly with a burnisher. Buff with rottenstone, and when a particularly fine finish is desired, buff with rouge. To clean silver, wash

well with a little spirits of ammonia reduced in strength by twice its bulk of distilled water, then rub dry and bright with soft leather. No kind of polishing powder will be necessary. Some men clean silver by first washing it with diluted hydrochloric acid, then immediately covering the surface with dry prepared chalk, brushing off the surface and rubbing clean with chamois skin. This acts very well, but care must be taken to get the acid thoroughly cleaned off, else it will have a tendency quickly to tarnish the silver again.

Copper is almost as malleable as silver, and works very well under the hammer in a cold state. Heat adds nothing to its malleability, altho, as in the case of silver, exposure to a low degree of heat followed by gradual cooling softens it somewhat when it has been rendered hard and brittle by long hammering. It polishes very well, but does not long retain its brilliancy because of its disposition to oxidize. Heating increases its oxidization, and repeated heating and cooling would soon wear it entirely away.

The beginner will find that brass was most used on the old arms, for usually the furniture or fittings such as the butt plates, trigger guards, patch boxes, etc., were of brass. This material is a combination of copper and zinc, and since zinc is not so malleable as copper it renders the brass less malleable. Nevertheless, it forges out very well under the hammer in a cold state, and this is the only condition that it can be worked in. Hammering increases its hardness rapidly, soon converting it into a very fair spring metal. Brass springs are quite common, but are seldom used on gun work. They are all made by repeatedly hammering or rolling the metal while cold; as in the case of both silver and copper, heating and gradually cooling removes the hardness.

Ramrods — Often these antiques have the ramrod missing, also the thimbles and under-rib to hold them. It is well for one to know how to make the ramrods, for the weapons are not complete without those in place. They are made in two forms: the straight rod for the rifle and the tapered rod for the shotgun. The wood best suited for this purpose is hickory, which is split and then turned into shape. Other woods may be used—ebony, snakewood, beefwood, osage orange, etc. Rifle rods are made in sizes from $\frac{3}{16}$ inch and larger, according to the bore of the rifle; shotgun rods from $\frac{1}{2}$ to $\frac{5}{8}$ inch in diameter. The measurements given for shotgun rods are at the largest diameter.

To make these rods by hand, the wood is split as straight as possible and then rough-shaved into form, with either a draw-knife or spoke-shave. It is then planed square with a carpenter's plane, and

the square corners taken off, leaving the rod in an octagon form. A few strokes of the plane will remove these corners and it will be nearly round. A new file and sandpaper will finish it true and even. After the rod has been planed square, the best way to hold it for removing the corners and making it in octagon form is to have a V-groove made in a piece of hard wood the length of the rod in which to lay it. Otherwise, it will be very difficult to hold while using the plane. Round straight rods can be finished with a tool like a beading plane, and if this tool is of the proper form and the work is turned around two or three times during the operation, a good rod can be made very quickly. Pieces of broken glass may also be used to advantage in reducing rods. Finish with fine sandpaper.

After the rod is completed, the ends can be turned down, and brass tips turned and placed in the ends; one end concave to the form of the ball and the other for attaching a wormer, scourer, and a section with a slot or mortise cut through it so that a patch can be inserted. Care must be taken when using such a wiping rod, that it does not become wedged in the bore on the up-stroke. When this happens pour a little warm water down the barrel so as to saturate and soften the patch and it can then be withdrawn easily. A cold-drawn steel rod may be made, but a rod made of hickory or any of the woods mentioned has no equal.

Stocks — Old stocks have usually been varnished, and this coating must be removed preparatory to repairing and refinishing. This is best done with commercial varnish remover, procurable at any paint store. If there are dents these can usually be raised by placing over them a check cloth saturated with hot water and pressing with a hot flat-iron. This will form steam and bring the dents to the surface. If wood, however, has been removed, the plan will not work, and you will have to inlay patches of matched wood. When placing a patch in a piece of wood, never follow straight outlines. There are no straight lines in nature, and your patch must not have any. Follow grain lines as far as possible and when you have to cross them do it in an uneven and broken manner. It is a good plan to take a good-sized piece of board and examine its whole surface for a configuration that closely resembles the grain you are trying to match. Having decided its location, sketch an outline which will follow the natural figure of the wood as nearly as possible and cut this out with a small jig- or fret-saw. Slant the saw a trifle so that the patch will be slightly wedge-shaped. Place the patch over its allotted place and with a sharp scriber mark its outlines. As pounding on old wood

should be avoided as much as possible, it is best to remove most of the wood in the mortise by means of a Forstner bit. This has no spur and bores a flat-bottomed hole. Then, with small chisels and gouges, cut out to the scribed line. Glue both surfaces and clamp your patch in place until the glue is dry.

When refinishing a stock, under no circumstances use varnish, for it is not a good finish for a gun. There are two better finishes; the quick one is with automobile lacquer, which should be applied with a spray gun to enable one to get enough body. Brushed on, it is most difficult to add material, as the brush washes up the underlying coat. This is a good finish. It is durable, will stand hard knocks, and polishes to a good luster. It has a further advantage in that it can be easily renewed and brought back. For maple, this lacquer finish, I think, is the best. The other finish is the gun-maker's standard finish—the rubbed-oil finish. For walnut and similar dark hard woods it has no equal. It is a finish that use improves and age beautifies. Full instructions for imparting an oil finish are given in Chapter XII, Volume I.

To use varnish remover, saturate a cloth with it and rub it over the stock. Allow it to stand for half an hour and then give it another wetting. The first application softens the paint or varnish and the second one loosens. It can now be scraped off with a blunt tool, such as a putty knife. Then sponge off with another coat, rubbing and scraping until the wood is clean. The wood must now be rinsed in clear water and benzine until every trace of the remover is obliterated. This is essential or it will attack the new finish.

Darkening a Stock — Oftentimes you will wish to darken a stock. After all inlays are in place and the wood is highly finished and polished, "aging" a piece of wood is done with acids, either in the raw state or in mixtures. Acids produce various colors in different woods when used in the raw state. First, a piece of sample wood must be experimented upon with the raw acid. This should be used quickly, being allowed to stand from five to ten seconds, then washed thoroughly with hot water to kill any further action of the acid on the wood. The wood is allowed to dry and is again polished; then it is given the raw-linseed-oil treatment, letting this oxidize and then polishing and using the finishing oil described in the first part of the chapter. With this information, I believe all the essentials for reconditioning can be applied to any antique stock, so that it may be put into shape to present the best possible appearance for any collection. By all means, try to have the gun look

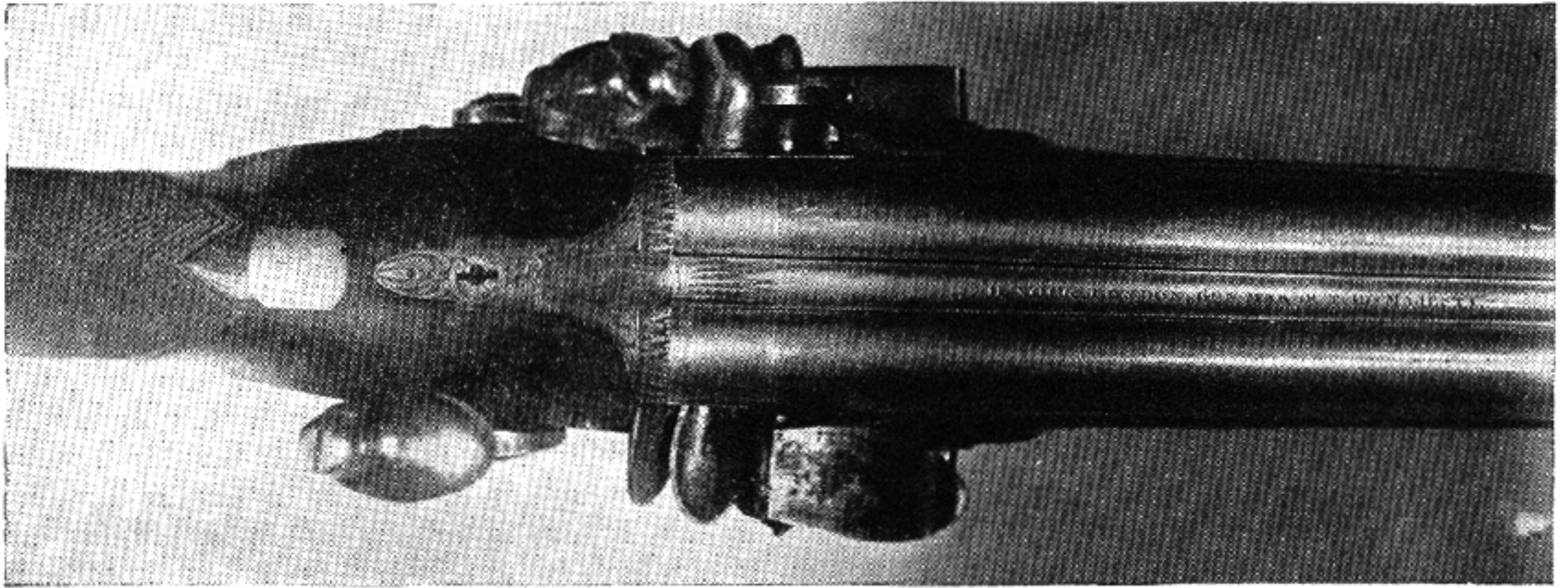


Fig. 142
Flint-lock double gun made by H. Nock. Note the separate breech plugs, connecting the tang

as much like the original as possible.

Antique Finish for Stocks — To give an antique appearance to the stock mix the following:

60 cc. nitric acid
15 cc. tincture ferric chlorid
5 cc. distilled water

Into the nitric acid put about 150 grains of steel filings. Mix in a small stone jar, outside, for the filings will cause a reaction in the mixture. If steel filings cannot be secured, use steel wool. After the action of the acid has stopped, let cool and add the tincture ferric chlorid and distilled water. Then strain into a bottle. Having this solution prepared, take a ball of cotton or a clean cloth. Wet well with ammonia and rub over the stock lightly. Let dry. Form a new ball of cotton, or use a clean cotton cloth and apply the solution to the stock. It is best to wear rubber gloves when doing this, for if the acid gets on your finger tips, it will cause the skin to crack and peel off. Apply the solution very liberally. After applying, wash with hot water to kill any further action of the acid, and let dry. If the color is not dark enough, apply another coat, and let dry thoroughly; then polish with No. 3/0 steel wool and No. 5/0 sandpaper, and polish with rottenstone on a rubber pad or sponge to bring out a high finish. Next prepare an oil by using:

1 pint raw linseed oil
1 oz. alkanet root
30 cc. turpentine
200 gr. lampblack

Boil these, taking care that the turpentine does not come in contact with the flame, or it will ignite. Let cool, and apply to the stock once every two days, until the wood ceases to absorb any more. Let stand for one week and polish first with No.

3/0 steel wool and then with rottenstone on a rubber pad or sponge. The stock will now have a wonderfully pleasing appearance, as the color will come out with the real antique tone which every one admires.

Ancient Arms — Ancient arms should not be refined unnecessarily. Their utility is completely at an end. Their only place is in a collection. Care must be taken, when replacing any broken or missing parts, that these are not finished in a manner superior to the original parts. Much of the metal work was beautifully forged but had no other refinement. The new work must be of the same quality, showing the same delicate hammer work. The finished work, if placed in sulfuric acid, will have the effect of metal eaten with age.

Flints for Flintlocks — The real old gun that looms so big in America's early development and in her struggle for independence was the flintlock; this gun must always remain a picturesque reminder of those spacious days. It is still with us in goodly numbers, and good specimens can be obtained by the collector. For this reason we shall add a few words about the flints that constitute the salient points of these guns. Flints for guns and tinder-boxes are manufactured even today, and the trade-name for the men and women who make them is "knapper." This craft name has almost disappeared, except in the vicinity where flints are still made; but it survives in the surname Knapp. The sole remaining place where the industry of flint knapping flourishes is at Brandon-on-the-Ouse in England. Today the Brandon knappers still make and ship flints for guns to Central and Western Africa, and make "strike-a-lights" and tinder-boxes for Central Europe, where the peasants prefer

them to matches. This industry at Brandon far antedates firearms, for we know from discovery of the deer-horn cleaving tools and flint arrowheads in the vicinity of the old workshops that flint implements have been made there since the stone age.

The best flint for gun work is the most translucent of the common black chalk flint. It should be put in with the flat side upwards, standing clear of the hammer, yet long enough to go through it. Fasten it in with leather washers, as lead strains the lock and cloth is dangerous, for it is liable to catch fire. If you are very particular about the neat appearance of your gun, make a punch for stamping the leather, and change it as often as you put in a new flint.

To make a flint strike lower, you have only to reverse the usual way of putting it in; but if you want it to strike higher, you must either put in a very thick leather washer, or screw the flint in with something under it. This temporary way of regulating a lock to make the hammer fall is worth knowing as it often saves a lot of time. To get the flint to throw a good spark, place fine cross lines on the frizzen with a fine slitting needle file, care being taken not to get these too deep.

In concluding this chapter a word must be said about the old Kentucky rifle. The backwoods hunters who used the long Kentucky rifle had a very imperfect idea of its capabilities. These guns were provided with a rear- and a fore-sight. The sight was immovable and could neither be raised

nor lowered, consequently the gun could not be adapted to circumstances of long or short range. The elevation of the sight usually crossed the line of vision and that of the flight of the bullet about 100 yards distant; hence shooting at a shorter range was apt to be a little too high and at longer range too low. In those days of pioneer life on the frontier, "match shooting" (it was not called target shooting then) was very popular and was always confined to a certain distance; 60 yards off-hand, or 100 yards with a rest. The marksman was permitted to take his choice of modes. The prize in a "shooting match" was usually beef. A fat ox was put up to be shot for at so much per shot, which was something on the plan of the modern raffle. When the amount asked for the animal had been made up, the shooting commenced. The best shot took first choice, which was one of the hind quarters of the ox; the second-best took second choice, which was the other hind quarter; the third-best took third choice, which was one of the fore quarters; and soon to the fifth choice, which consisted of the hide and tallow. Happy occasions, indeed, were those old "shooting matches," and splendid indeed was some of the shooting. A regular attendance upon target matches of more modern times with all modern appliances, in the hands of marksmen with national reputations, has never shown us better shooting at 60 yards off-hand, or at 100 yards with a rest and open sights.

After these old percussion rifles have been given

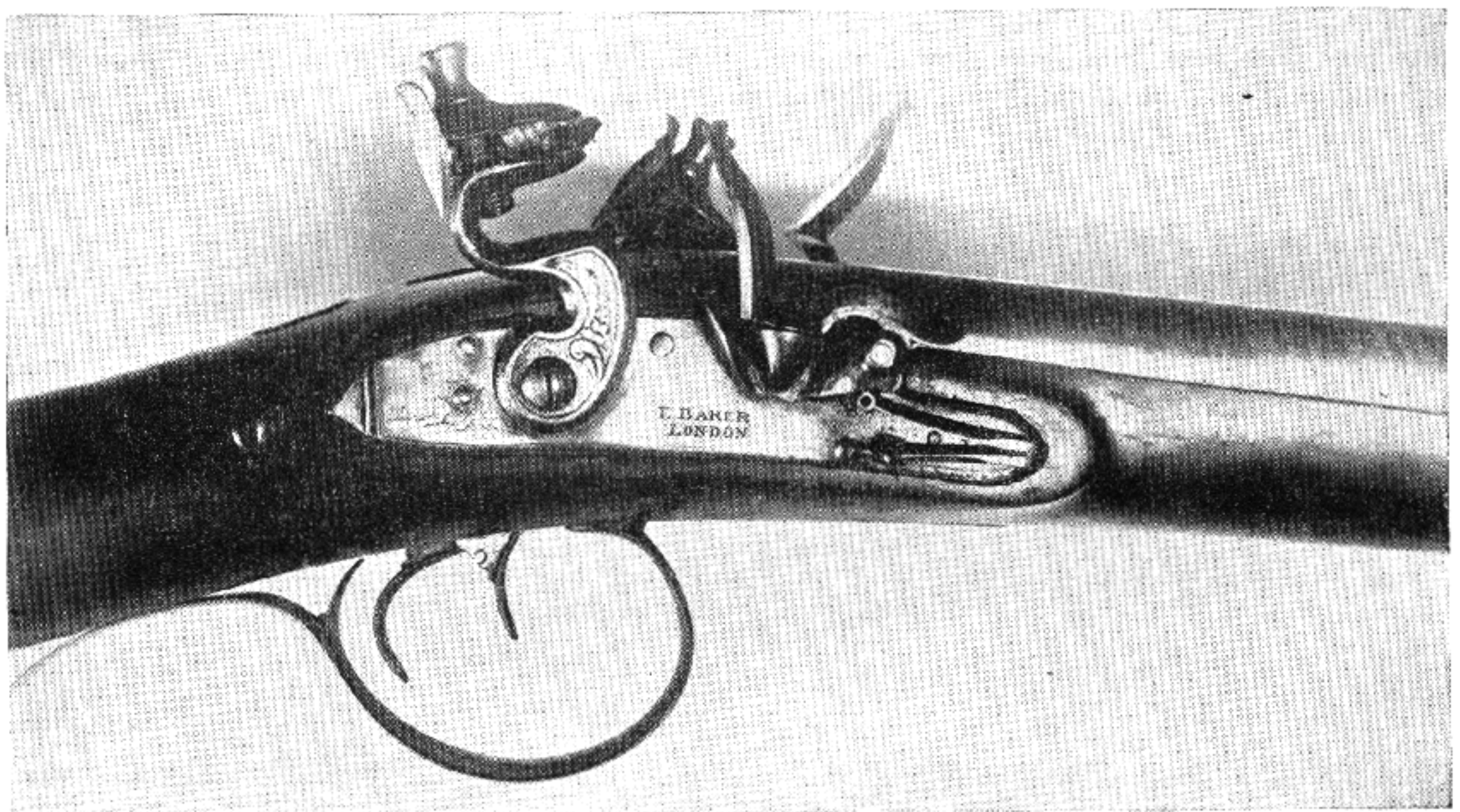


Fig. 143
Flint-lock double gun made by E. Baker

the necessary overhauling to secure the fine shooting qualities that they were once capable of, the beginner will take great delight in their use. If he is so fortunate as to own a real Kentucky rifle in fine condition, there is no greater thrill than testing for skill of marksmanship, holding the rifle on the object while the flint falls, seeing the flash and then hearing the explosion. Modern arms are simple, but if we could develop the art of holding as our forefathers did with such weapons, modern arms would be more than simple to use.

I can not help but express great distress at the way some of the old rifles are worked over or reconditioned by some collectors. Some of these men cannot be approached on the subject of proper finishes, for they have their own ideas about them, regardless of right or wrong. Picture for yourself a fine old Kentucky rifle with a well preserved maple stock inlaid with silver and brass furniture, after the stock has been sanded down, the beautiful wood given a dark French polish, and the brass furniture and steel parts buffed to a high finish. Then picture, if you can, how this rare old piece would look if it had been given a coat of varnish.

Reconditioning old arms and placing them again in working order requires considerable forethought, especially when parts must be made that are missing. This is usually simple but laborious, for you must be able honestly to term the work hand-made. By all means do not make any additions to, or change, these arms in any way, for they may be very valuable some day for their authenticity; if this is detracted from in any way the arm will be worthless. It is permissible, of course, and often more interesting and practical, to remodel certain

types of obsolete arms, making them useful for experimental purposes.

The late financial depression has revived many curious things. We find men doing things more simply because they are more economically done that way—things that our grandfathers did. Strange, is it not, how the lack of money reduces the status of the civilization by which we measure culture—how we are made to realize that wealth is the principal factor productive of our great "machine age"? Among the many "regressions to the primitive" I find that some of my correspondents and sportsmen friends refuse to give up shooting simply because they cannot afford standard ammunition for their arms. These tenacious souls have unearthed old muzzle-loaders, percussion-loading shotguns, and even some old cap-and-ball revolvers.

One can always cast his own bullets from lead found in a scrap yard, plumbing shop, etc. Black powder and the percussion caps can be purchased very reasonably; in fact, black powder can be made by any one who will use care in its preparation. It is very simply compounded as follows:

75% potassium nitrate (saltpeter)
10% sulfur
15% charcoal (willow)

Before the wood is placed in a retort, remove all traces of bark. Heat between 550 and 600 degrees Fahrenheit; bake until wood becomes porous. When it is completely made into charcoal, let it age two days before using.

Flowers of sulfur will not prove satisfactory. Use only the stick sulfur and grind to the size which will prove most suitable for your particular needs.

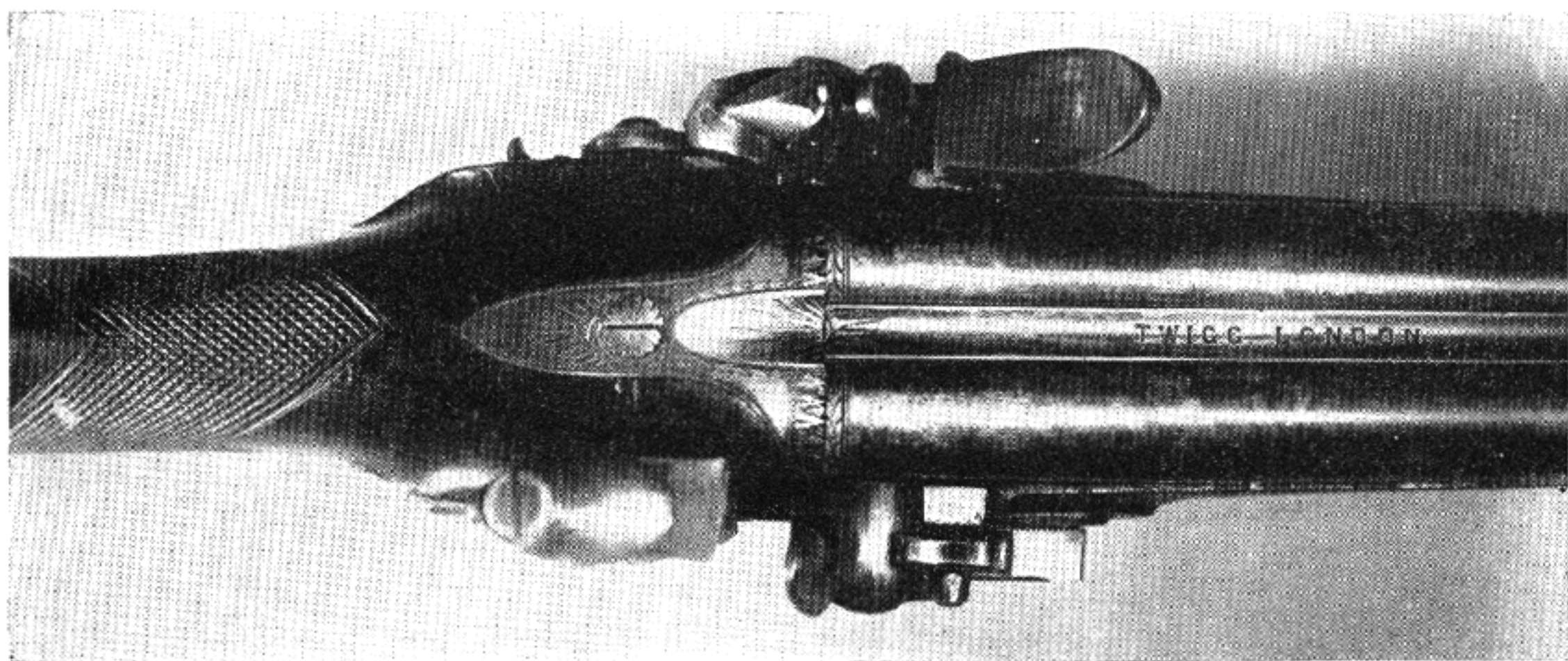
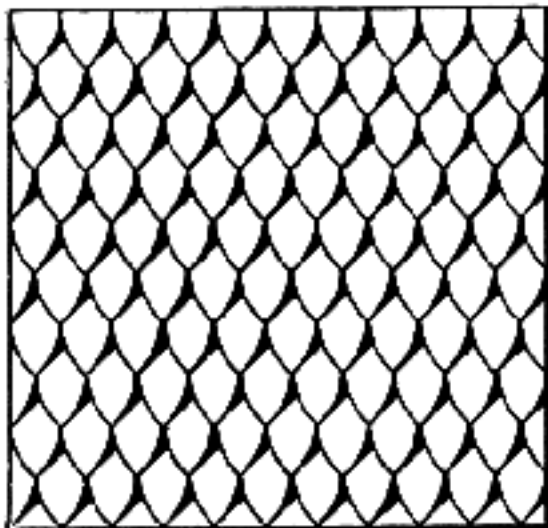


Fig. 144

Flint-lock double gun made by Twigg. Note the solid breech

CHAPTER XXV

Shotgun Repairs



Shotgun Repairs

THE open season for game is comparatively short, and today there is no immediate prospect of its being lengthened. Trap shooting is admittedly an artificial means of enjoying our well-loved shotgun, but until the hawks and crows and other pests of that category pass into extinction we shall continue to experience the genuine thrill of the sport it was intended for. Because of the great variety of uses it is adapted to, it has been placed among our greatest mechanical achievements in the development of small arms. There are few articles fashioned by man for use in which more features of beauty and utility have been harmoniously blended than in a fine shotgun. The untiring efforts for improvement on shotguns in the past fifty years have added much to our knowledge of these arms, particularly those of the British makers and craftsmen. The love of beauty is inherent to a greater or less degree in us all, and those possessing the keenest appreciation can admire a shotgun every day in the year and exult in the pride of owning such a work of art.

I must be excused from trying to describe the perfect shotgun, for I would be tempted to select the arms of the British; being unaccustomed to superlatives, I shall let the reader judge these himself. No type of arm is so susceptible to refinement and embellishment as a shotgun, and it is a recognized fact that men will spend more money for such an arm than for any other, in order to have the best quality of materials and workmanship. Skilled men who build such arms are fast disappearing, and the younger generation does not seem to have the patience or perseverance to devote the years of painstaking application requisite for the title of "expert."

There is but one other human sentiment which may fairly be said to challenge our appreciation of the beautiful for first place, and that is our inborn admiration of strength and power. In our never-ending struggle upward, these qualities mean very much to us in the way of furnishing sustenance for our ever-hungry progeny and protection from co-existing nature and reality. Therefore, to insure our continued existence here on earth we must possess weapons according to our social standing among the mass; but since we have not all been

placed upon this earth in equality, all of us cannot fill our cup of joy with the best. Accordingly, the makers of arms try to have a variety within the reach of every individual requirement, and he who is not so fortunate as to own the best can nevertheless own an arm that he will cherish as tho it had been made for a king.

If the student wishes to become a careful workman on the better grade of shotguns he must not only be mindful of the work on the gun, but be careful in his treatment of all work entrusted to him. Skill calls for careful application of principles, and that can come only from long hours of diligent practise upon one or more subjects; therefore, a temperate mind free from worry must be maintained to carry out some of these undertakings on the mechanical arrangements in some of our better arms. Pride must also enter into the best work on these weapons, and above all, there must be a guiding mind intent upon the fashioning of a weapon to its ideal.

Some men like to take their shotguns apart and put them together again. In a number of cases this is not requisite, for it does not in any way add to the general efficiency of the gun, particularly when the proper tools are not at hand. In some instances I have recommended removing the locks and stripping the action, but I would not advise the same treatment for a two-thousand-dollar weapon as I would for the mediocre run of shotguns. If any repairs should be necessary on a high-grade arm, and if a competent man is not within easy reach, the student himself must endeavor to make these repairs; but it is not advisable to practise on any gun that functions satisfactorily.

Because of the numerous and complicated shotgun actions made, it is next to impossible to give directions for them all in one chapter; the subject must be treated as a whole and due allowance made on the instructions given. Many shotgun actions puzzle an expert gunmaker to take apart and repair. To a trained mechanic who can study the actions as he takes them apart, however, will come a thorough and direct understanding. He will use the greatest care and forethought in every move and recognize the advantage of not marring the finish of so much as a screw head.

As seen in the instructions in Chapter XXIV, Volume I, on the cleaning and oiling of guns, many little kinks enter into our methods of working on a lock. In a side-lock gun, for example, the main spring is removed first; this is done with a gun-spring clamp or a pair of lock vises. If you do not have these tools, a clamp can be made by filing a notch or slot in a $\frac{1}{8}$ -inch piece of sheet metal, the size and width of a main spring when it is at its full compression and the tumbler in its cocked position. Slip the notched piece of steel over the main spring, release the sear, and push down the hammer. Since the spring is firmly held in the clamp, it is an easy matter to remove the rest of the mechanism.

There are numerous little untold ideas, and the student is left to solve many problems found in disassembling and assembling a gun lock, especially if the arm is at all complicated. The first consideration is that of the essential tools. These usually consist of a good set of screw-drivers to fit different-sized screw slots, padded vise jaws of felt, spring clamps, special fixtures to compress main springs in box actions; a complete set of auger-brace screw-drivers to remove screws which cannot be started with the hand tools; fine oilstones, lapping rods, fine flour emery, fine pillar and needle files, dent raisers, and various other tools described elsewhere in these volumes. Screw-drivers are the most essential tools in the list. Nothing so mars the appearance of a fine arm as the heads of screws spoiled by having a driver slip and turn up a bad burr on the head. Screw-drivers cost very little in time or money, and when made with the straight portion fitted well down into the slot, they never slip. If hand pressure does not remove a screw, the brace screw-driver may be employed. Do not hesitate to grind the point of a driver to fit some particular screw slot. If it is constructed as described in Chapter I, Volume I, these ends can be ground a number of times, as they have been made for just such purposes. If you should attempt to make or buy screw-drivers for every known width and diameter of screw head found in shotguns, your collection would mount to the same figure as a wood-carver's set of chisels—over one hundred.

Choke Boring—The student should not be misled into believing that this operation alone produces a satisfactory pattern in any gauge. True, some wonderful results are obtained in this way, but the principles involved in producing this mystery must be better understood. The controlling factors must be made more clear, and the reason why a certain boring will give a particular pattern

and why other methods will give the opposite results must be comprehended. Different manufacturers of shotguns have their own standard methods of putting chokes in shotgun barrels; some are good, some fair, and others just impossible. The last-named are the cheaper arms in which they have swaged the muzzle in order to place a choke at the end—a very crude and cheap way of doing this operation. This is often referred to as a “jug choke” by old-timers who were accustomed to handling the cheap Belgian arms which at one time flooded this country. Some owners of these arms even placed the muzzles in a vise to give the end of the barrel an elliptical form, using the expression, “To give me a slathering shot on game.” I do not believe there is any topic that has been more hotly discussed than barrel choke in shotguns; even today it is not understood, nor has it been settled correctly in a number of minds. I am not going to try to argue it out, for ammunition is too strong an antagonist against any argument. The term “choke-boring” appears to have originated back in the muzzle-loading days and to have been carried to the breech-loading system with a better understanding of its merits.

To the American or British sportsman the term “choke bore” simply means that the diameter at the muzzle is less than the diameter at some point behind the muzzle, and that these bores are made in various lengths. Any shotgun barrel constricted at the muzzle to the extent of 0.005 inch may be termed a modified cylindrical bore. A full choke may be reduced to the extent of 0.030 inch. Some even constrict the choke more, but this is rarely seen on the best arms; the greater reductions are only found on the cheaper arms. After passing a certain limit in reduction the choke always defeats its main object by giving irregular patterns; often it reduces the pattern to such an extent that it does not open, except at a certain distance, which often varies. The larger the bore, the greater must be the reduction at the muzzle; therefore, we cannot use the same figures for a 20 as we could for a 12 gauge. The reduction of the bore, to be effective, must finish close to a given length, and that should be approximately $1\frac{3}{8}$ inches or less. When made over $1\frac{5}{8}$ inches in length, certain makes of ammunition must be used in order to find the best load for that particular choke. When the opposite extremes are found, such as the short choke at the muzzle, all objects are defeated, and whatever is done in trying to make various corrections only leaves a mediocre gun in one's possession. There are guns with reduction of the bore three inches or more from the muzzle which fail to throw the shots close together, but there is greater penetration than

from a swedge choke. Such a condition can be lapped out with a recess choke and will produce some beautiful patterns. Some barrels are bored oversize and still have the correct diameter of reduction at the muzzle. How often we see a man take a ten-cent piece from his pocket to see if it will enter the muzzle! Such a test does not do justice to the true conditions. It is an established fact that if a coin will go in one barrel and not the other, it tells without a doubt that one is a choke bore and one a cylinder. This test is similar to using a "go" and "no go" gauge where the limits are large but the size between is unknown. At times 0.002 or 0.003 inch makes a vast difference. Suppose that the bores of both barrels are determined by the coin method and one is cylinder and one choke. How often have you shot a barrel tested by this method and found that your supposedly choked barrel gave the poorest pattern, while the barrel which the coin dropped into gave the best! This condition is caused by overboring and can be corrected only by reloading your own ammunition and using a larger-sized wad to hold back the shot column.

When making a choke-bore barrel, the manufacturer leaves it 0.050 to 0.060 inch smaller than the gauge it is intended for; in a 12 bore, the bore is left about 0.690 in diameter. The barrels are bored within three inches of the muzzle with a standard boring tool, using a piece of white pine as a "sprill" and paper liners to bring it up to the desired size. The tool, however, is allowed only to come within the specified distance and then withdrawn. This is rather a tedious process, it being rather difficult to remove the metal from that part of the barrel nearest the muzzle. After sufficient metal is removed with the boring tool another boring tool with a taper on the end is inserted. This tool is of a different nature from that of the boring bit; it is chamfered off toward the point in order to give the desired shape to the cone of the choke and the flat between the top of the choke and end of barrel. By the use of such a tool the choke is kept perfectly straight and true with the barrel. This operation is not used by all shotgun makers—some bore the barrels to the desired choke size and use the same tool to bore out the barrels to the gauge required.

It is the practise of the manufacturers of cheap shotguns to bore the barrels cylindrical, or nearly so; then reduce the muzzle from the outside by forcing the end into a die until the internal diameter of the muzzle is about 0.040 less than the bore. This is a very cheap way of accomplishing the desired results, and is therefore regarded as a makeshift plan. Nevertheless, the barrel is choked,

which answers for a lot of defects in other parts of the bore.

After the rough-boring operation takes place, the fine-boring follows. Of all the processes the shotgun barrel passes through in the course of production, fine-boring is the most important, as upon its proper finish the shooting of the barrel is entirely dependent. The term "fine-boring" is included in all that is done to the inside of a gun barrel after the rough-boring previously described, and enough is allowed for this operation. The operations are as follows: rough-turning of blank, drilling, reaming, turning, rough-boring, choke-boring, fine-boring, chambering, lapping or final polishing.

The fine-boring by which the inside of the barrel is enlarged to the required bore size, allowing enough for the final lapping operation, is done on a reaming machine. Various manufacturers have special machines which have been in use for a number of years. The tool, however, revolves at scarcely half the speed of the rough-boring reamer, and cuts on one edge only; whereas, the rough-boring and choking tool cuts on two sides. The tool is made to fit the barrel by means of a piece of hard wood packed with strips of paper between the wood and tool to fit the bore. This makes a scraping cut, removing only 0.002 inch on each passage of the tool into the barrel bore. A free supply of the best lard oil must be used as a lubricant, not only in this operation but in every operation where a tool of this nature is used. By using the same tool with additional packing it can be made to bore several sizes out of the barrel. The tool has but one sharp edge; the other is rounded and stoned to a high polish, which acts as a burnisher, while the two remaining edges are prevented from touching the bore by the wooden "sprill." The amount of "cut" is regulated by the packing, usually one paper liner inserted between the tool and the wood; the thickness of that paper is determined by the amount desired to be removed each time between the bore and the tool when the bit is next inserted. The tool is ground square, as Figure 55 illustrates, and is fifteen inches long on the cutting sides; this length centers itself better in the barrel and also has a tendency to keep the bore straighter. The tool turns in these operations and the barrel is held stationary in a fixed carrier which has considerable freedom on the head of the carriage. The tool fits quite loosely in the head, in that way acting as a floating reamer.

After the barrels are bored to the desired size they are chambered. Two reamers are used, one roughing and one finishing, but to obtain the finest chamber and cone, a burnishing reamer should be employed. Make them to the desired chamber

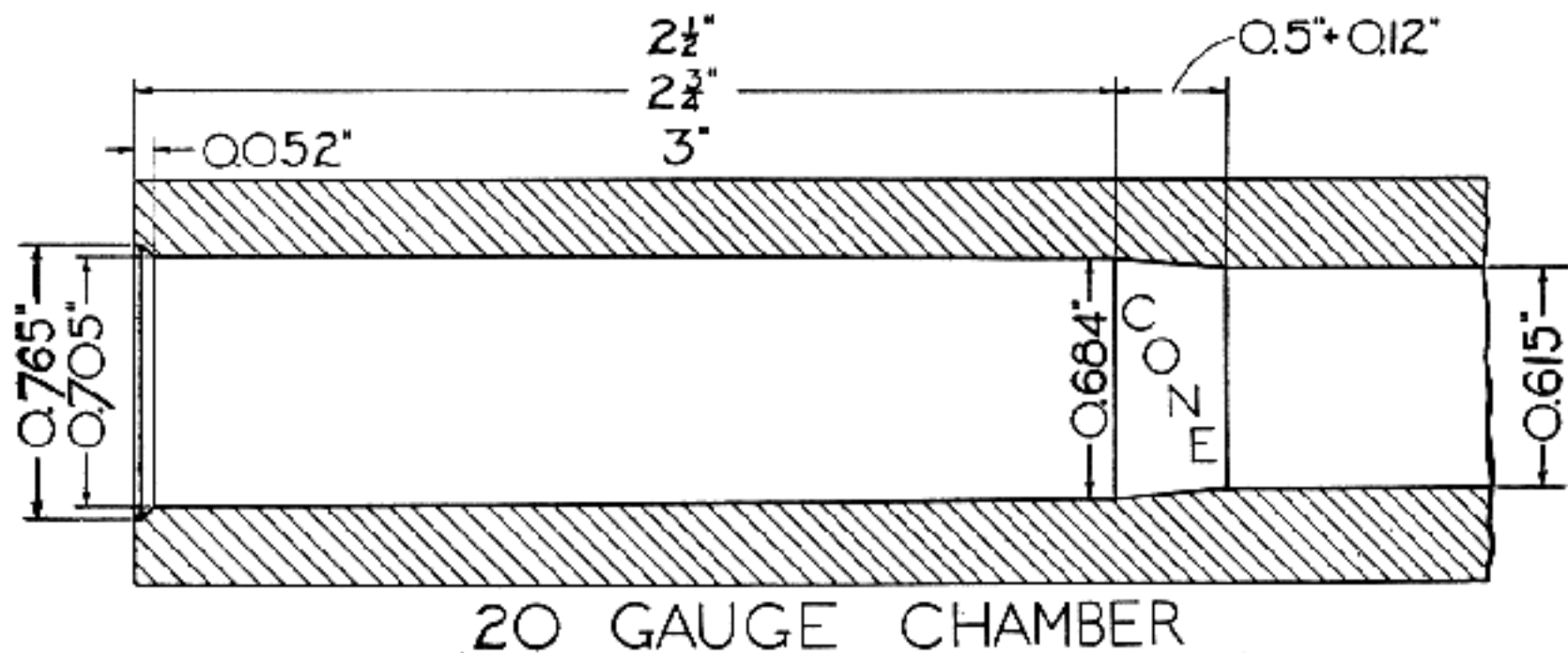
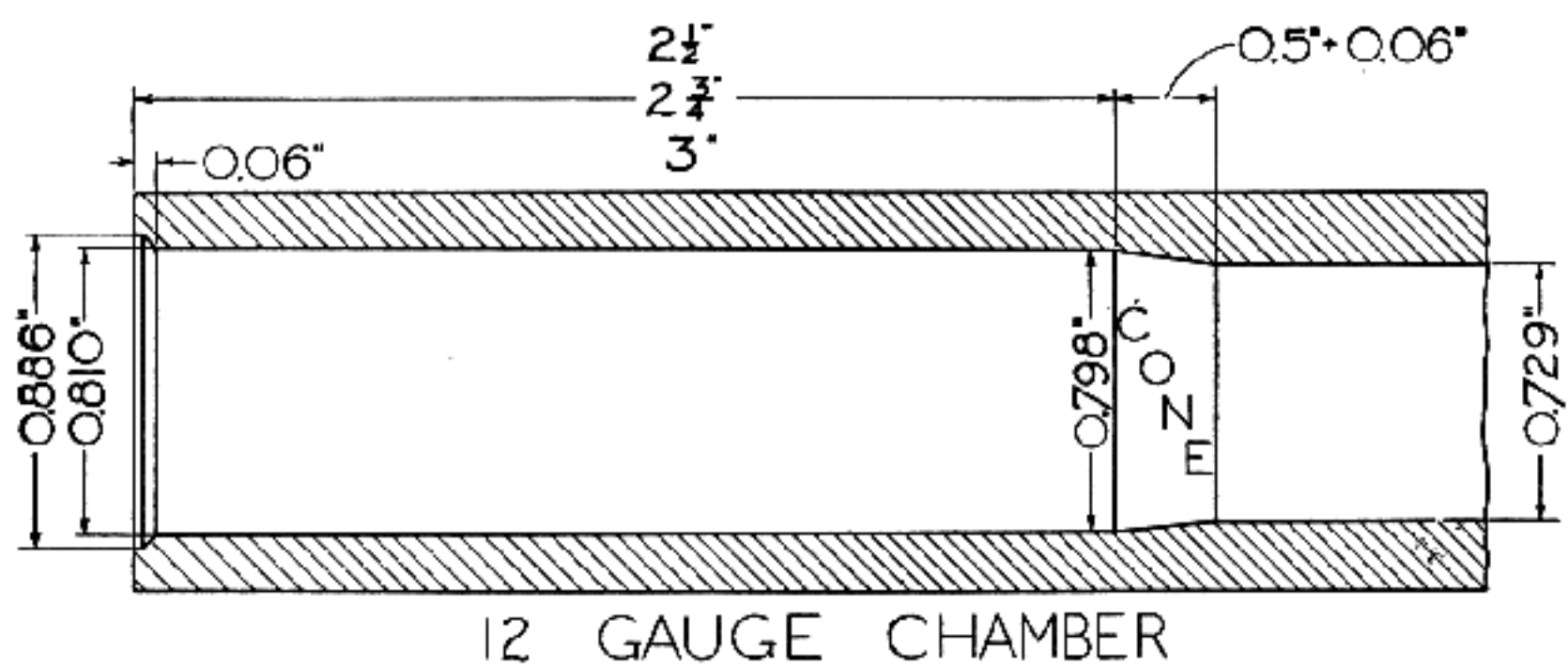
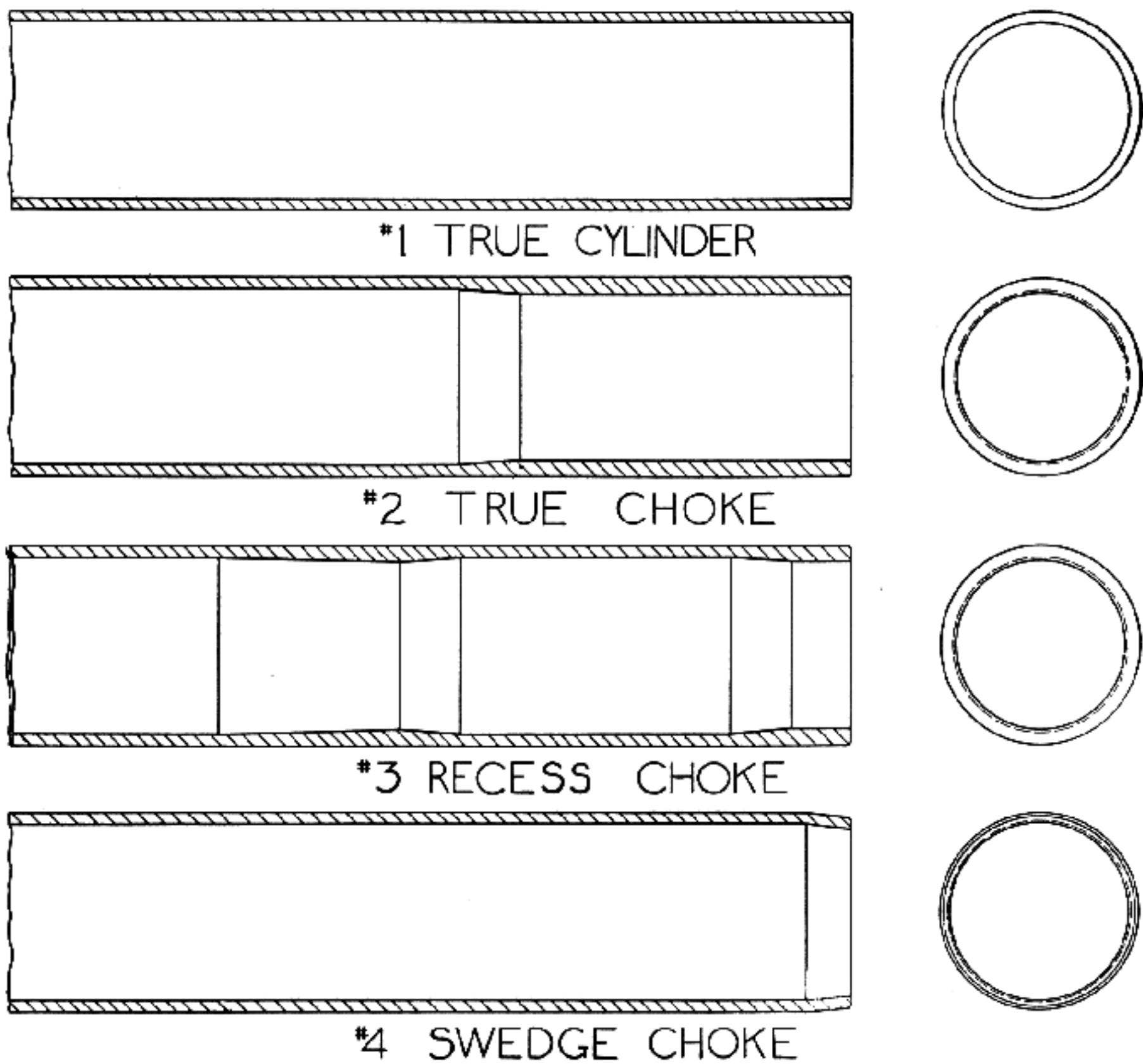


Fig. 145

Barrel chokes and shotgun chambers

diameter and for the gauge intended. The chambering operation is accomplished in a lathe with the dead center placed in the center of the reamer. The reamer is turned with a tap wrench and gradually forced in with the tail-stock screw. The chamber and cone must be in exact line with the bore of the barrel; so the reamer is provided with a pilot which projects ahead of the cutting portion and centers itself in the bore of the barrel, which it must fit with about 0.0005 inch clearance between bore and pilot. Often a bore is left 0.006 inch smaller than the standard size in order to try for closeness of pattern; whereas the chamber is always to one size and the pilots of the chambering tools must fit the bore of the barrel. When that size is made a standard to test by, it will be the smallest size ever to be required for testing purposes; whatever is taken from the bore is obtained by its final finish, completing the test after the gun is finished or before the bluing operation takes place.

The proper shape at the end of the chamber, which is a gradual taper into the bore, is called a "cone." Different manufacturers have various lengths of cones, some short and some rather long. The correct length is about $\frac{7}{16}$ inch. Figure 145 illustrates a 12 and 20 gauge chamber in which a tolerance has been given for the cone; this is a flexible length, hence the large variation. A cone should never be made abrupt; at times a much longer cone is required, but it should never be any shorter than the given length.

How many barrels do we come upon that seem to have a perfectly straight bore from chamber to choke, or to muzzle, aside from the finer shotguns where great care has been used in the lapping operation? What is known as a true cylinder bore is a barrel that is not "choked"; that is, there should not be any point between the barrel and chamber, nor should the end of the cone to the muzzle have any variation in size. If any, it should never be more than 0.002 inch in different places throughout the entire length.

Figure 145 illustrates the four usual forms of "choke"; No. 3 is the "recess choke" in a choke barrel which is often seen in a number of foreign guns. No. 4 is the "swedge choke" or jug choke found on cheaper arms. The only method of producing No. 1, the true "cylinder," is by the lapping operation.

The final polish to the interior of the bore should be a mirror-like finish instead of just a polish such as we see in the bore of almost all guns completed with the finishing tools and never lapped. This mirror-like finish of the barrel, to which regularity of shooting is due, is produced by a process which

very few manufacturers use except on the best-grade guns, for it entails an added expense. A barrel highly finished will be known by the remarkable closeness of its shooting. Such barrels are obtained with a long lead lap coated with fine flour emery and paraffin oil as a lubricant. This process may be accomplished with the aid of the same reaming machine that is used for reaming or boring the barrels, except that the speed must be increased. A lathe may also be used for this operation by constructing a special holder to be fastened to the compound rest. As the lap is passed back and forth through the barrel from end to end, a perfectly true, highly polished surface from chamber to choke is obtainable.

The lap is cast on the end of a cold-rolled steel rod and then turned to the required bore diameter. The lap is kept constantly covered with emery and oil. After every little tool mark is removed a new lead lap is cast upon another steel rod and this is used with rouge or Vienna lime and oil.

As the barrel is fixed on the carriage of the reaming machine or lathe and the lap is inserted and set in motion the barrel is moved back and forth very slowly along the revolving lap in order to form the inside surface perfectly and remove any slight inequalities that may have been left by the finishing boring tool when this operation took place. It will also finish it as finely as possible, which is necessary if high-class regular shooting is to be obtained in the hands of good shots. Such a lapping operation renders the barrel more easy to clean and makes it less liable to lead or even foul. Too much care cannot be given to this operation, owing to the speed at which the lap revolves. A barrel being bored very thin at the muzzle is apt to bend out or the ribs may be loosened or twisted because of the heat generated by the lap, so during this process water should be freely applied to keep the barrels cool.

After knowing the methods and principles used for choke-boring a shotgun barrel, the next problem is to know the proper results of the efforts applied to accomplish these various patterns. As an example, let us suppose that the gun is more or less choke-bore; to dispense with any choke in one barrel is to sacrifice efficiency, for choke-boring is the only method by which the outward expansion of the shot can be controlled. The amount of choke best suited to any shotgun will depend upon the particular thing for which the arm is to be used and the skill of the user. A trap gun does not require the full choke which most of them have, yet it needs enough so that the gun can be shot either on the 16- or 28-yard line, and give a good pattern. When deciding the amount of choke, it must be

borne in mind that the pattern shown on any target does not fairly represent the position of the shot at any gun mount. Assuming that a certain ammunition has been found best suited to the choke, some individual velocities go ahead while others lag behind, and so actually the pattern is never exactly what the target represents it to be. A full-choke barrel is for sizes better than a cylinder; that is, a barrel much larger would be needed to shoot a heavier load and so make an equal pattern; therefore, at long ranges a larger barrel and heavier loads could never equal a choke-bored barrel. Unfortunately, this is only found when great care has been given to the interior finish of the barrel, and a number of trials are sometimes required to find that performance on the targets at various distances. The principal advantage of a true cylinder bore is that it possesses a larger killing circle up to 20 yards, and beyond that range the second barrel must come into play with a choke to vary for the purpose intended.

Many men picture the shot column as passing through the choke or constriction in its original form. This does not actually happen. Spark photography showing shot charges emerging from the muzzle at various stages of their flight prove that the shot column is completely intact, the individual pellets of the charge having been acted upon directly or indirectly by the taper walls of the choke shown in Figure 145. The original formation of the charge has been changed and the initial direction of its movements, especially regarding the outside pellets and those adjacent, has been altered. When the charge begins to expand as shown in photographs, the breaking up is not due entirely to the action of atmospheric pressure, but also to the fact that the pellets which were originally at the bottom of the column have been deflected toward the top. Those to the right taper to the left or vice versa; therefore, each individual pellet that makes contact at the tapered choke is deflected from its original direction of flight, and these deflected pellets change the course of the pellets near them. The result is a closer grouping of pellets than could ever be had with a true cylindrical bore. A cylindrical bore tends to expand the shot upon emerging.

It is agreed that the last influence the barrel has on the shot column is at the choke, and it is evident that the tapered part of the choke deflects the pellets from the straight line of their original flight and causes them to cross the line of aim and strike the paper on the opposite side from that which they occupied in the gun barrel. It is further evident that some of the pellets in the center of the load are not affected by the deflecting disturbance

caused by the passage through the choke, and these pellets carry nearly true to the center or in a straight line. All this explains why an overchoked gun makes a poor pattern, or too acute an angle to the lead, making the flight of the outer layers of pellets expand and consequently causing open patterns.

The mathematically inclined student can prove with figures, the action of the angle on shot charges, if passed through a choke, as shown in Figure 145, No. 2. Take a 12-gauge barrel as an example, with a 2.5-inch length of choke; the taper leading to the cylindrical portion, we shall say, is 1.5 inches. The bore of a 12 gauge is 0.729 inch, while the cylindrical section of the choke is .695 inch, giving a total constriction of .034 distributed over the 1.5-inch length of taper. The taper on one side would be 0.017 inch, or half the total constriction of 0.034 inch. A 40-yard range contains 1,440 inches and is 960 times the length of the taper (1.5 inches); however, the deflection at the target would be 0.017 inch multiplied by 960, or 17 inches from the center of the pattern. Therefore, if one shot pellet could be fired from a shell, and it followed along the surface of the bore, it would be deflected upward when it reached the tapered lead, and would strike the target approximately 17 inches above the center of impact of the full-shot charge. This illustrates, in theory, the tendency of the choke, lead, or taper, to influence the direction of flight of shot pellets. All inside pellets are given this deflection by the choke; however, many of them are acted upon by other forces, which to some extent counteract this effect of the choke. Fine patterns are possible from a full-choked barrel, finished by the reamer and not lapped, but only for a few shots, no matter how perfect the reamer or how fine the boring tool has left it. Tool marks will gather sufficient lead to produce irate and patched patterns when chilled shot is used, and after that trouble starts. Friction then takes place. The shot column against the inner surface of the barrels, up until the time it reaches the taper or beginning of the choke, is intact. But in the portion of the bore directly in front of the choke or restriction, friction is considerable and causes leading. The introduction of copper-plated shot will minimize the leading, as the copper coating forms a hard outer surface, and a good many charges can pass through a barrel before the copper deposits will equal the deposits of lead left by the few loads of old-style chilled shot. Lapping must take place until a mirror-like surface is produced in the choke and taper to eliminate any lead fouling.

From this simple explanation, the student should

acquire a basic understanding which will enable him to experiment with the various degrees of choke boring; for, as we know, actual experience is the greatest of masters. If you are interested and intend to pursue the subject further, this elementary knowledge will endow you with a clearer conception when other more detailed books are read.

Loose Actions — The usual advice given when an action has become loose on the hinge pin or bolt, is to peen the cut-out or make notches in the lumps. This is good advice to follow when a cheap gun becomes loose at any of these points, but to do so on a fine arm is unpardonable. Those who wish to accomplish a peening operation on shotgun lumps may do so to tighten the joint, but there are better ways of completely tightening any loose joints between the body of the action and barrels. The jointing consists of fitting the barrels to the action. This is a matter of importance, for the life of the arm and also the "safety" depends upon these joints being tight. A properly joined gun will seldom shoot loose. The fitting of barrels and action requires many trials in order to bring the parts together to bear evenly against the standing breech, and the flats upon the barrels must be firmly bedded upon the action's bottom face. The spotting-in is done with Prussian blue and must be repeated many times until each surface fits evenly and closely against the other part.

If an action is loose, the best plan is to fit a new hinge pin, that is, unless the bolt requires fitting also. Some hinge pins are fitted into the frame while others are screwed into the opposite side to hold them in place. After pressing or forcing the old pins out it is usually necessary to anneal the action and case-harden it again. Before the annealing takes place all parts must be removed from the action and heated in a box or pipe containing lime or charcoal. The contents are heated to a cherry-red and allowed to cool in the container. If the action were thrust directly into the furnace flame, the metal would be more or less scaled because of oxidization.

When the action is ready to be worked on, re-fit the barrels to the action; use Prussian blue on the flat bottom portion of the barrels and the face; then spot this in, removing every little high spot with a fine pillar file at the bottom and face of the standing breech. You may find it necessary to use small scrapers for this operation as well as the fine files in order to remove spots which can not be conveniently removed with a file. When completed, clamp the barrels very tightly together and ream out the hinge-pin hole with a reamer which will remove sufficient metal to make the joint in

the lug true and round. Sometimes the barrels and action can be clamped together and the hinge-pin hole lapped so that a perfect bearing surface is secured without annealing the action, which should be avoided whenever possible, unless the student has the equipment to re-case-harden the action correctly. First, try to lap the hinge-pin hole before annealing the action; however, this is usually done by the manufacturer of the arm rather than the gunsmith or student. By lapping this hole the complete removal of the high and low spots takes place, and when the new pin is fitted, it has a perfect bearing surface upon the entire radius in the lump.

The use of small scrapers, as suggested, to remove high spots that cannot be removed with files, requires considerable practise; it would be well for the student who is about to perform such an operation to practise on sample pieces of steel before attempting the scraping of an action. Scrapers can be made from old pillar files by grinding off the cuts on the end. It is then necessary to draw the temper to a dark straw or purple in order to maintain the edge. The square flat sides must be stoned to a keen cutting edge and kept that way by the free use of oilstones while in the act of scraping down a surface. Much care must be exercised in the use of any scraper to keep it from digging into the metal. Only remove a fine scraping cut over the point in which the metal is to be removed, and no more. I would not suggest a scraping operation if a file can be used.

The removal of the old hinge pin is often a rather difficult job, and if it is to be pressed out, a special wedge must be made to fit the action channel so that the action will not be sprung when pressure is placed upon the pin. A special steel block must be made so that the action will be at right angles to the pressure applied, and a hole of sufficient size made to allow the pin to pass out freely upon its downward travel. Nearly all hinge pins are put in from right to left and removed from left to right. In some actions small screws are placed in the pin to keep it from working out. Some are applied from the end radius while others are placed in from the flat of the action. These screws should not be forgotten and their removal should take place before pressure is placed upon the pins. When such screws are discovered the hinge pins are usually screwed into place, but before the removal of any, ascertain the method used to fit them.

A new hinge pin should be made of good tool steel or alloy steel which has strength and density. Turn the pin about 0.0003 inch larger at the bearing surface of the radius, and if it is to be a press-fitted pin, allow about 0.0005 inch larger. If it is

to be a screw-fitted pin, allow at least a one inch shank so that a lathe dog can be fastened to one end and a perfectly tight thread fit can be made together with shoulder bearings. When the pin is placed very tightly in the hole, screw up the shoulder with all pressure possible, scribe the outline of the action on the pin, and under-cut to a depth so that sufficient strength remains to reset it again in the hole. Place a prick-punch mark on the north and south sides of the pin, allowing a slight angle; this is the true screw slot which is to be milled out with a fine slitting saw or fine hack-saw blade. The threaded end should project so that when it is faced off no center will show. After the screw-driver slot is milled in the head, the pin is set back in place and filed to the form of the action, and likewise on the threading portion. After both ends are finished and engraved, the pin is hardened in oil and the temper drawn to a dark blue over a steel plate or in fine sea sand, and then set in place to remain. The slight angle given to the screw-driver slot can now be pulled straight in line with the action by a brace screw-driver and pulled up tight by enough force so that it will never come loose. The 0.0002-3 inch oversize of the pin will give a very tight fit on the radius, and also when the action is opened or closed. This must be done a number of times to free the radius on the pin, but after fifty or a hundred shots are fired it will be at its proper set.

The bits, or grips, and bolt are next inspected. After the hinge pin is fitted there may be a little movement up and down between the barrel flat and action after the top lever is completely in its locked position. If so, a new bolt must be made or the slots filled in and new ones located on the lumps. A common method often recommended is to force the slots together. This is perfectly satisfactory on a cheap shotgun, but I do not advise such methods for those who wish to do better work. Careless quack ways often ruin a gun, so if the owner takes pride in his work he will never do such a shiftless job, even on a cheaper gun. Figure 146 illustrates the correct method of doing this work, which is

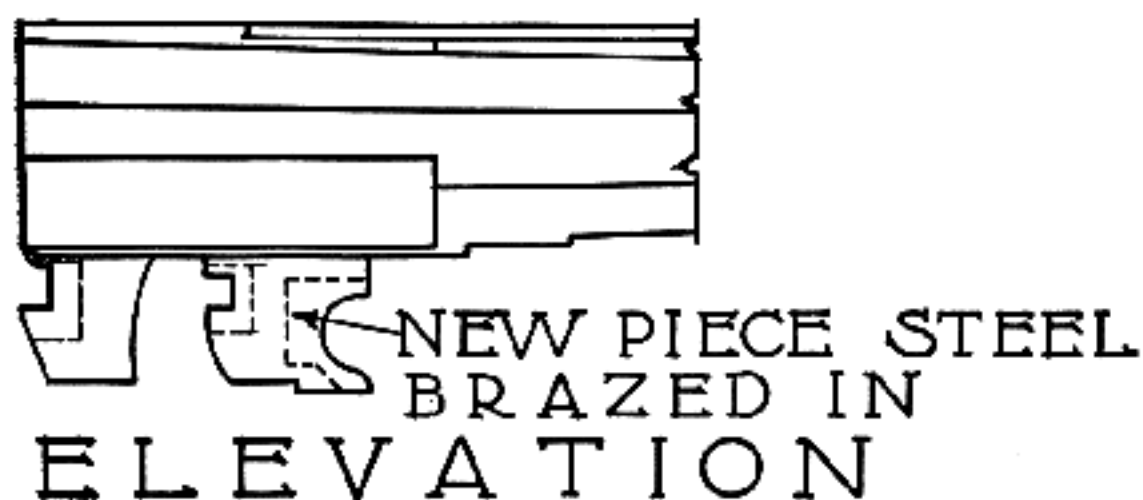


Fig. 146

Methods for making insertions in worn parts of shotgun lumps

filing or machining these slots out $\frac{1}{8}$ inch larger at top, bottom, and front, and making and fitting in a steel block. The dotted lines show these; the steel pieces are brazed into place and then new slots are filed out. In this operation, extreme care must be taken to have the bottom bolt enter evenly and with a perfect bearing surface. The bits or grip in these slots must be so that the bolt fits very evenly and squarely with a pulling-down action which will equalize the strain. A crooked, worn, or badly fitted bottom bolt is very apt to break, since it would have to stand the whole strain of the explosion. Therefore, this must be thoroughly inspected before the slots are filed out; whereas, in a well-fitted bolt the strain would be borne by the slots in the lumps as well as the bolt itself.

With the barrels joined to the action and adjusted as perfectly tight as the day the gun came from the manufacturer, you know that the job is well done and complete. On all the best guns, the ejector mechanism must be gone over. You may have made a slight change when fitting the other parts, and since the successful working of the arm depends wholly upon the accurate adjustment of the various parts, the firing and extracting mechanisms sometimes have to be refitted and made to work in more perfect harmony with the other parts.

Barrel Work — If the instructions in the first part of this chapter are beyond the comprehension of the beginner who has never had any mechanical training whatever, it will be well for him to begin his training with some of the more simple methods before he advances to the most complicated work. Start with cutting off the barrels of a shotgun if the muzzle has been damaged or an end has been blown off because of some obstruction in the bore, replace sights, lap a recess choke in cut-off barrels, fit ends of sawed-off barrels, and resolder the ends of double guns, etc.

Cutting off shotgun barrels at the muzzle removes all the choke in the end of the barrels, especially if very much is removed back from the muzzle. If only a small amount is removed and the gun you are about to perform this operation on is choked a considerable distance back, then a part of the choke remains, which is better than no choke. Regardless of choke you still have in your possession a shotgun, but if a muzzle is badly damaged it is worthless until the damaged end is removed.

With a combination square set against either the right or left barrel, scribe a line straight across each barrel; then reverse the barrels and do likewise, only connecting the top lines at right angles. These are the lines used as a guide to saw the barrels, for which a fine-tooth hack-saw blade is used. Hold

the barrels in a vise between padded jaws in a horizontal position with the chamber end supported on the gun brace. If the barrels are very thin, small pieces of wood must be made and placed between the top and bottom ribs and then clamped in the vise. Many a fine barrel is ruined by applying too much pressure on the barrels, particularly when they are very thin. After the barrels are sawed off, use a small knife-edge square and file the ends with a small mill file, test for square in every position, and solder the gap left between the ribs. The inside of the barrels and also the ribs must be filed off smooth with a fine needle file that can be used in all corners. This is done so that it is possible to tin the ends and have the solder adhere. Cut out a piece of tin to the exact form between the barrels and ribs and drive it in place, about $\frac{1}{8}$ inch from the end. It is placed in this position so that no solder will run down between the ribs and barrels. A heated soldering iron will close this end; allow a small amount of solder above the top and bottom rib. After being filed down, a continuous flat surface will exist between the barrels. Polish the end with fine emery cloth wrapped around the file and use the emery cloth in one direction only; complete the finish with a piece of crocus cloth in a similar manner.

For the front sight, drill a new hole in the exact center of the rib about $\frac{3}{16}$ inch back from the muzzle. Some shotgun sights are driven in on a taper and others are screwed into place. The former method is the most commonly used by shotgun manufacturers because of the simplicity with which they are driven in at a given depth; whereas a sight which must be screwed into place is more or less marred by instruments. It is necessary to place it a given distance from the top of the rib and have it tight at the same time. New shotgun sights which are purchased from the manufacturer have an instruction sheet together with square reamers to enlarge the drilled hole so that they can be driven in at any depth. Figure 147 shows a standard set. One particular point which must be



Fig. 147

Lyman front and rear ivory shotgun sights

taken into consideration when these sights are set in place is to have them in the exact center of the rib. A diemaker's square is used to locate the true

center, a small center-punch mark is made, the hole is drilled and reamed, and the sight driven into place.

After the barrels are shortened, it will probably be desired to have a choke in one or both barrels again. To make a recess choke—like that shown in No. 3 barrel in Figure 145—is very simple. As large a one as this is required, but be sure to have a length in the recess as long as the shot column. This is easily measured by removing the shot from a case and giving the same length to the choke that you are about to make.

The best fixture or head to use for this operation is a dental polishing expanding mandrel in which small pieces of glued circular emery cloth are used on a rubber expanding head and then inserted in the breast-drill chuck or used on the end of a motor. It is possible to expand the rubber emery-cloth keeper to any desired size by just tightening the knurled nut. Place a mark on the spindle to the depth you wish it to go in from the muzzle. Since the circular discs of emery cloth wear rapidly, keep the expanded head well against the walls of the barrel. When such an expanding arbor is used on a motor this recess can often be cut out very quickly, but if you only have a breast drill to perform this operation with, it is a rather tedious operation; still, with patience it can be performed easily.

At times it is not possible for the student to obtain one of these dental polishing heads and he must make his own expanding polishing arbor from a piece of hard wood. Take a piece of beech or white maple and turn out an arbor on the lathe or cut it out by hand, one end to fit the breast-drill chuck and the other end made to a diameter which will fit the end of the barrel after the emery and rubber bands are built up. On the end which holds the emery, drill and counter-sink the center, and screw into this a common flat-headed woodscrew. Then with a fine hack-saw or a coping saw, split the end two ways a distance back which will allow for expansion. Stretch rubber bands on the end and build up to a diameter which will just enter the barrel. Coat them with glue, roll the rubber bands in No. 90 or 100 emery, and allow to dry. Flour of emery is used for the final finishing laps. It will be well to make six or eight of these, as they are simple to make; as soon as one wears out, it should be replaced with a new one and also re-coated with glue and emery. By the time the last one is completely worn out the first one will be dry enough to use. With one end of these laps tightened into the breast drill, chuck and also mark or ring for the correct distance. As you are turning the drill, rapidly working it back and forth, a considerable

amount of metal can be cut out; but just as soon as the emery wears down and the rod becomes loose, withdraw it and tighten the screw on the end and then insert it into the muzzle again. Measure the recess frequently with inside calipers, carefully transferring and checking the measurement with the micrometers and comparing the measurement with that of the one taken before the operation was begun.

The rounded ends of the laps will give the correct rounded taper to the front and rear of the recess. The polishing operation should continue until the recess is enlarged 0.010 inch larger than the diameter of the bore. The direct object of this recess at the muzzle is that when the shot column strikes it, it expands enough so that when it hits the choked end it will have sufficient contraction to give the desired choke effect. The length of the straight portion should never be less than one-half inch. Be careful not to lap any metal out of the end, for this is the place where the diameter must hold, and when inserting or withdrawing the lap do not allow it to revolve.

The gun must be patterned often to see the results produced by your efforts. If patterns are not understood by the student it will be well to give a brief outline of the methods generally used for these tests. The diagram made by the pellets fired at a sheet of paper (48x48 is the usual size) is the "pattern" of the gun shooting. To ascertain the arm's shooting power, all the student needs to do is to fire at one of the large sheets of paper with one of the standard charges used for its gauge. For comparison with other results, the number of pellets striking within a thirty-inch circle may be taken to judge the shooting of the gun. A good close pattern is always a guaranty that the arm will have sufficient power to kill; the greater the mass of the shot or pellets, the closer is the pattern. No close-shooting arm has inferior penetration; therefore the nearer each pellet mark is to the common center, the less will be the distance between the first and last shot of the charge. This is the usual meaning of a close pattern. A bad or patched pattern proves a number of things; either the gun is improperly bored, the choke is not right, or the correct load is not found for the individual gun, etc. The closer the pattern is at forty yards, the longer the killing ranges of the arm will be with the intended load. I could devote much time to the subject of various patterns secured by altered chokes, but as space does not allow me to go into detail, I shall let the reader carry out his own test from his own angle, of loads from various gauges, securing patterns and killing circles which may be approximated.

It has been suggested to use an expansion reamer in the muzzle of a shotgun barrel to enlarge it and produce a larger pattern. Whatever you do, never thrust any form of expanded spiral or hand reamer into the muzzle of a shotgun. The only tool to use for the enlargement of a choke is either a shotgun choking bit or a fine finishing tool; or if it must be a reamer, a burnishing reamer. These are very expensive to make and the greatest amount which can be removed with one reamer is 0.002 inch, so it is much better to use the lapping operation as given in Chapter XVIII.

Removing Dents from Barrels — It is very easy to get a dent in a thin shotgun barrel through a fall or other cause. It is not advisable to shoot a shotgun if it has a very bad dent, because it is liable to split the tube when the shot strikes the bulge. Dents are easily removed, however, if one has the correct dent raisers to insert in the barrel and force the metal out again to the surface. Figure 148 illustrates three standard plugs; one is solid and the other two are adjustable forms working on a taper. In the same drawing the standard figures are given for each shotgun gauge which should be a standard for all shotgun bores, but because different manufacturers do not adhere to these sizes it is much better to use the adjustable gauge. The straight plug gauges are made in sets varying 0.002 inch in diameter, and as the figures given in *A* are the standard size of barrels, the variations must be minus from these figures. As an example, for a 12-gauge plug the maximum size would be 0.729 inch; the No. 2 size then would be 0.727 inch, and so on down until you have a set of eight plug gauges varying 0.002 inch, and the smallest would be 0.715 inch, which would be the starting plug.

In using the adjustable plug it is necessary to have a solid plug gauge to start out a bad dent; the adjustable taper gauge follows. One must be very careful with these taper gauges, for a great amount of pressure can be placed on the wedge effect which will bulge the barrels out and make it difficult to bring them in again. Either style of dent raiser must be made of tool steel, harden-ground and either lapped or polished. A true cylindrical surface free from grinder or tool marks will not place elongated scratches in the bore. Hours of labor are spent to secure this mirror-like polish which can be destroyed in a few minutes, and to remove such marks will often take a long time with a fine lapping operation. The drawing in Figure 148 is self-explanatory. Two flat pieces of tool steel are tongued and grooved on the shaper or milling machine and the tongues and grooves sur-

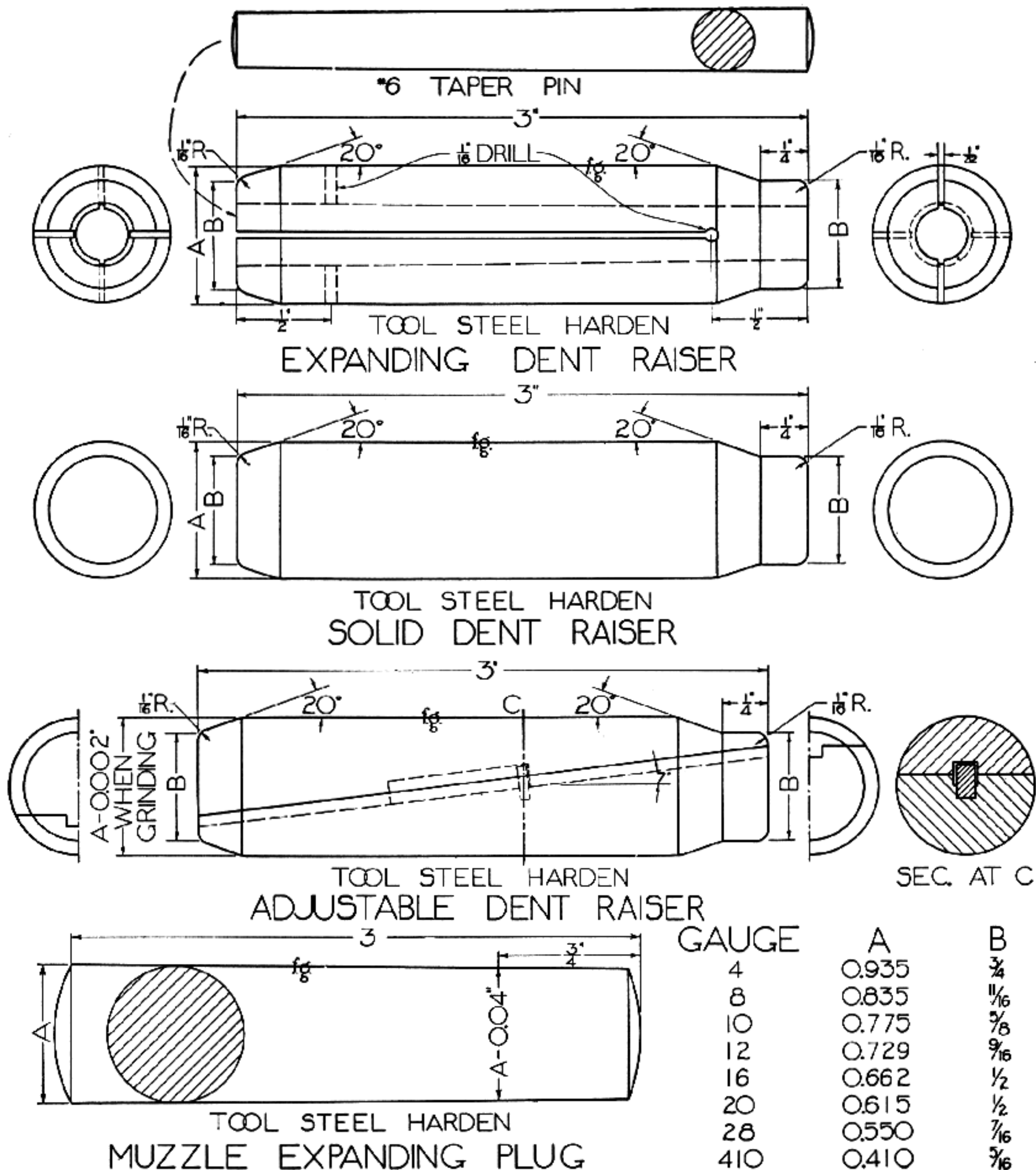


Fig. 148

Shotgun barrel-dent raisers

face-sweated together. The length should be left 1 1/4 inches oversize so that it will be possible to fasten a lathe dog to turn and grind the plug. Center the two pieces so that they will have between a 10 and 12 degree incline to the tongued and grooved section. Turn the plug in the lathe on center, allowing about 0.015 oversize for the grinding operation. Neck in the two ends so it may be broken off after they are completed and grind

off the broken sections straight across the ends. To harden, heat the two until they can be broken apart, and then scrape off the lead. At this stage it is well to place the pin in position as the dotted lines show; it is not necessary, but is placed in this position so it is possible to drive the wedge only a given distance. After the hardening operation takes place, the tongued and grooved surface is polished and the flat portion again sweated to-

gether. Use sufficient heat to just melt the solder, and bring them into the exact position as when taken apart. Grind to size and polish the outside diameter to a mirror finish. Heat the gauge again and remove all traces of solder. To use, place the raiser in the barrel, and hold a rod against both ends. As the gauge is inserted to its smallest size, place the raiser over the dent, hold one end with the rod from the front, and expand the wedge from the rear, which action pushes out the dent. A lead or fiber hammer should be used to tap lightly over the dent to even the outside surface of the barrel. If this operation is carefully done there will be no apparent indication of a mark upon the outside or inside of a barrel. A set of these dent raisers for the different gauges of shotgun barrels, harden-ground and lapped to size, is indispensable to any one doing very much shotgun work. They are invaluable not only to the gunsmith but to the man who happens to have a large collection of shotguns. It is such an easy matter to remove a dent with these that a set pays for itself in a short time.

The simplest method of removing dents is to make the dent raisers from fiber. Figure 148 illustrates a steel tool; turn the plug from a bar of round red fiber to the intended gauge, and also drill the center and ream it with a No. 6 taper-pin reamer. Use a standard No. 6 taper pin, which is carried in stock by most hardware dealers. When the center is reamed the pin should extend from the end at least one-half inch to allow for expansion. After the plug is removed from the lathe, it is drilled in four places; one-half inch from each end. The opposite holes on the other end of the plug should be 90 degrees from the other two. With a fine hack-saw or slitting saw on the milling machine, split the plug up to the holes from the opposite ends; when completed, there is only a web holding each end, and when the pin is inserted, expansion takes place evenly against the walls of the barrel.

A steel plug can also be made in the same way by hardening and grinding the outside. A dent raiser made in this manner is equal to the wedge raiser shown in the same illustration. If the student does not wish to go to the trouble of making the expansion plug from fiber, a set of plugs can be made like the one of solid steel shown, just as good as the hardened and ground plugs. This soft material will not harm or scratch the inside of the finest barrel. To use the expansion fiber dent raiser, thoroughly wipe the barrel out so that there will be no foreign matter to adhere on the fiber plug. Insert the plug with the pin in position, and with a piece of brass tubing place the plug over the dent. By inserting a solid piece of the brass from muzzle and a solid brass rod from the breech, the taper pin can

be driven into the raiser, expanding it to such a degree that the dent will gradually raise to the surface. As this takes place, the outside of the dent is lightly tapped with a lead or fiber hammer to smooth out the surface and at the same time expand the metal around the dent so that it will come out even and smooth. This operation requires great care, for if too much pressure is placed on the pin, the expansion will raise the surface of the barrel on the outside, as with the wedge raiser.

Many times a muzzle is dented or crushed in; the only way to correct this is to drive a muzzle-expanding plug in from the breech end of the barrel. Figure 148 also illustrates one of these plugs which is made on a taper and will take care of any barrel except those having a cylinder bore and greatly oversize. In such rare cases, a special plug is used from the chamber end and driven into the muzzle; as the plug is gradually tapped against the crushed end of the muzzle, tap the end of the barrel with a lead or fiber hammer to secure an even and gradual expansion of the metal to bring it back in place. Such a plug will evenly expand any badly bent-in muzzle, but it should never be inserted from the muzzle end because of the taper on the plug; it allows the end of the muzzle to become bell-mouthed, and such a condition will affect the pattern undesirably.

Special Ribs on Single Barrels, Etc.—I receive various inquiries for solid and ventilated ribs to be placed on gun barrels, but usually when the owners are informed of the work involved they use the arm with a rib, or try to place one on, especially if they have machine-shop equipment to do such work. A solid or ventilated rib can be placed on any gun barrel, particularly the ventilated type, as this rib is the easiest to work on a barrel and at the same time the most satisfactory in appearance. Barrel ribs are made between $\frac{1}{4}$ and $\frac{1}{2}$ inch in width, and the material mostly used is cold-drawn steel, machined to fit over the top of the barrel. The usual size of steel a rib is made from is $\frac{1}{2} \times \frac{3}{8}$ inch for shotguns, and $\frac{1}{2} \times \frac{1}{2}$ to $\frac{1}{2} \times \frac{5}{8}$ inch for rifles. Correct measurements must be made and the barrel and rib first drawn up on a sheet of paper; make it full size, and when these measurements are made in detail they must be adhered to throughout the machining and filing operations.

The best way to ascertain the correct height of a barrel rib when placed on the barrels is to take the length of barrels and from this length your figures. Different lengths require difference in the height of ribs. As a general rule, forty yards is the distance that any shooter fires at a given object,

and at this distance a heavy charge of shot will drop about 12 inches. Because sights on a shotgun are fixed sights, it is necessary that the end of the barrel be so elevated as to compensate for this trajectory at the established distance, or 12 inches at forty yards. Naturally a lighter charge of shot will not drop so much as the heavy one; therefore the figures must be on the heavy charge.

To ascertain the correct elevation, take the thickness of breech and muzzle, and carry out the figures so that the rib at the muzzle will be depressed. In shooting at forty yards, allow 0.004 inch for every yard that can be multiplied by 0.004, which will be the drop of the rib, or difference between heights at the breech and the muzzle of the rib for a 30-inch barrel. The front sight is not included in these figures. As an example, establish a set height at the breech which will be as low as a rib can be set; 0.004 inch multiplied by forty yards gives 0.160 inch which the rib must be depressed lower than the rear portion, forty yards being set as a standard. If the distance is greater, it will be necessary to depress the rib much lower, altho this is half the range of a well choked gun. Holding is taken into consideration to secure the difference, which will be explained later in the chapter. The difference we are concerned with now must be made by depressing the rib at the muzzle in order to have the pattern come in the center of the object shot at. Sweat both ends and middle of the rib, and at the tip end of rib, at the muzzle, place a small lump of solder in the center to be used for a sight. Test the gun with the standard intended load at forty yards. The first trial usually determines the changes to be made. The lump of solder used as a sight should not be any higher than the intended bead front sight.

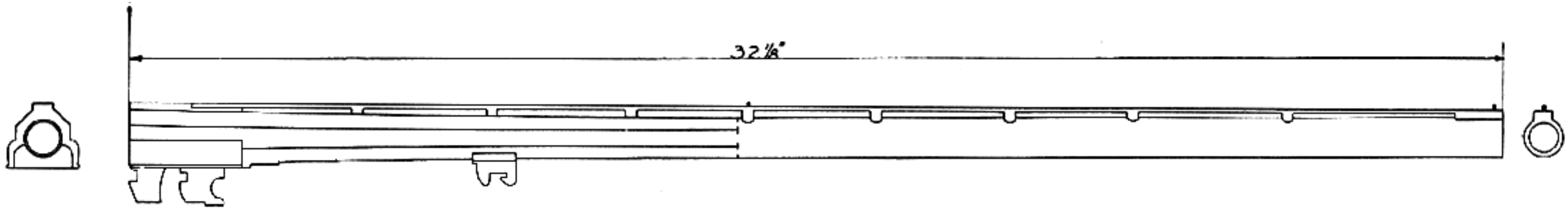
Assuming that the trial and height are proved to be correct, the actual making of the rib is a matter of machine and hand operations. The making of a ventilated rib requires the shaping-out of the legs or brackets at given intervals along its entire length. These may be spaced to a given distance along its entire length or may be shortened or lengthened either from the front or the rear, but a given length for each bracket produces a much better appearance to the finished rib. After the machining operation, a rib will look rather crooked and bent out of shape, so it must be straightened before being fastened to the barrel. Sometimes because of the thinness this straightening may be done with the hands alone, by bending and twisting the rib. If there should be short crooks, the hammer must be brought into use. Select a hammer that has a flat peen across or at right angles to the handle. The peen should not be too sharp, but smooth and

rounded at its edge. To straighten, place the rib on a smooth piece of hard wood clamped in the vise. Hold the rib on this, and with the peen of the hammer, strike light blows on the inner or curved side of the rib. Do not strike hard enough to dent or bruise the rib so as to show on the surface or the opposite side. By a little practise a rib can be made very straight and true. A rib should be straightened after every operation so that it will not be so badly bent that it requires too much finishing to make it look well.

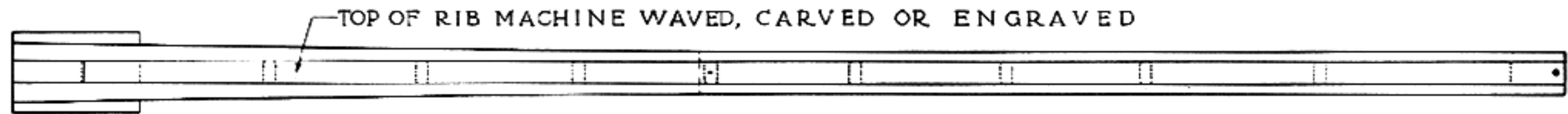
Matting the top is next in order after the machine work. Refer to Chapter XXII, Volume I, in which the correct tools and methods are given for this. Also refer to the drawing which illustrates the matting and border tools. A beautiful matted surface can be placed on its entire length, or again, if you have a milling machine, fine cross lines can be made; these are often seen upon some of the finest shotgun ribs. However, with the hand tools the student can produce a very pleasing effect. Matting a rib usually springs it out of shape very badly and also stretches it considerably; therefore, it must be peened and made perfectly straight again before it is fitted to the barrel.

Before fitting a rib to a barrel, a special holder must be made. Use one side of the hardwood piece on which all the straightening operations were made; this will save making a new one. Fit one side of it into a properly shaped groove, and make four clamps of wood, or use parallel clamps to hold it firmly in place in order to file out the radius in the brackets. Coat the barrel with Prussian blue and secure the bearing surface on each leg. This spotting operation will enable them to be worked down gradually until a true and even contact is made on each bracket in their respective locations. To remove the high spots, file lengthwise with a half-round file, and file so that the outer edges will fit closely and the center will have just enough freedom so light can scarcely be seen. The half-round file used for fitting the ribs should have the tang bent toward the flat side, so that when the file handle is put on, it will not interfere with the filing operation.

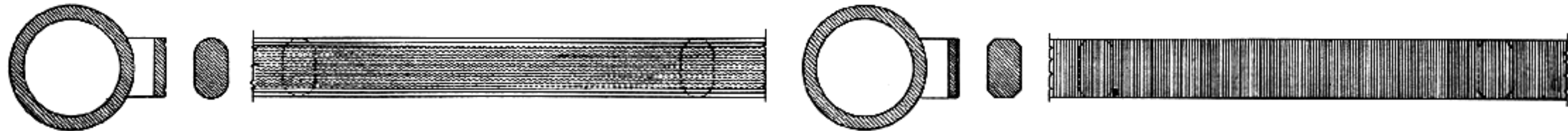
With the rib thus prepared the soldering or sweating operation follows. Since the radius section of the brackets is filed bright and smooth, so must the locations be upon the barrel. Bear in mind that solder will not adhere unless the surfaces are bright. With the rib held over the alcohol torch or Bunsen burner, warm each leg to the proper heat, just so the solder will run free, and by wetting the surface with soldering acid, together with the solder, a perfectly soldered surface is obtained. Each bracket must be done likewise until



BREECH ELEVATION OF RIBBED SHOTGUN BARREL DESIGN MUZZLE



PLAN OF RIBBED SHOTGUN



MACHINE WAVE DESIGN

STRAIGHT LINE ENGRAVED



CIRCLE PATTERN ENGRAVED

SQUARE PATTERN CARVED



DIAMOND PATTERN ENGRAVED

FRET PATTERN ENGRAVED

Fig. 149
Designs for ribbed barrels

the entire number is gone over. Have plenty of solder adhering to the radius, but try to keep it off the sides and under side of the rib. Also be very careful not to heat the rib so as to blue or blacken it, for in that case solder will not adhere, and the surface thus made must be repolished before going any further with the tinning.

When all the brackets are well tinned the inner surface of the rib must be well finished with fine emery cloth. Be careful not to disturb the solder on the radius of the brackets. The rib is again clamped in the groove on the straightening plank, and by holding it in this position there is no vibration and a high finish may be obtained.

Draw-file or draw-polish the barrel where the rib is to be fastened, and be very careful to have the surface bright and clean or else the solder will not adhere. Place the rib in position, mark each location where the brackets are to be placed, and tin. Be sure to have the space large enough so that when the brackets are in position the solder has a good space all around. Heat each place on the barrel over a Bunsen burner and only heat it enough so the solder will just run. Wet the surface with soldering acid, and with a bar or piece of wire solder-tin over each section which was laid out for the rib brackets.

When all the spots are tinned and the barrel is cool, place the rib in position, confining it in place with small "C" or parallel clamps over each bracket, and see that the rib is held firmly and at the true center on top of the barrel. Commence at the breech, and heat both the barrel and rib carefully over the Bunsen burner at the point of contact. Be extremely careful not to overheat either the barrel or rib, but just enough so the solder will run. To control this, hold a piece of wire solder in your hand and constantly test, and when it just begins to melt on the surface of the steel, withdraw and continue to the next bracket, and so on until the rib is soldered the entire length of the barrel. When cool, remove the clamp and wash thoroughly with hot water. This will remove the acid which would otherwise rust the bright surface of the steel. Wipe dry, and if the work is to stand for any

length of time, oil it lightly with No. 3 sperm oil, by rubbing it over with a rag which has been moistened with the oil.

The best way to remove the surplus solder at the joints is by means of scrapers. An old flat file about six inches long with the teeth ground off on each side may be used there and also on the sides for one or two inches at the end; also grind the end square. By using the tool in the manner of a chisel, it is very effective. A scraper made from an old three-square file with the teeth ground away at the end is also a very good tool to get into the corners, which could never be reached with the flat file. Carefully remove all traces of solder, for bluing will not take effect where any solder remains.

Figure 149 illustrates a ventilated rib barrel and also six sections of different styles of brackets: straight, round or pear shaped, and the diamond form. The straight bracket is the easiest to make; the pear or diamond forms have more work attached to them, but they look more artistic when completed. Figure 150 shows a rib extension which can be fitted over any standard shotgun rib on single-barrel guns; this allows the shooter a better sighting plane.

To Re-solder Ribs—It often happens that double guns have the rib loosened from the barrels at the forearm lug. It is an easy matter to reunite these. To do so, carefully raise the loose rib as far as possible without bending it, and hold it thus in place by inserting a piece of wood sharpened to the form of a wedge to retain it out from the barrels. With a thin scraper, scrape both barrels and rib where they come into contact with each other. Wrap the barrels well in different locations with soft iron wire; four to six strands to each wrapping, with the ends twisted together, are sufficient. Place the wedges between the wire and rib. Any small round cold-drawn steel may be used, just so that pressure can be placed between the wire and ribs. With the ribs thus in place, hold the raised section of loose rib and barrel over the flame of a Bunsen burner, and tin the parts, using only

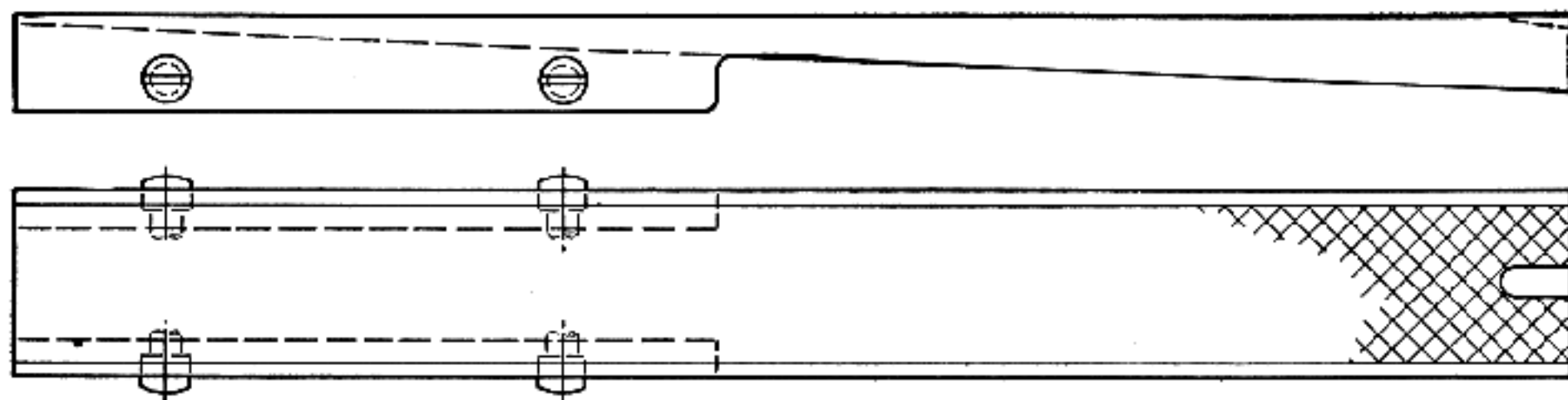


Fig. 150

Shotgun rib extension used on single-barrel trap guns

rosin and small soldering wire. When both rib and barrel are tinned, put the rib in place by wrapping wire over this section and hold it in place with a wedge. It may require two or three wrappings of wire in the location to hold a rib in place before a perfect job of sweating is achieved. Complete the sweating operation over the Bunsen burner. Exercise the usual meticulous care when placing it over the flame of the burner. If it is done properly the joint is scarcely noticeable. If it so happens that solder shows between the ribs and barrel, a scraper for such work can be made of a small three-square needle file with the sides ground to remove the teeth; sharpen it to a point. Binding wire, well wrapped around the barrels, and wedges set well in place, are a precaution against starting the ribs from the barrel by heat. With this security there will be no harm done even if the solder is melted between the ribs and barrels in proximity of the loose rib.

Loose Forearms — A common defect found in most of the cheaper arms is the common "snap-on" type of fore-end in which a curved spring steel lever is used. The length varies for different guns; some are about one inch long while others are even longer. One end has a pin to fasten it in one end of the fore-end iron with a small flat spring holding it out from the iron when removed. To tighten these, remove the lever and test with a file for hardness. If the file makes no impression on it, draw the temper over a gas flame until a very dark blue color appears, and then peen the lever, which is a method used to stretch the metal. Peen on both sides of the lever; by this operation a lever is often made to work very successfully. To check the amount the lever has stretched out, use a micrometer and compare the readings. After the lever is lengthened about $\frac{1}{64}$ inch, set it back in the forearm iron without the wood in place to see if it snaps into position very hard. If so, the peening has achieved the desired results. At times, less

curve will do the same thing. Since the lever is in a semi-annealed condition, straighten it out a little at a time until it holds the fore-end iron in place solidly. It also happens on this type of fore-end that the iron has become set too deeply in the wood; therefore, it must be refitted to have it snap back into place.

As a rule, very little trouble of this kind is experienced on the better grade of shotguns, as the system of locking is the best. It requires quite a few mechanical features which are not complicated but very effective in holding the fore-end in the correct locked position. When fore-ends do come loose it is usually caused by a broken or weak spring.

Arms which are now obsolete come in with lost fore-ends; it usually costs more to make a new one than a new gun could be purchased for. This operation requires so much machine work that it would not be practical to go into detail concerning it.

Broken Parts and Renewals — Occasionally broken parts can be repaired by welding or brazing operations. Naturally there must be some line drawn between the two methods. Parts such as trigger guards, hammers, triggers, etc., can be successfully welded, but the setting in of pieces of steel to be filed out for notches, etc., can be more successfully brazed than welded, because it does not require the heat radiated by the acetylene flame. Broken tumblers which have the firing pin integral with the body are best replaced with new ones or a new one made if on an obsolete arm. Welding the tumbler is not as successful as making a new one of a piece of well tempered alloy steel. Broken strikers are always made from chisel steel and given the correct heat-treatment, which will last the life of the gun. Some strikers or firing pins are made from very poor material and it is always well to have an extra set of these made up which may be used to replace one if it should break.

When working down the trigger-pull on a shot-

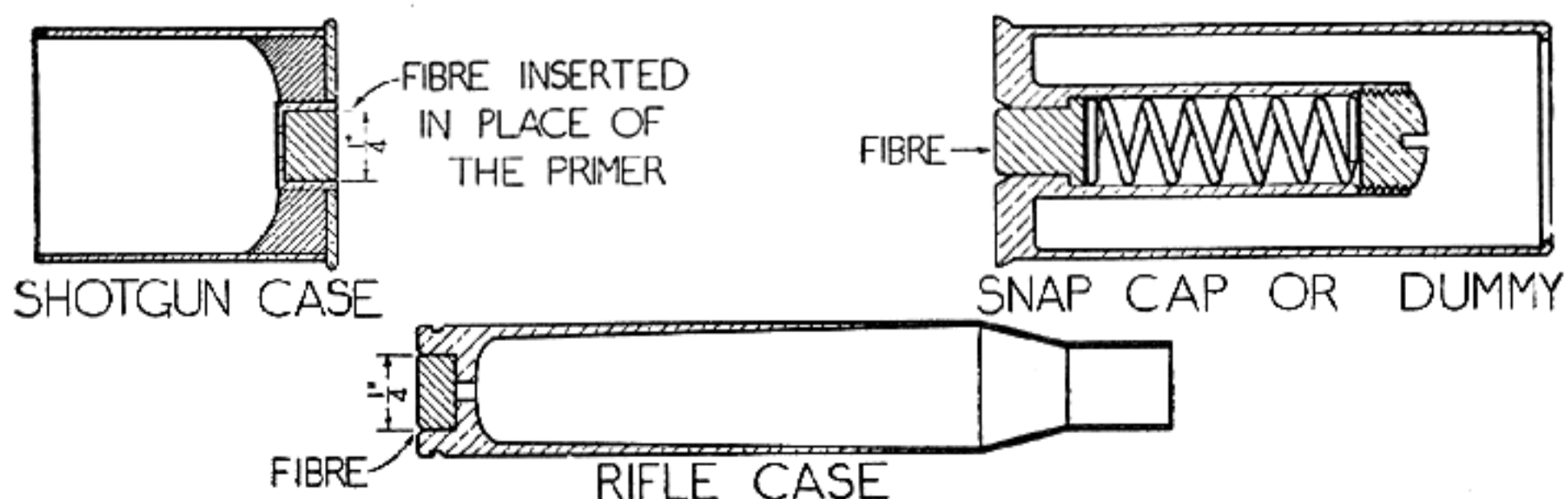


Fig. 151

Snap caps: used when trigger pulls are tested

gun, dummy cartridges or snap caps should be used in the chamber. For that matter, snap caps should be used on a number of firearms to eliminate the possibility of the breakage of firing pins. Figure 151 illustrates a method which can be employed on fired cases, by inserting a piece of fiber in the primer pockets. First, ream the pocket out to $\frac{1}{4}$ inch and turn a piece of fiber, either red or black. Press it in place and face it flush with the face of the case. By using these dummy cases in the chamber, you avoid all injury to the striker. The greatest damage is done by the continuous snapping of hammers and tumblers against empty space, causing the firing pins to crystallize and break; but inserting the fiber in the primer pockets eliminates such breakage. Snap caps can be purchased for any gauge of shotgun. These have a strong spring behind the piece of fiber, and when the striker hits the soft material there is enough tension in the spring to take up the shock of the blow. However, the dummy case made with the fiber inserted solidly in the primer pocket is particularly good, regardless of the gauge or caliber of the arm.

When most men pick up a firearm their first impulse is to snap the triggers, not only once but a dozen times. Such men are like boys who, when they have an arm in their hands, must play with it. They never realize the damage they do in snapping the gun. We must place a dividing line between a bolt-action rifle and arms which are constructed with a firing pin, either separate or a part of the hammer; the latter arms are shotguns, single-shot rifles, and some revolvers. When such arms are handed to these individuals, snap caps can be inserted without fear of their breaking the firing pins or strikers.

The usual cause for the breaking of firing pins is excessive snapping of the locks without a dummy or snap cap in the chamber. If pins have become damaged or are too loose in the action, the making of a new one is a simple matter, for all pins are made from high-grade chisel steel. To ascertain the size of a pin, try the old pin in the drill gauge, and if a pin is lost, gauge the pin hole with a drill from the set and select the size of drill rod which the drill has determined. On some foreign arms the holes in the action differ from our standards. If so, order the next larger size of rod, and polish or file it until it has the correct fit into the hole. Cut the pin to length, and file and polish the end to a radius. Harden and draw the temper to a blue. Refer to Figure 129, Volume I.

Damaged fillister-head action screws must be made up on the lathe and fitted into the thread. A number of the screws used on shotguns are not standard, so they must be made. Fit the screw

and undercut the head, and when in position place a small prick-punch mark on the head facing north and south. After removing, cut the screw slot either on the milling machine or with a very narrow hack-saw blade.

Wood screws are easily replaced, for such a large variety is made that one can always be found for replacement. If the wood has become rotten around the hole, fit in a wooden plug, glue it in place, and refit the new screw. Screw heads may be artistically decorated by referring to Chapter XXII, Volume I.

There are various little points which have been neglected in this chapter; one of these is the spring work in a shotgun, but as I have taken this up in other chapters, it will be unnecessary to rehash the same information. However, there still remains a bit of special information which should be imparted to the reader on the question of shotguns, and which, I am sure, will be quite welcome.

When I have taken men on the range to test their arms and try to teach them the correct "stance" in shooting, I have found that most of them willingly change their ways and are very apt pupils. There is one point, however—and this part of the subject need not have been mentioned—which sometimes eludes them. "How to shoot" is not merely discharging a gun. It is taken for granted that every person old enough to handle a gun should know how to fire it when loaded. What is meant then by "how to shoot" is how to shoot *well*, and in teaching any one to do this, one of the most important requisites lies in taking aim on the object at which the person is expected to shoot. Nearly all young people close one eye when shooting. With a shotgun a man will learn to take aim much sooner by keeping both eyes naturally open than he will by holding one closed, but it is a hard thing for many people to do. The "hiding eye" will "close up" just as the finger is pressed on the trigger, and with that closed eye there is always a deviation of the gun from the line of true aim. With a little practise one should see the powder gases at the muzzle with both eyes open. While shooting from a high point when light conditions are right, a few shooters can follow the bullet from muzzle to target, even on a high-velocity arm. Such conditions can never be realized by a shooter if he holds one eye closed, for it is only natural to assume that if he closes one eye he is robbing himself of half his vision. The one eye cannot see the whole of the object at which it looks, but only a part or one side of it; therefore, it requires the use of both eyes to see and estimate distance correctly; one eye may outline an object, but it calls for the employment of two eyes to give it a perfect perspective.

When an object is hastily caught within the range of both eyes, the sense of vision is instantly assured as to the position of the object, its distance from the gun, and if moving, the rate of speed at which it is moving. Through mental contact the brain is promptly impressed with all of this, which gives confidence, and consequently, calmness. Here the main object favoring success has been attained by calmness and a strong belief that the shot is going to succeed. The instant this is felt is the one at which to press the trigger. The western expression "crack down" means that a quick correct sight is secured, whether there is time to think about it or not, and hence an instantaneous discharge of the arm takes place with both eyes still on the object or game.

Distance requires elevation in proportion; therefore a rifle is fitted with sights which have both the elevation and windage to meet various distances. The elevation of the rib on a shotgun is fixed and immovable. But by a simple law or perspective, when you look at an object eighty yards away and mechanically bring the sight to bear upon it you have the action of the gun lower than if it were only forty yards off; whereas if you adopt the one-eye system, you fire at exactly the same elevation at all distances. It would be as absurd to take a level aim along the rib at eighty yards as it would be to fire a rifle at a range of 600 yards with the sights set at 100 yards. While everything has been done to give the correct sighting features, we have in rifles today to take full advantage of the increase of power. As long as the one-eye system of shooting is adopted by so many, the object, if hit at all, will be struck by only the outside pellets of the pattern and not by the effective central shot. The proper method is to throw the gun well up and into the shoulder; the drop and possible offset will then bring the gun right in front of the face; the head being erect and both eyes fixed intently on the object, the line of motion is commanded and the aim taken instinctively. The central shot or pellets have thus an allowance given them to compensate for distance and the motion of the object. You look along the imaginary line, higher at the breech according to distance, and at this elevation the gun is fired, exactly as a rifle shot sets his aperture sights to a given distance.

Because so many do not understand these simple laws of correct shotgun shooting they come in to have a stock changed to compensate for their bad shooting, or else present various other excuses. After their faults are pointed out they usually go away with a better understanding of their gun. I remember one very amusing exception, however. This man shot at thirty-one hill rabbits in one day

and only raised a few feathers from their tough hides. He wanted a gun to use a special three-inch shell and No. 2 shot so that he could penetrate the hide of a hill rabbit. If any of my readers go after hill rabbits, do not blame the gun or the ammunition you are using, but yourself and the use of one-eye shooting.

The most important advantage we derive from the use of two eyes is that it enables us to see distance, or the third dimension in space. That this vision is not the result of experience as monocular vision is, is obvious from the fact that distance is seen as perfectly by children as adults; it has been proved by naturalists that animals newly born appreciate distance with the greatest correctness.

In many instances a shotgun shooter wishes to know the patterning of his gun after changing the choke. The following tables and methods are a means of understanding this as well as the methods of figuring out the percentage of choke. They show the per cent of total pellets in the thirty-inch circle for four different choke borings of barrels at the range indicated. The number of pellets represented by the percentage for any size of shot-charge is easily figured by knowing the total number of shot in the charge.

Example—Charge $1\frac{1}{16}$ ounces of No. 4 shot fired at 40 yards for an improved cylinder barrel. Total of pellets, 181, multiplied by 50 from the table, and divided by 100. Answer, 90.5—pattern 90 per cent.

Range	True	Improved	Half	Full
	Cylinder	Cylinder	Choke	Choke
	Per Cent	Per Cent	Per Cent	Per Cent
30 yds.	60	72	83	95
35 "	49	61	71	82
40 "	40	50	60	70
45 "	33	42	50	60
50 "	26	33	40	48
55 "	21	27	32	39
60 "	17	22	26	32

Oz. of Shot	Size of Shot						
	4	4½	5	5½	6	6½	7
1½	255	300	330	360	405	450	510
17/16	244	288	316	345	388	431	489
13/8	234	275	303	330	372	413	468
11/16	223	263	289	315	355	394	446
1¼	213	250	275	300	338	375	425
13/16	202	238	261	285	321	356	404
11/8	191	225	248	270	304	338	383
11/16	181	213	234	255	287	319	361
One	170	200	220	240	270	300	340
15/16	159	188	206	225	253	281	319
7/8	149	175	193	210	236	263	298
13/16	138	163	179	195	220	244	276
¾	128	150	165	180	203	225	255
11/16	117	138	151	165	186	206	234
5/8	106	125	138	150	169	187	212
9/16	96	113	124	135	152	169	191
1/2	85	100	110	120	135	150	170

Do not become too anxious concerning the tech-

nical performance of any shotgun or its ammunition. Such matters are usually studied by the makers of the best guns.

The shooter who makes tests of patterns and penetration should never take his results too seriously. Nearly all the standards are based upon averages, and concrete results may vary considerably without implying that anything is wrong.

Many who may suspect themselves of being poor shots should see whether their guns are choked too greatly. Shooters in constant practise can often turn it to better advantage than the occasional shooter. To have the right barrel a true cylinder often saves a man from missing very easy shots and also saves for him a considerable amount of game.

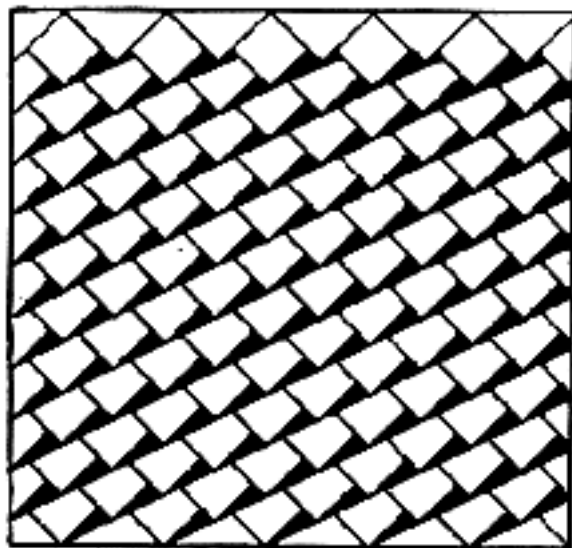


Publishers' Photo Service, N. Y.

Fig. 152
Sunrise: and soon the ducks overhead

CHAPTER XXVI

The Art of Gun Engraving



The Art of Gun Engraving

THE engraver is classed as an artist. Gun engraving is indeed a profession, for it requires years of study to become dexterous and a master of the art; and when it comes to a finished gun engraver who is capable of originating elaborate designs which are oftentimes masterpieces, such talent means a lifetime story. Only a true artist, when he looks upon these illustrations, can appreciate the value and effective beauty in such perfect workmanship on metal. Art of this nature requires an extraordinary amount of patience and love for the work. The engraver not only uses various tools to chisel these designs on the steel surfaces of a firearm; he must be able to use a pencil and pen to place his thoughts on paper first, perfect in every detail; he is an artist combining manual and artistic skill in his execution. Such a man is like all genuine artists, calm and temperate, never mingling with the crowd or superficial society. A perfect understanding of the beauties of life is that which endears him to those who love the work produced by his hands.

This chapter has been made possible by Mr. R. J. Kornbrath of Hartford, Connecticut; various illustrations it contains are from his hands, and every one is a masterpiece. His ability extends not only to sketching or painting this work on canvas or paper, but transferring it to steel parts with chisels and a hammer. Do not, however, be awed like the young painter who, when he saw an original Rubens, burned his palate and brushes. First, acquire the principles of free-hand sketching with a pencil, then transfer the drawing through the aid of engraver's transfer wax, on the steel, and carry out every little detail with well-defined lines. Experiment on small pieces of steel with some simple line or scroll engraving, and when you become proficient, apply your knowledge and skill to more elaborate designs.

If you have attempted to etch steel as described in Chapter XXII, Volume I, there is little doubt as to whether you can master this art. The term applied to engraving on steel is called chiseling and is achieved with a hammer and various forms of chisels. The most-used chisel is a pointed or onglette graver. Companies handling such tools may be found listed in the appendix. A No. 5

or 6 Renard is preferable, and these tools can be made by yourself through information obtained from chapters pertaining to that type of work. (See Figure 153.) A complete set of engraving tools costs very little in comparison with others used in gun work. Perhaps it will be easier for one who is just starting and is not accustomed to handling the chisels, to have deeper lines laid out on the steel surface, for much can be done with engraving tools if the design is etched into the metal first.

The steel that gravers are made from should be the finest quality of tool steel containing a high percentage of carbon. It will prove cheaper in the end to procure these tools. They are mostly made in Switzerland, France, and Germany, and because of the makers' long experience the steel from which these gravers are made and their temper are perfect for work upon gun parts. The gravers come from the manufacturer without handles, but these may be had in any desired shape. A regular file handle may also be used with a steel plug inserted in the end of it. The steel plugs are made of cold-drawn steel and the file handle is drilled out from the end, the tang of the graver not being touched. This plug is inserted so that the hammer will not touch the wood, which affords a solid base when the hammer strikes.

All gravers must be kept at a very keen cutting edge and only stoned from the point. There is a special graver sharpener made, in which the graver is set and held at the correct angle, while on the opposite end there is a roller which reduces all friction as the graver is brought back and forth in the act of sharpening. The stones used should be fine Washita and Arkansas perfect white to produce the keen edge. A special graver sharpener is not usually required, unless one wishes to hold the same angle on all the tools he is using.

Figure 153 illustrates different forms of gravers; flat gravers come in numbers from No. 0 to 14; pointed onglette gravers, from No. 0 to 6; half-point and knife-edge gravers only come in one size. There are two half-point gravers, right and left hand. Bevel gravers are numbered from 1 to 6; square and lozenge gravers from No. 1 to 8. Flat chisel gravers come in three sizes, Nos. 1, 2, and 3;

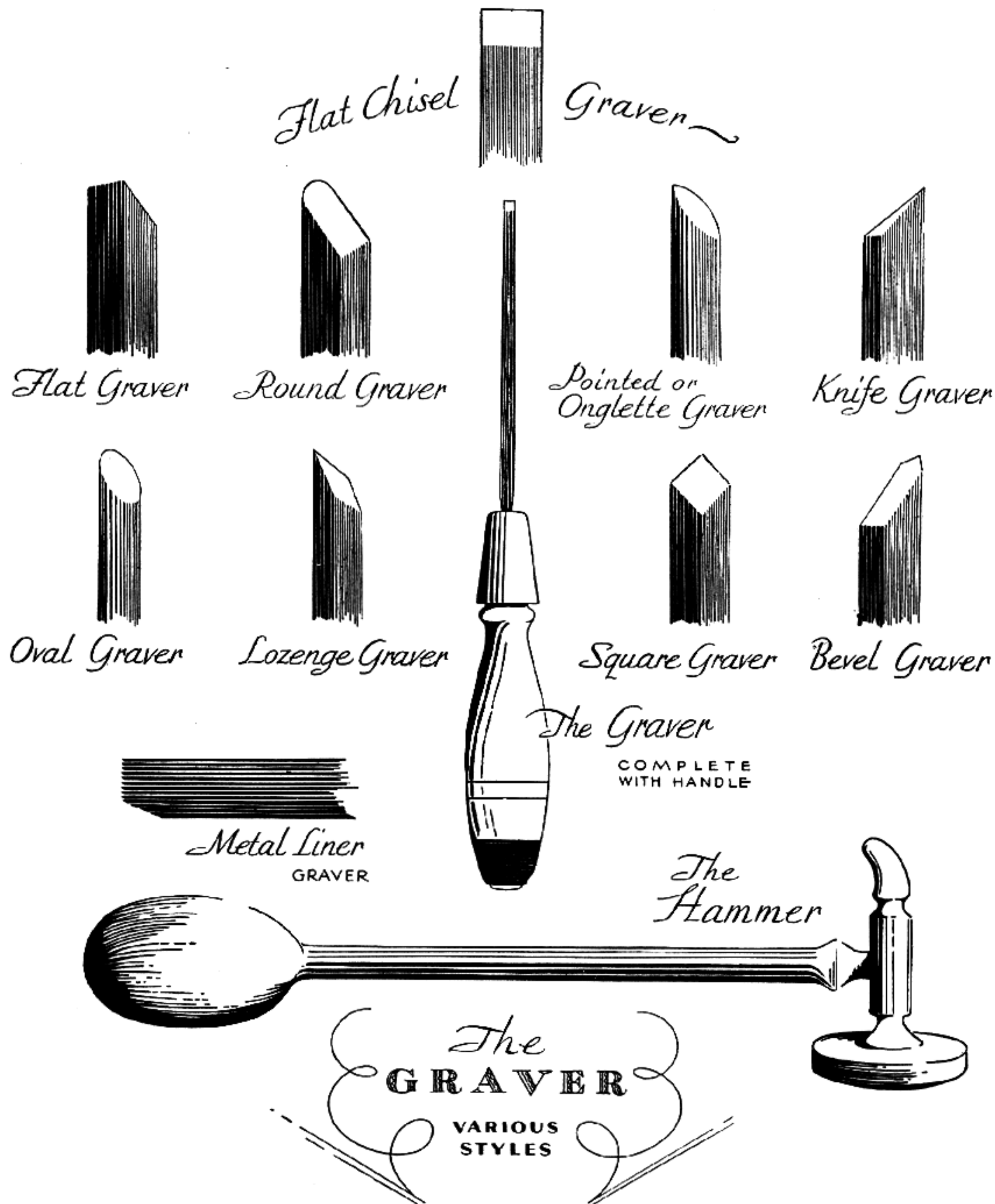


Fig. 153
The steel engraver's tools

and also flat graters from No. 36 to 49. Lining graters are made in thirteen sizes from No. 8 to 32. There are from two to twelve lines to a tool, No. 8 being the coarsest and No. 32 the finest.

Chiseling is done by holding the tool in the left

hand and the hammer in the right. A special hammer should be used for this work; it should not be too heavy and neither should the handle be too clumsy or out of proportion, but rather have a little spring to it as the blows are struck. The

object or part of the gun to be engraved or chiseled is held in a vise and the work is done standing in an upright position. When cutting straight lines, place the tool on the object and tap the handle of the graver or the steel insert with the hammer. Special care should be taken not to tip the tool too high; this is to prevent digging too deeply into the steel. Only practise will bring a straight and evenly cut line to depth and clearness. The beginner will find the cuts ragged and uneven, but if he applies determination and gives himself time, improvement is certain to be his reward, and he will find just as much pleasure in engraving designs upon metal parts of a rifle as he will in making a new stock from the finest Circassian walnut. In chiseling straight lines, the tool is held steadily in one position while the handle is tapped by the hammer; no wrist motion is required.

In chiseling curved lines, the wrist of the left hand, in which the tool is held, plays the most prominent part in the execution of the work. In cutting a line curving to the left, the wrist assumes the same motion, and if the line is curving to the right, the wrist follows the line in that direction.

This also applies to short curved lines, but on long curves a certain degree of body motion is also necessary along with the wrist. All this work is done standing up, and the body motion consists of stepping along and turning with the curved line while chiseling. In whatever way the curve is cut, the body naturally moves in that direction.

A spiral must be chiseled in sections; certain parts are chiseled toward the right and others toward the left. This also applies to less curved lines. Such work is best done in an engraver's swivel vise, but if you only have the regular bench vise which swivels, it can be left loose and turned in the desired directions. By turning the swivel vise, you often save chiseling a curved line from two different directions; all you have to do is stop chiseling when unable to go on, turn the swivel vise, and continue chiseling in the same direction. It will frequently be found necessary to swing it to right or left during execution of the work.

Shading of leaf work is usually done with a lining graver, which Figure 153 illustrates. These graters are made in a variety of widths and a number of lines, and are used in the same manner as a chisel

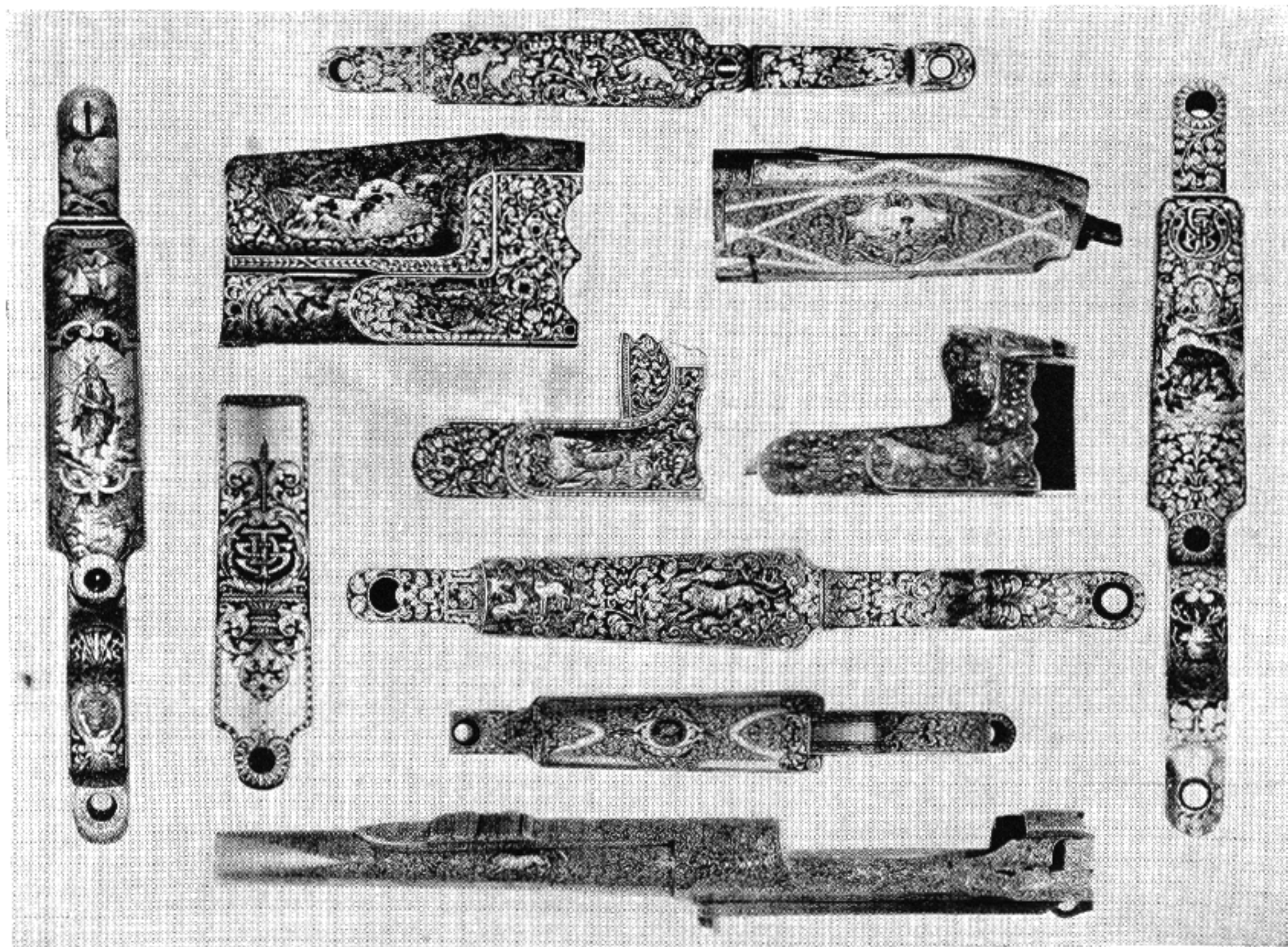


Fig. 154

Only the finest engraving is appropriate for the better arms

which makes several lines at once. These tools should be used often by the beginner, for they produce very finely shaded lines. By tipping the liner a little to one side or the other you will find that the lines produced graduate in depth and some very nice shading can be produced. This lining tool is seldom used by the gun engraver who is producing a fine piece of work; instead, all the shading of ornaments, etc., is done with a hand tool which only produces one line at a time. The beginner can use a number of lining tools on sight ramps, line of sight over the receiver, or other places about a rifle where fine shaded lines give a pleasing appearance. Much patience and practise is required to have clean and evenly cut lines on a steel surface, but if one has a talent for drawing, together with determination and willingness to give such work a trial, he will spend many hours of pleasure.

Etching — Before a design is etched into the metal parts, instead of using varnish to cover the design, the finished gun engraver uses a lacquer of his own preparation; it consists of one part white beeswax, one part mastic, and two parts pulverized Syrian asphaltum. Melt the white beeswax in a clean receptacle and add mastic. Mix the two ingredients thoroughly and add pulverized Syrian asphaltum. All should be melted together evenly by stirring while they are under heat. It requires some time before these parts are mixed thoroughly. Keep agitating by constantly stirring until you are satisfied that all is mixed. Pour the contents into a pan of water, and while it is still warm, press it into small bars with the fingers. This material produces the covering lacquer for the design to be etched; however, it cannot be used for covering in that state. When ready to cover the design, with a sharp knife scrape a small amount off a bar into a shallow, small, clean dish and add enough pure spirits of turpentine to dissolve it. Always keep this lacquer protected from dust, etc.

Should the part of the gun which is to be etched have any screw holes or other openings, they should be plugged with wood and wax and the part thoroughly cleaned to remove any oil spots. Should the design to be etched be of a complicated form, the engraver draws it free-hand on the gun part with a steel marker. This should be done before the part where the surface to be etched is cleaned.

The design is now ready to be covered with the lacquer, which is done free-hand with the aid of a fine pen, just as if drawing with pen and ink on paper. The lacquer should not be too thin but just thin enough to flow readily through the pen. Care should be taken not to touch any part of the design already covered, before it is thoroughly dry. If

you do not touch it at all, even dry, so much the better.

When the ornaments are covered with this lacquer and are thoroughly dry, the large surfaces on the gun part, such as the under side, are then covered with a mixture of asphaltum and wax, which the gun engraver also prepares himself by melting the two together. This, of course, must be warm in order that the surfaces may be painted with the aid of a small brush. When you are certain that no metal is exposed with the exception of the background which is to be eaten away around the orna-

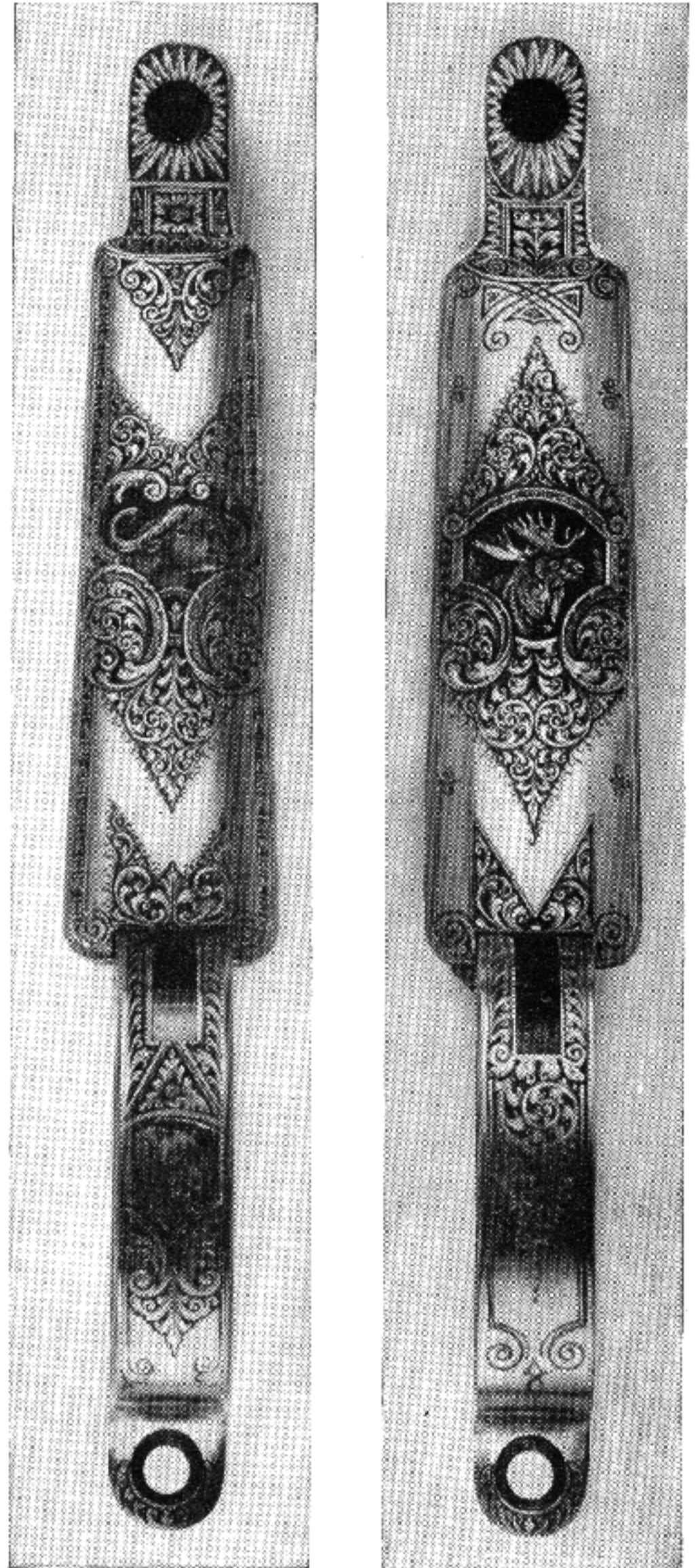


Fig. 155
Mauser magazines and floor plates. Animal heads
in high relief work

mentation, then is the time to hang the gun part in the acid—as described in Chapter XXII, Volume I.

For fine and deeply etched designs, the design or ornamentation, especially stems of leaf work, should

be held a trifle heavier upon the steel parts being etched, or else the acid is likely to under-eat to such an extent that the fine lines will disappear altogether.

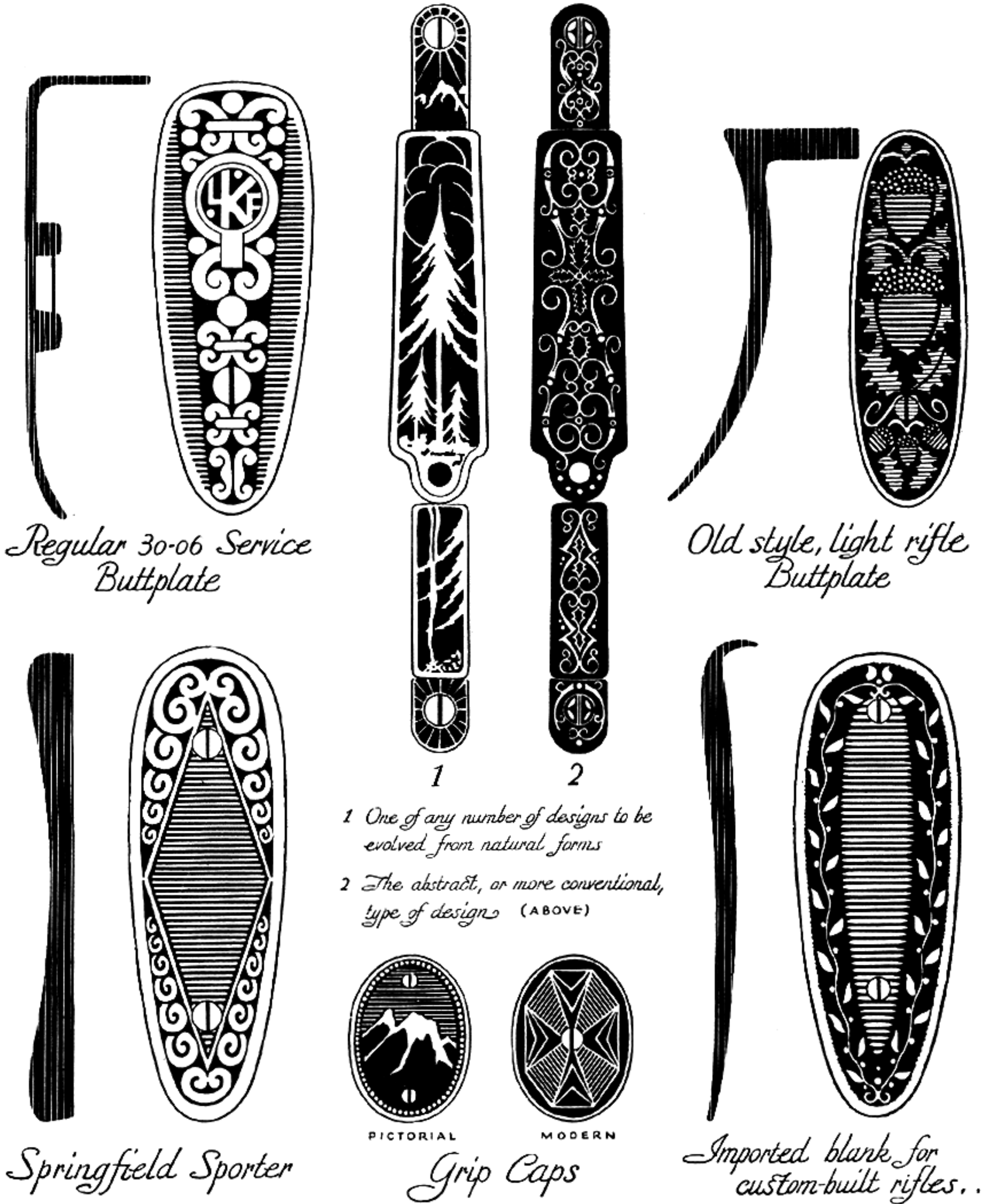


Fig. 156

Design suggestions for etching or engraving on butt plates, floor plates, and pistol-grip caps

When the gun part is etched deeply enough, take it out of the acid and wash with water. The covering lacquer is removed with the aid of a cloth dipped in turpentine and the wax with a little heat and a soft cloth.

The gun engraver now has the ornaments in relief with the background eaten away. He proceeds to use his engraving tools for the purpose of cleaning out ragged lines, cutting out fine points of leaf work, and—very important—the shading of leaf work. It may be that you wish some modeling of the ornamentation which has been etched out. All this is done with different tools and punches, and the one who knows his profession is capable of producing a most beautiful piece of work. Matting of the background will add much to the work.

Of the few useful articles which can be decorated to a high degree without marring their beauty or efficiency, the rifle, shotgun, and hand gun are foremost. The prevailing idea that engraving is very expensive is without foundation. Because of their erroneous ideas many sportsmen would rather have a plain gun. A firearm devoid of any engraving looks very well when new, for the coloring of the bluing or case-hardening on a shotgun action supplies the requisite ornamentation. When the firearm becomes a little worn, the hardened surfaces begin to assume a far different color, especially on a shotgun. When the bluing begins to wear off, it changes the steel to a dirty-white hue. The rich blue on trigger guards, bolt handles, forearm irons, etc., also wears down to the bright white metal. On shotguns, the joints between sections of the action and barrels become too apparent and are obtrusively to the fore, and the gun offends the artistic eye more and more as time advances; whereas, the wise expenditure of only a few dollars for some fine scroll engraving would furnish lasting decorations. The greater the wear, the more the fine qualities of the engraving and graceful outlines of the arm appear. Figure 156 illustrates various designs that can be used either for etching or engraving.

Many object to engraving because the weapon cannot be so readily kept clean; therefore, the lines of the engraving should be kept shallow so that the engraved surface is as easily cleaned as any of the plain parts. The real objection appears to have been the practise of high relief work on cheap arms; the difference in quality and price dependent upon the amount of engraving rather confused the buyers of these arms. The natural effect of this was that such engraving was a comparatively cheap process badly cut into the metal. These inexpensively produced arms had a few dollars spent on the engraving and were sold as, and represented to be, arms of the best grade. These guns mostly came from

Belgium and Germany and importers sold them at extremely high figures.

Of recent years the demand for highly engraved guns has greatly increased, and because of these demands I have sent all my work of this type to Mr. Kornbrath. He has supplied some beautiful specimens of decoration, as the cuts will show. In some instances the work consists simply of scroll design, while others are of sporting subjects chiseled in low relief in the metal itself; in others, the decorations have taken the form of allegorical figures embossed in high relief upon the floor plate, guard, and barrels, in gold, platinum, and other precious metals. The cut which has an Indian design upon the floor plate and guard of a Springfield is one of the finest examples of the engraver's art. Naturally, a masterpiece like this greatly enhances the value of a gun, and it is an easy matter to spend a thousand dollars upon decorations alone.

In the engraving of guns for customers, the usual recommendations are not elaborately engraved decorations unless all other parts are within keeping; these comprise beautifully figured wood, barrel and fittings perfectly blued, and fine checkering or carving. The money so expended, if it could not be spent to better advantage in workmanship on metal and wood, could at least be so expended that attempts to misrepresent the cheapness in workmanship would be rather misleading. Appreciating to the fullest extent the real worth of appropriate engraving upon firearms, I never care to have the finest arms bare of decoration so that when once the gloss of newness has gone they present a bald appearance.

Fine workmanship is in itself an excellent indication of quality, and fine mechanical skill is more noticeable in perfect fitting and outlines. Ornamentation or engraving is probably more noticeable than any other point on some firearms. Decoration need not be wholly confined to the engraving of lines; the greatest beauty of all is the graceful contour of a well designed gun, proportionate in every part, boldly outlined, yet gracefully turned where too sharp an angle would offend the eye. Then, too, the checkering upon the pistol grip and fore-end not only enables the user to obtain a surer grip, but is in itself very attractive when well laid out and skilfully executed. The well engraved gun will have every bolt, every pin, every part, not only proportionate, correctly fitted, and well made, but so placed as to be of actual service and its position utilized in the usual scheme of decorations so that upon close examination it would appear that, without that most minute line or point, the weapon itself would be incomplete.

The gun lover must face the fact that the game

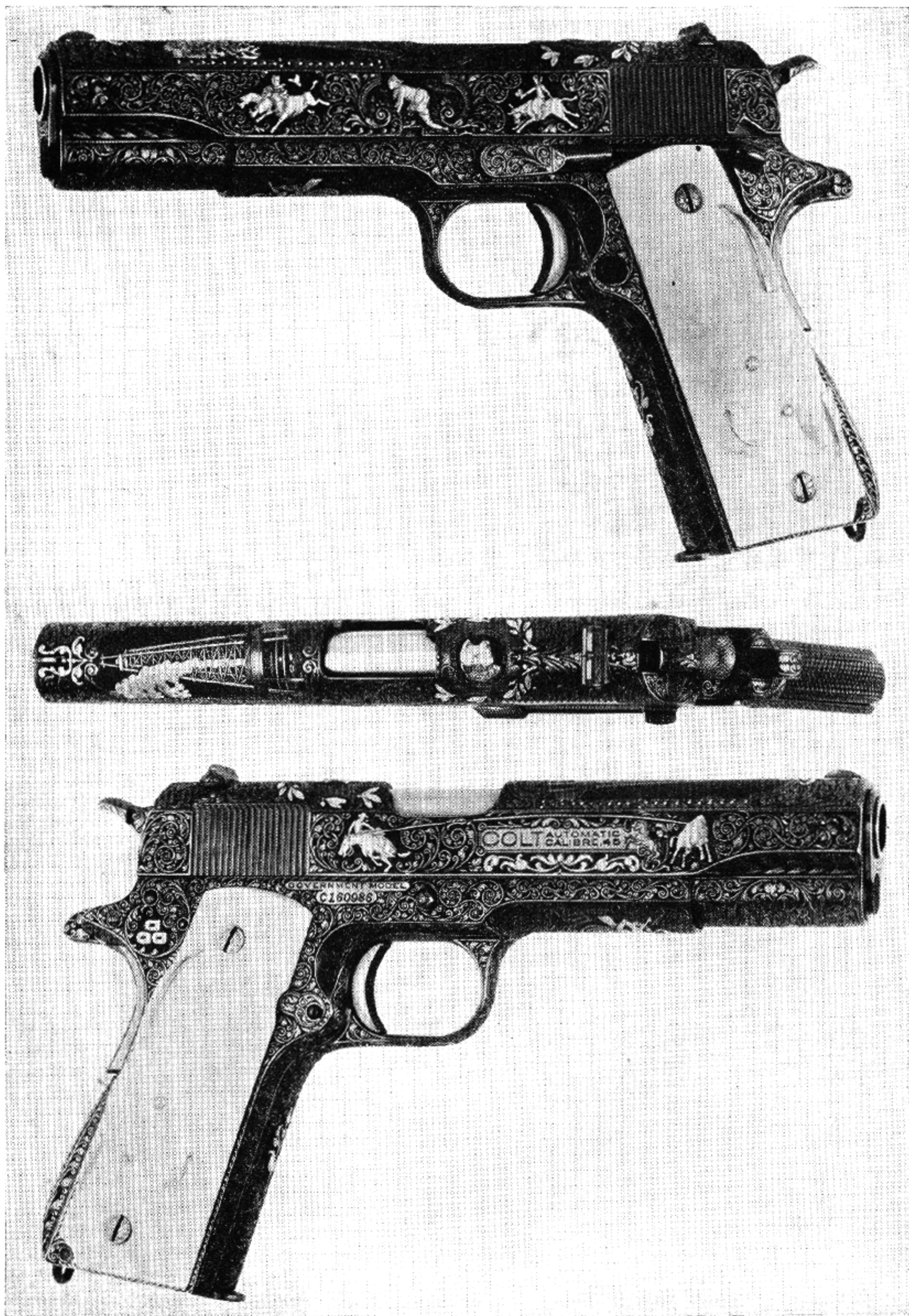


Fig. 157

Colt caliber-.45 automatic pistol. Figures in gold and platinum inlay. High relief work. Note the steer's head carved in the ivory grips, and the diamonds set in for the eyes. A beautiful work of art

of America is disappearing year after year, the ever-increasing army of hunters—as well as the bag limits—growing slimmer. It would almost seem as tho the sportsman and true gun lover must take the greatest pleasure in arms themselves, and handle and look upon their beauty day by day; therefore gun makers must turn out arms of greater beauty so that these men can take their keenest pleasure in dreaming of their performance, their fine appearance, and lastly their art value, of which he can be justly proud when an artist has carved upon its steel surface figures of game that roamed our mountains years ago.

It will be well for the beginner to study the best designs of gun engraving and not copy some of our American arms manufacturers who only place a lot

little better grade than the ordinary. Engraving such as this may catch the eye of the novice, but to an experienced rifleman it cheapens the weapon. If engraving is to be used, have it executed by an experienced engraver for a few dollars which will offset the plainness with real hand work and include a bird dog, or even some game scenes which would add greatly to the beauty of the arm.

The British engraving consists usually of very fine scrolls forming small patterns, and not the large free-hand sprawling lines of many of our designs. Fine English scroll is beautiful, and to be fully appreciated must be examined closely with a magnifying glass. These designs should be copied; the charm of this work is that it is not obvious at a distance.

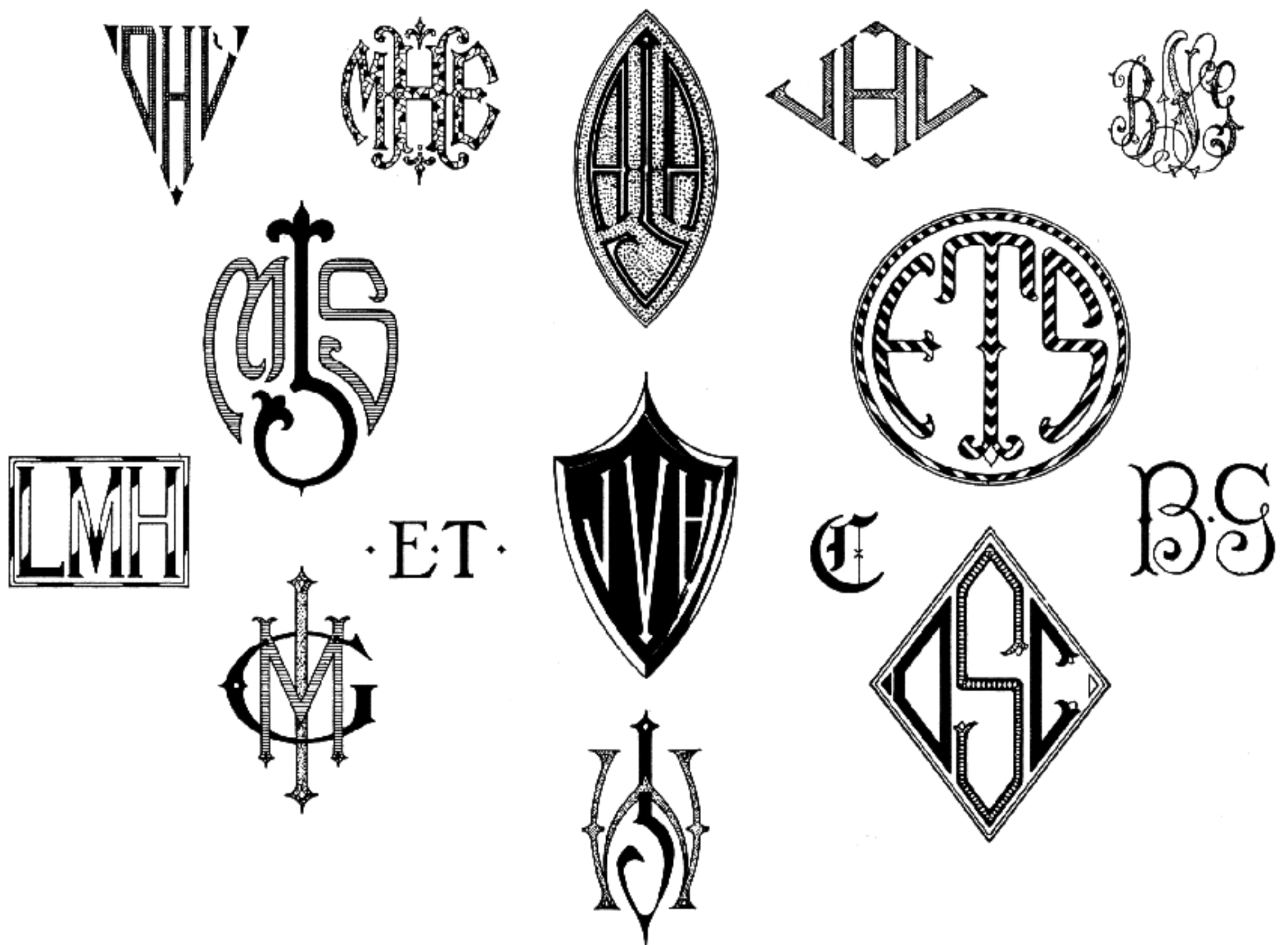


Fig. 158

Initials for monograms, engraving, etching, etc.

of meaningless lines on a gun. Usually these arms are covered with heavily carved scrolls which are a disgrace to a weapon; to copy these is out of the question. I have seen well-made American arms on which the makers went to the trouble of stamping dogs, ducks, geese, etc., on the sides of their guns to give the appearance of a high grade or a

figures such as dogs, birds, deer, moose, elk, and one's initials or monogram, appear to better advantage when finished in gold. The outlines of the animal or letters are first chiseled, and dovetails are cut or chiseled up along these outlines with small chisels of various sizes with round and flat points or edges, straight lines with straight points,

and curved lines with round points. Steel is thrown up to anchor the metal in various places and then the pieces of gold, which consist of 24-karat gold *wire*, are laid beside each other and hammered into place, one at a time, until the figure is filled with gold. The use of a flat punch over this gold will force these gold wires together and the connections between them will not show when the inlay work is completed. The edges are then trimmed and full details are carved or chiseled out, even to showing the hair. Figure designs are rather difficult to engrave, and it will be well to practise on a steel or copper plate before any attempt is made on a gun

part. If you are able to draw all the animal designs illustrated in this chapter, and transfer them on metal, you are an artist. When using gold, do not have it stand out boldly as tho it were hung there; it should be in the form of a relief design and constitute a part of the engraving itself. Relief work consists usually of nature studies drawn from nature with a pencil. Do not try to engrave until you are able to draw successfully with a pencil. You will only increase your difficulties so much that you will be dismayed and give up further effort. Choose a simple nature study for your first relief engraving, small and yet effective, such as small leaves, ferns, etc. Do not have one leaf cover the whole action, but place a number of small ones connecting with each other, their stems forming other parts of the design. Many times your efforts will be lost, but there is always a way to correct a bad slip of the graver.

Often the owner of a fine gun, or a person about to have one made, wishes to have a scene from one of his hunting trips engraved on a part of his gun. This is possible not only with pictures of trips or trophies, but with pictures of hunting dogs. All can easily be incorporated by the experienced engraver, and also by the student—after considerable practise. If you are not able to carry out the chiseling effects, allow the work to be done by the etching process.

Engraving, as you know, is cutting lines into the surface of a gun part or any other steel surface. Such work should be done with fine, firm lines cut into, not scratched upon, the metal surface. All, of course, depends upon the artistic sense and skill with which you are able to execute the work. Any design may be traced upon the metal and cut up to a certain degree. Very fine scroll work is the accepted standard, for these lines best adapt themselves to the first requisite of engraving from the gunmaker's point of view, namely, the hiding of

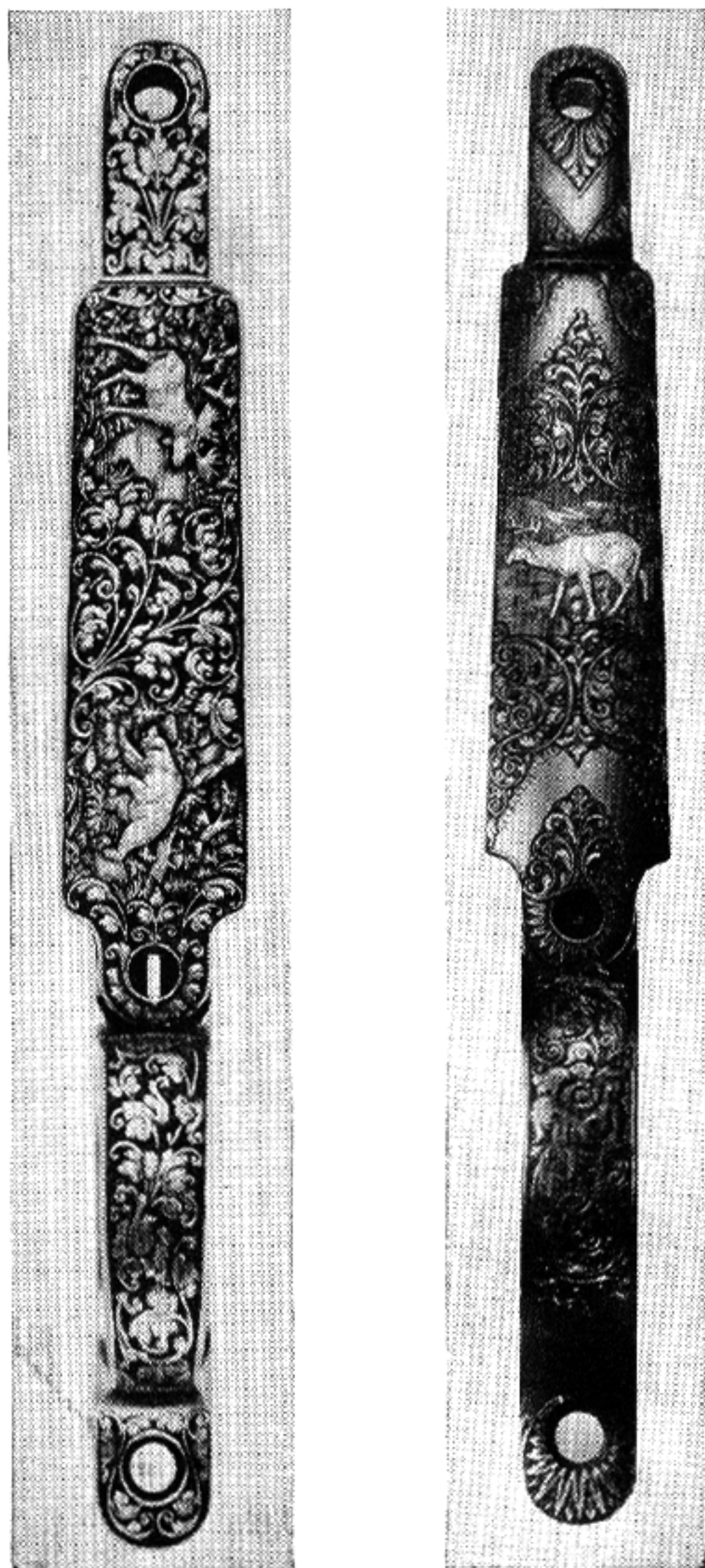


Fig. 159
Springfield magazines and floor plates. Animals in gold. High relief work



Fig. 160
Model 39 Marlin rifle, caliber .22, engraved with snake and bear in gold. High relief work

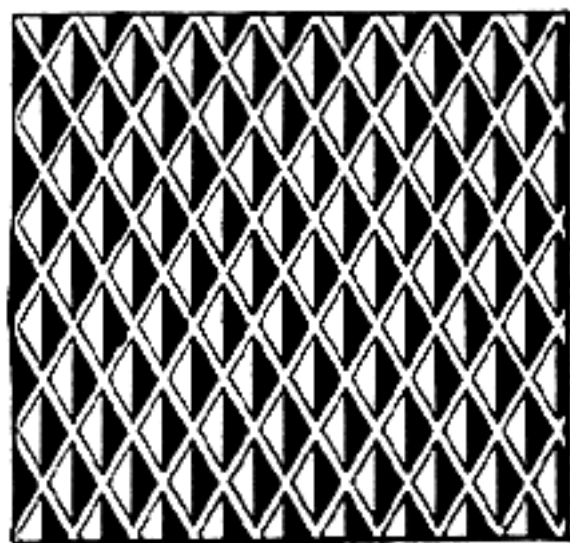
joints, screw holes, ugly straight lines, obtrusive pins, etc. The gun engraver should by no means neglect to make screw heads, pins, etc., constitute part of the decoration. The engraving of animals, bouquets, and other subjects demands greater skill and a clearer perception of artistic effect.

The use of tools and their proper angle to the work is one point which must be realized through experience. To hold a tool at the correct angle so that the perfect fine lines can be produced is a matter of long hours of practise; not impossible after

you chisel out some sample pieces on cold-drawn steel plate. Then you can study the effects of the various pressures you have been applying with the hammer upon the end of the handle where the graver is inserted. Rigid rules are a means of becoming perfect, and in the end your work will show a vast improvement. This class of work brings your artistic ability to the fore, and from such constant application of your efforts you will become an artist of a fine order.

CHAPTER XXVII

Appraisal of Craftsmanship



Appraisal of Craftsmanship

WE ALL, as we pass through life, pick up and absorb preferences which ultimately determine our standards. An interesting feature of this is the wide divergence of preferences and the impossibility of their reconciliation. That even this is good is at once apparent, for the likes and dislikes of each of us supply the infinite variety that is the spice of life.

Fortunately most preferences are the result of personal satisfaction and are therefore honest and free from mere prejudice. Good workmanship, freedom from break-down, reliable average performance, should and do constitute favor. Still there is something more than this, something often quite indefinable, which nevertheless invariably tips the scale in one's estimation. Nowhere is it more surely evidenced than in the choice of a gun. There are three kinds of people who buy guns. One type buys them merely to kill things with; to these they are merely a tool. A second loves hunting and guns equally, and as his skill increases he delights in making the quest more difficult and the means more exacting. To him a gun is never a tool—it is of all his inanimate possessions the one most loved. It is the companion that he takes into the solitudes; it is the lengthened finger with which he secures his quarry; it is the instrument upon which he tests his skill. This man's hunting season embraces the whole year, for his beautiful weapon is never hidden away. It has an equal share in his hunting stories, it is associated in his happiest memories. It is his "gun." The third type is the gun-crank pure and simple, he to whom hunting is merely the opportunity to test out a formula or attempt the impossible. To this last group we must always stand indebted, for the endless quest of its members has brought us the improvements and developments that make the modern gun so efficient and beautiful. To the great second group, however, do we turn as we contemplate the gun and its uses and philosophize in our own little way. Its members generally exhibit the balanced opinion. It is for them that we like to make guns.

We believe that outside of the general utility in a gun, balance, by which we mean the harmony and proportion of all its parts and the beauty of lines, is the most appealing. And nobody has ever been

able to get beauty and harmony into a gun who did not first have them in his soul—who has not made guns first because he loved to make them and secondly because they were the means through which he secured his bread and butter.

Now when we come back to our subject and attempt to appraise craftsmanship we must not lose sight of this last statement—that guns made by men who love guns and who try to express themselves through them, will always be better guns than those made by a machine, however ingeniously or skilfully turned out.

I am going to talk to you for a few minutes about some of the salient features of good guns, and I want you to be kind enough to let me use as examples two well-known makes—one American and one British. I pick these two from the long list which embraces all nations, not because I claim superiority in them to others, but because they are representative makes, are associated with generations of gunners, and are familiar names wherever guns are talked of. Please do not accuse me of being prejudiced or invidious when I mention the names of Westley Richards and Parker Brothers as hooks upon which to hang my thesis. Westley Richards' inventions are an important and integral part of every modern double gun—cocking by means of the barrels, the box lock, the top lever, the fore-end ejector. And as to our good American maker, I am sure no other maker in America will be so ungenerous as to feel annoyance that we should use the famous old firm as our native exemplar.

Both of these makes, as it happens, are identified with the box-lock style of mechanism, Parker Brothers exclusively, Westley Richards predominantly. Now it happens that I am among the warmest admirers of side-lock guns as made by the great London makers, and admit, offhand, their inimitable beauty; but I do not hesitate to say that, aside from this, they have no advantages over the box-lock and that to be of equal quality they must inevitably cost much more. This, therefore, gives us our first suggestion; namely, where cost is an object you will always get a better gun for your money in a box-lock gun. It may be urged that I am not giving proper consideration to the dismount-

able qualities of the side-lock; to this I answer that if you must take your gun to pieces, Westley Richards' detachable lock system enables you to do this with no tools whatever except your fingers. We shall enlarge upon this later.

Over-and-Under Guns — When discussing the best quality of modern workmanship, it is well to bear in mind the practical achievements of the past. In short, sum up their all-around advantages and make comparisons of them with further modern advances of proved inherent utility and design in all points made under a wise supervision to ascertain what is the best type of modern gun to choose. Since reference has been made to the Westley Richards arms, a description may as well be made of some of the fine points of their "Ovundo" or "over and under" principle of design as presenting a wonderful example of a high-class arm in this style. The Westley Richards "Ovundo" gun, top-lever action, embodies all the well-known features of the makers, such as the new quadruple grip, top safety bolt, Westley Richards ejector mechanism, hand-detachable locks, hinged cover plate, and their reliable one-trigger system. These guns are box-lock guns but have dummy side plates resembling a side-lock gun. These are used so that opening traps in them may be provided enabling the one-trigger mechanism to be oiled with a tip of a toothpick and kept properly cleaned. For applying the necessary oil, the ordinary gun must be stripped down—a practise to be avoided except by a trained

mechanic. These side panels obviate this difficulty and constitute another superior advantage of the "Ovundo" construction. The illustration shows this feature both in rifle and shotgun. (See Figures 161 and 162.)

The main principle of design, together with perfect craftsmanship, must be a prime consideration; for if a gun, no matter how well made, is constructed with a working movement which presents great strain and great friction, such designs will speedily wear out. Some would advance the idea that this would be the case of an over-and-under gun because some peculiar strain and friction cannot possibly be avoided. It is not so in this present day and age when the finest materials possible go into construction. This is true of materials as well as workmanship. The great modern advances in the chemistry of alloys has given us steels of hardness, ductility, strength and non-corrosive qualities that exceed everything hitherto available.

Figure 163 shows an important part to decide upon—the principle of the locking features. No special rules can be given to govern the formation of this selection other than simplicity and safety—always worthy of favorable consideration. Naturally, the greater the simplicity the better, provided it works to the full accomplishment of all the ends desired. Next to simplicity may be selected durability, and next to this may come the principle of good shooting and safety of the arm. The Westley Richards "Ovundo" gun, whether in a rifle or shotgun, was not designed to satisfy a natural desire

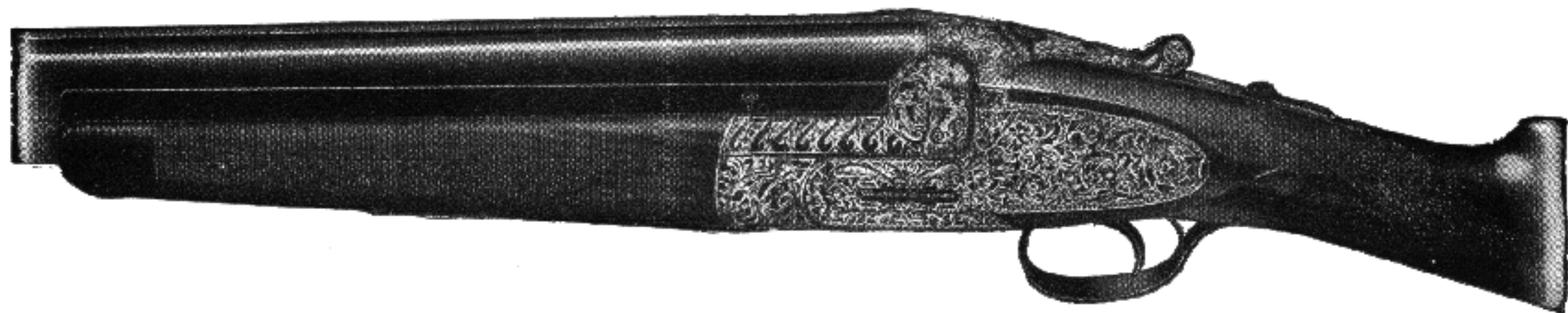


Fig. 161
Westley Richards "Ovundo" gun. The shotgun



Fig. 162
Westley Richards "Ovundo" gun. The rifle

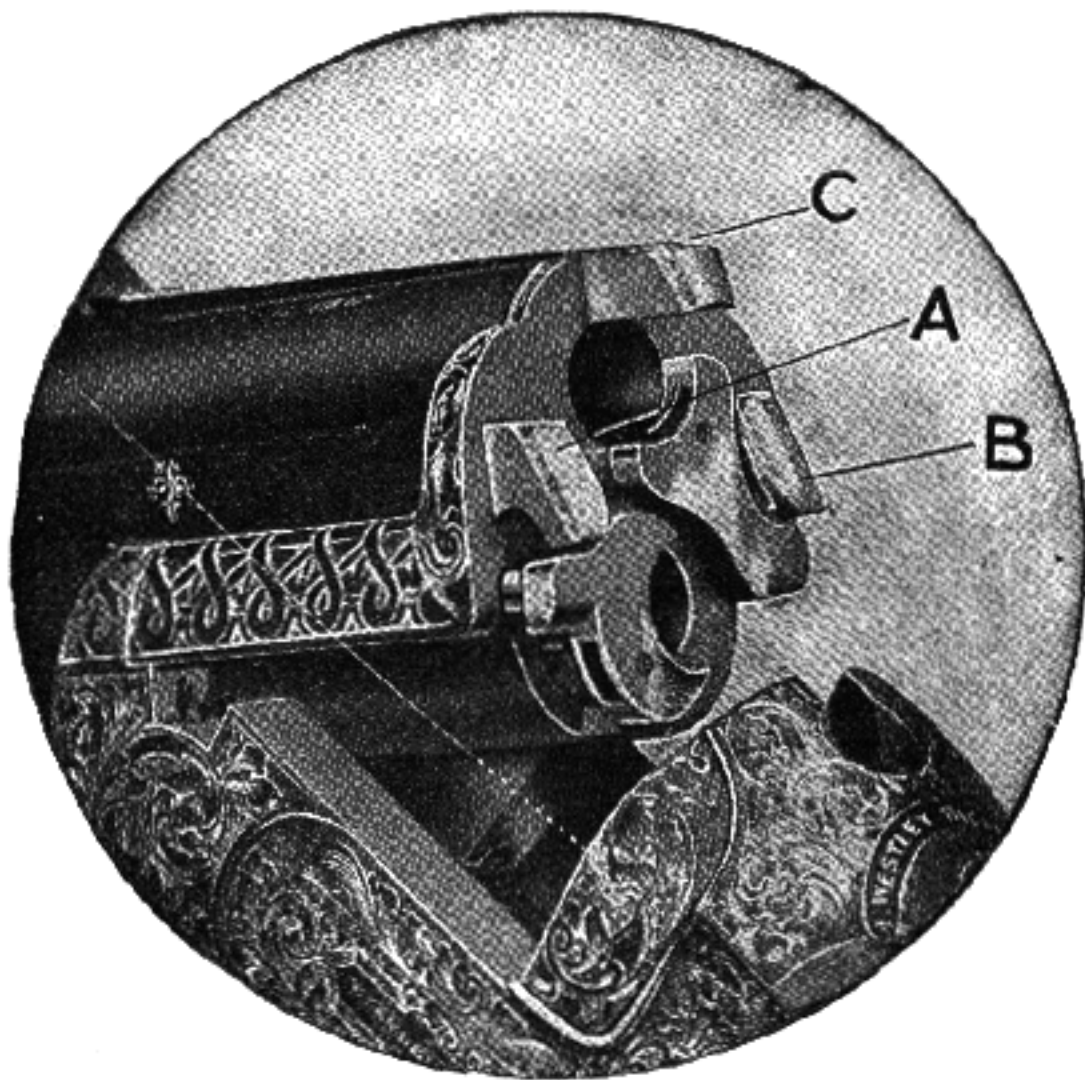


Fig. 163

Westley Richards "Ovundo" locking features

for a change, but to achieve definite and important ends, the chief of which was to provide a narrow, convenient, and well defined aim line to hold the eye, as opposed to the obstruction formed by two barrels and the connecting top rib of the ordinary "double gun" over which the eye can stray at large.

There is little doubt that the narrow sighting base throws into high relief errors in aiming and is therefore an advantage. Placing the barrels one above the other instead of side by side secures a high advantage, and permits a better view of the object at the moment of aiming than is possible with the side-by-side construction, which often obscures the object entirely and causes hesitation instead of that quickness of trigger-pull that is so important an element of successful shooting.

The extensive use of guns designed and constructed on lines of the particular over-and-under models here illustrated enables me to offer a gunmaker's opinion concerning their general characteristics for sporting uses. A casual acquaintance with mechanical principles will assure the owner of one of these guns that all vital matters connected with opening, closing, and firing have received very favorable comments. Naturally, an inspection reveals the agreeable features of simplicity, strength, and easy working, without going too far into technicalities. Effective discharge is insured in the gun locks constructed on the detachable principle. A pair of extra interchangeable locks which can instantly be inserted into the gun are a complete insurance against having any hunting trip end in failure.

ments is the permanent attachment of the cover-plate to the body of the action by means of a hinge which can be opened and closed in the same manner as the lid of a watch case; the locks when removed will remind you of a watch with its beautiful finishes. It is very interesting to discover that each lock in this type of gun functions perfectly with nearly seven limbs, as compared with double that number of parts found in the usual side lock of ordinary guns; this fact may be verified in the simplest manner, for these locks can be instantly removed with the finger and thumb without the aid of any tool to facilitate inspection, cleaning, and oiling.

The mechanical arrangement of barrel and breech fittings insures rigidity and firmness to withstand the repeated firing, which may extend over a lifetime of use. The ejecting mechanism in the fore-end of the stock, with an improved one-trigger, fires the barrels in any order, right-left or left-right, continuously, as may be found expedient.

Many sportsmen who come to my shop are rather inclined to doubt the utility of guns made on this principle. They probably overlook the fact that invaluable assistance is rendered by the less obstructive hindrance of barrels placed one above the other. Close observation of the habits acquired in game shooting will reveal the slight pause made by many shooters prior to pulling the trigger. This is caused by the natural desire to obtain a better view of the bird at the moment the gun butt reaches the shoulder. They cannot have the mind and trigger finger work together, because the bird is wholly or in a large measure obscured by the width of the side-by-side barrels, and while the time thus occupied may be scarcely measurable, it may comprise the whole of the difference between killing and missing the game. This desire to get a clear view of the bird is common to all shooters, and is responsible for more failures than any gun-stock misfits, poor ammunition, and all other alleged causes put together. It seems to me that, while it is not in human nature to overcome this difficulty entirely, those who acquire a reputation as fine shooters have found the method to counteract the adverse effects of these habits. Where none of these rules can be brought to bear it is natural that the inexperienced gunsmith or gun lover should turn to these chapters for aid in forming judgment upon the quality of any gun; hence a few unused ideas may not be out of place.

All the movements of the action should be smooth and all the joints should fit perfectly. The locks should have due consideration; when the gun is opened it should break down without much effort. The increase or decrease of power should be

Detachable Locks — One of the latest improve-

extremely gradual and not great. Throughout these movements there should be a quick locking of the bolt as the top lever is released. In cocking the arm the locks should emit a clear ringing sound as the sears engage the notches. When once heard, this too can never afterward be mistaken.

We now turn to the chambers and the seating of the shell. The counterbore of the chambers and the length and width of the action bed should be closely observed. The counterbore should be cut clean and deep enough to take the rim of the shell without leaving the slightest projection, else the arm will not close properly. But if, on the contrary, the counterbore is too deep, the shell comes back upon the standing breech before the charge makes its exit, which is a means of increasing the recoil and renders accuracy less certain.

I find that the over-and-under guns assist shooters in another way; this is in the shape of the forearm, which in form and substance differs considerably from the shallow fore-end usually attached to double guns with ordinary barrels, as the fore-end of the previously named gun covers the lower barrel entirely. Such increased depth fills the forward hand most comfortably, and prevents the awkward overlapping of the barrels with the fingers which many users find a serious hindrance to correct aiming. This changed form of the forearm in over-and-under guns is often to be commended as giving a much firmer hold, thus increasing the user's command over his weapon and conferring facilities for increased speed in gun swinging and in raising or depressing the barrels. Motions are not well assured by the rather insecure hand-hold obtainable on the customary forearm of the older type of gun.

Let us go back again to the detachable lock system, as seen in Figures 164 and 165. Each lock in this construction becomes a separate unit, acting in complete independence of the other, which it cannot in any way disturb; by such



Fig. 165
Westley Richards detachable lock

a method greater efficiency is secured under the stress of repeated firing. Some men superficially argue as if such a refinement were but a selling point for the fashionable trade, and had no practical utility; such an opinion, however, could not be held by any one with a sound knowledge of gun-lock construction and requirements. This design omits useless and disturbing limbs, and from these improvements there result other subsidiary advantages in the construction of high-class guns. At the same time it maintains the hammer and striker in one piece and so removes the need of a separate striker—always a possible danger of breakage. Whatever merit lies in mere detachability is best exemplified, in my opinion, by the freest and simplest of all designs in firearm construction.

Single Triggers — There is perhaps no part of the modern gun so vital as the one-trigger mechanism, and I shall hail the day when all double guns are equipped with such an improvement. In principle it is a distinct aid to quick shooting. Its instantaneous action confers a great advantage upon the user; comfort, celerity, and reduction of personal movement contribute to a greater proficiency. It secures the same length of stock for both barrels instead of the two different lengths inevitable in a two-trigger gun. How many sportsmen have considered that the rear trigger of a two-trigger gun is usually placed about three-fourths inch behind the front trigger from which the stock length is secured; consequently the user is compelled to

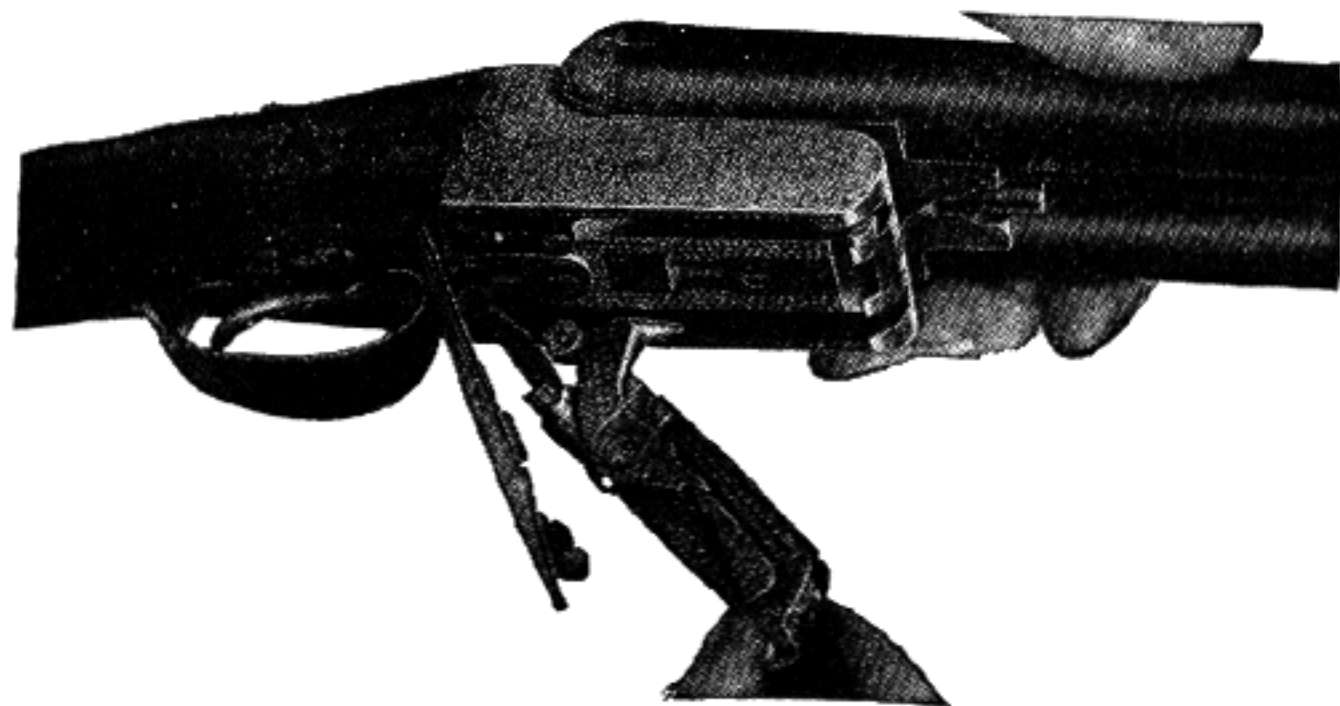


Fig. 164
Westley Richards hinged cover plate

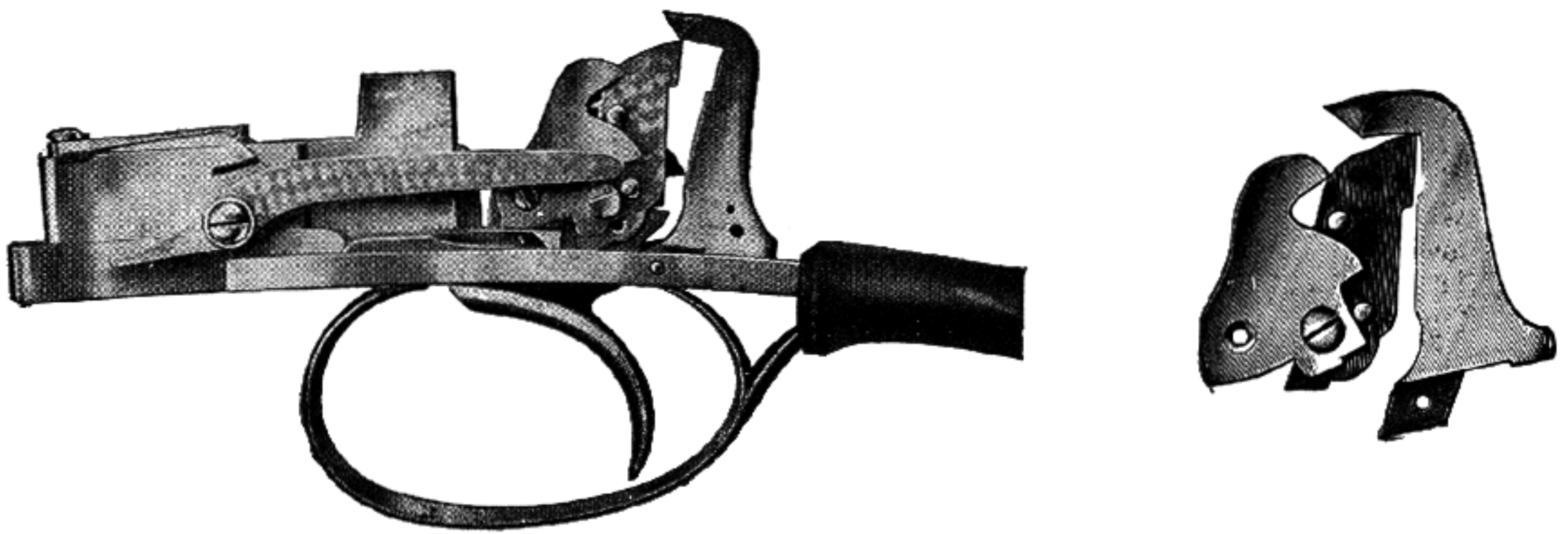


Fig. 166
Westley Richards single-trigger mechanism

shift his hand and adjust his aim each time he fires the two barrels in succession. Not so with the single trigger; there is one length and one constant adjustment for both barrels.

The principles underlying the single-trigger mechanisms of Westley Richards and Parker Brothers are fundamentally the same. Both mechanisms have been refined and perfected by experience. Both are selective, both are on the two-pull principle, both act independently of recoil. The workmanship in both is the very best.

These advantages, briefly stated, are provided by Westley Richards' and Parker's latest design of one-trigger mechanism. That was their original designation as it is today, but here guidance above all other points is often required. During many years past there has been issued a variety of single-trigger systems, many of them, whose faults have been laid to the principle itself, defective in the methods adopted. There never is a limit of any mechanical differentiation involved, and opinion is often expressed without the slightest attempt to distinguish one method from the other. Such an outlook is really deplorable, because it involves in a false estimate the conclusion that all methods of constructing and designing guns with one trigger instead of two can be classed together, in a sort of round-up; good and bad alike are refused that critical discernment which should naturally distinguish one class from another, with the result that the faults of the bad ones are applied to all, including even the best conceived design, altho the Westley Richards system, at least—as Figures 166 and 167 illustrate—is fundamentally free from vices in action which are inherent in all single-trigger systems whose limbs are controlled by or subject to the action and effect of recoil.

The vibration set up by the explosion of the cartridge and the movements of the gun under recoil are disturbing elements, and they vary greatly

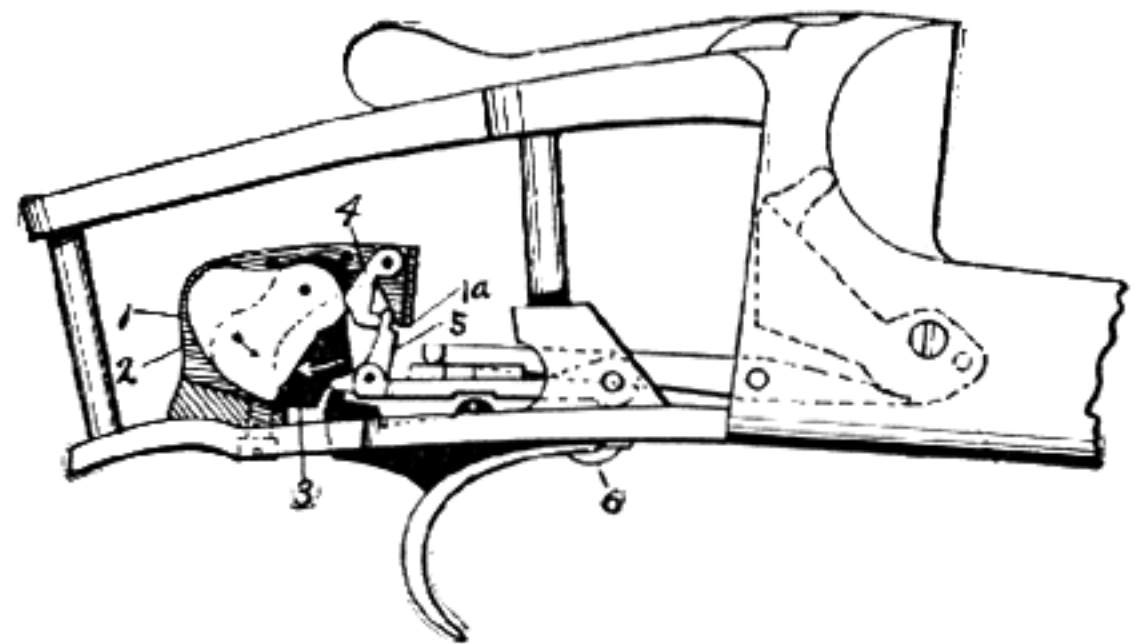


Fig. 167
Parker Brothers single-trigger mechanism

in an act. A mechanical device which is governed by such inconstant agents cannot possibly assure regularity of action, however ingeniously designed or constructed and even carefully made. That fault was evinced in the original three-pull system when snapping off without cartridges. Such a trigger mechanism required three pulls to operate the two barrels. The second or intermediate pull is actuated by recoil—which is variable and admittedly cannot be relied upon. This trigger system unfortunately started with the handicap of an erroneous conception which has led to much unnecessary confusion and disappointment.

In order for a single trigger to be absolutely reliable it must be a two-pull mechanism, and its action must be independent of recoil. The first necessity was to break completely away from false estimates of the condition to be met and to receive a clear idea of a principle immune from the faults attaching to a system built upon such an error. That is only to be found in a mechanical device which is not subject to the effects of recoil; the recoil can neither stay nor accelerate, and is operated at the shooter's will as quickly or as deliberately as it pleases him, whether under light, heavy or indeed any variations in the effects produced by the cart-

ridge discharge. These ideas are attained in the Westley Richards and Parker one-trigger mechanism.

Recoil is not employed to operate the mechanism and there is no long draft of the trigger in firing either barrel; both pulls are short, clean, and quick, and thus imperative to perfect holding and shooting. They have perfect selective action; either barrel can be fired at will followed immediately by the second barrel. The shooter, therefore, never

for we have not developed that high quality of workmanship which is so essential in fine arms of a better type, when conceived with wonderful ingenuity of purpose, where the cost goes over one thousand dollars. The prohibitive duty placed upon the best arms coming into the United States causes me to agree with Will Rogers when he calls the United States "Cuckoo Land."

Figure 168 illustrates Parker's Invincible, one of the highest-grade guns made here in America, a

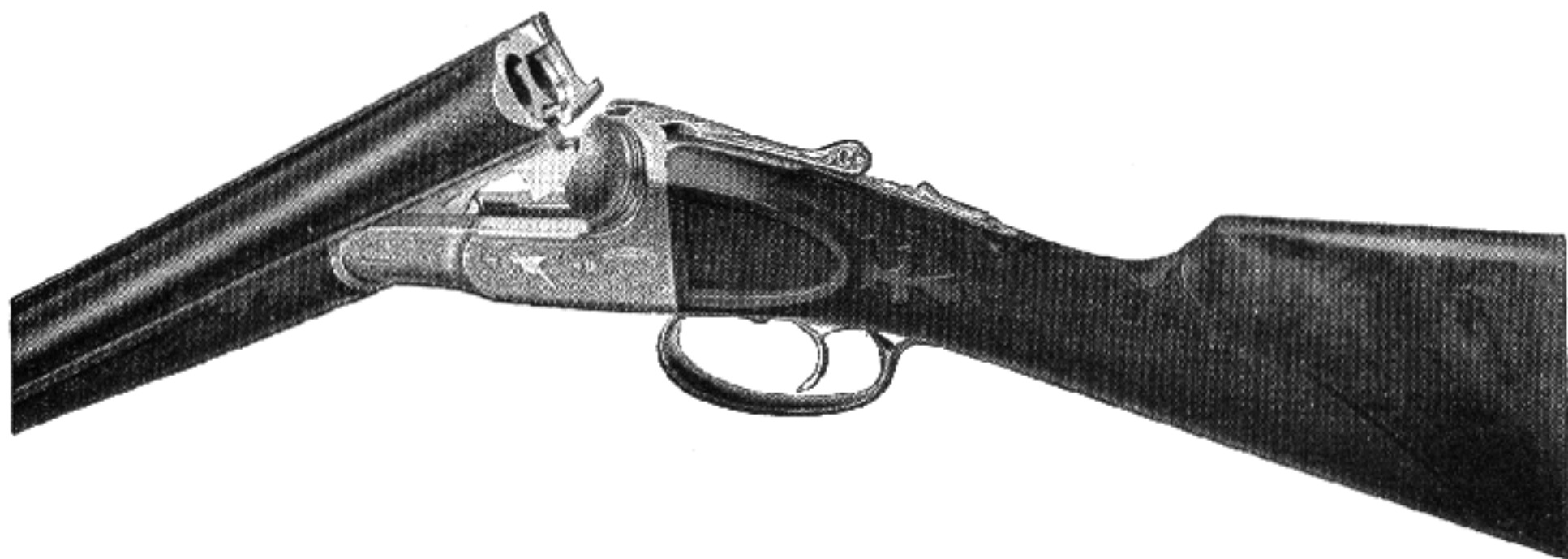


Fig. 168
Parker Brothers best shotgun

has to fumble with his trigger or place himself into exceptional postures—awkward and therefore fatal to accuracy—in order to fire double shots. The action is easier and more natural than firing a two-trigger gun, and considerably faster. It makes no difference how the gun is fired or what a shooter's peculiarities may be, either in pulling the trigger or handling the gun. It acts just as perfectly, regardless of recoil, and will always act the same.

In referring thus to one American and one British firm of gunmakers, I am by no means denying that good arms are made by others makers, whether in England, Germany, Belgium, France, or the United States, for this would be going wide of the truth. There are some gunmakers in all these countries who turn out the finest the world has seen, and the most costly. But exterior finishes should never be a guiding point of selection. Often arms are models of perfection in outside appearance, but when the best shooting is ascertained it is often discovered that they have not proved themselves superior. To be more substantial in my remarks, the less finely finished and less expensive guns of the American manufacturers have given the American product an enviable reputation throughout the world. Naturally there is a separating line in the purchase of a cheap gun, and when funds are low it is much better to secure a gun of American make than one of foreign manufacture. On the other hand, when we choose the very best we must go to England and select a British gun,

beautiful example of skilled craftsmanship. A "best" gun, in my opinion, is one perfect in design, simple and efficient in its parts, fashioned by the most skilled hands, with each component mechanically disposed and cunningly interrelated, and adjusted with precision. Such a gun should exhibit, in other directions, qualities of corresponding attainment; barrel-cuppling and exact shape and size of internal portions finely bored, gauged, and finished, thus insuring the proper action for attaining the best workable velocities, complete regularity, and even pellet distribution. A gun of this kind provides the most desirable balance, and by reason of the disposition of parts, spring, weights, and diameter assures pulls capable of fine and lasting adjustment, which can be readily effectuated to suit individual wishes and taste; also an efficient system of ejectors and a reliable selective single trigger independent of recoil. Finally, it is one whose product of constructive craftsmanship is reflected in the exterior lines, which present a happy symmetrical effect.

The locking of the barrels in the Westley Richards and the Parker guns presents perhaps as wide a divergence as will be found in any comparative systems. Messrs. Westley Richards have always been the exponents of an elaborate and emphasized bolting system consisting of the usual Purdey under bolts and a "doll's-head" jointed on the radial curve and locked with a sliding bolt. This is an expensive plan and requires unusually



Fig. 169

Another Parker Brothers shotgun

close workmanship. It is obviously impossible in cheaper grades or in machine production. Nevertheless, we all must admit its great strength and thoroughness. Messrs. Parker's system, in comparison, seems ridiculously simple, for only one of the bottom lumps is bolted and the top extension provides little other than a guide to the extractors. Yet so adequate are the contact surfaces and so positive the bolting that no criticism whatever can be leveled against it. Rather we must all congratulate the makers that they have achieved such good results in so simple a manner.

No higher recommendation can be given any gun than is found in the bare facts about a certain Parker which came to me for repairs. The owner purchased this gun in 1897; it had Damascus barrels of the A.H.E. grade. It needed tightening of the action, a few dents removed, the stock repolished, and barrels and action refinished. This was the first time this gun had ever been in a shop for repairs—convincing proof of the lasting quality of an adequately priced gun! The average layman will be prone to state that better materials and workmanship were placed in the arms of thirty-six years ago, but he forgets that we in the mechanical field are gradually advancing in a cycle of evolution and year by year see improvements over the past, be they ever so small. The fact must never be forgotten that the world owes its progress to men who could see beyond their noses, who could conceive of things no one had actually seen. "Everything that is attained starts with a dream of it," is a

saying we all know to be true, yet we go on forever giving the big rewards to the doers. The man who can only dream lives in a hostile world, as I have found. His real world is in his mind, and when he steps out of it into human society he is only a stranger and alone. To be successful he must combine his dreams with accomplishment, for the world of today is ruled by people who do things.

The eye teaches you to recognize at sight the predominating distinctions of fine craftsmanship. In cases where there are no means of ascertaining the quality of a firearm from the grade stamped or affixed or the test made by a responsible maker, the gunsmith will naturally be forced to turn to his own resources. What these are I cannot state. The firearm should be subjected to a most critical examination, in obedience to rules set apart for such examining, after which the shooting qualities should be thoroughly tested. To no apprentice should be entrusted such a shooting test, tho he should be at hand to learn these requirements while the work is being performed by an expert. When a man purchases a firearm he does it in the expectation of becoming the owner of a gun qualified to shoot well, and no matter how perfect it may be in various other respects, any deficiency in this particular is sure to rouse him to a high state of ire and dissatisfaction with the makers.

The exclusive models in Figures 170 and 171 give an example of this conception. They show products of superior merit, executed by the most skilled and disciplined craftsmanship within modern

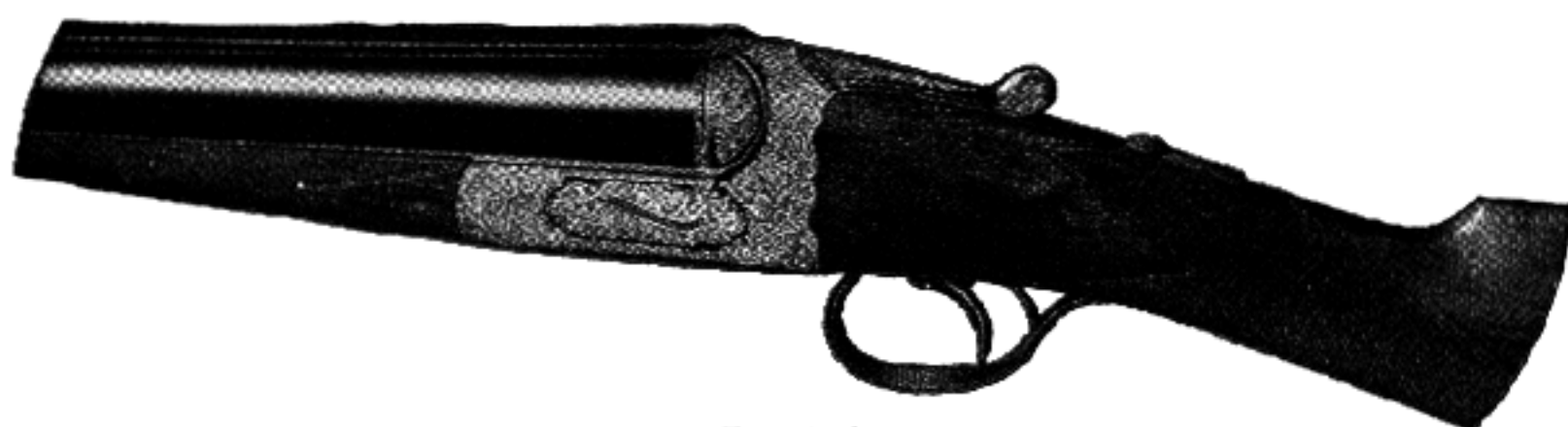


Fig. 170

Westley Richards best shotgun



Fig. 171

A better example of Westley Richards best shotgun

command, while at the same time they display an application of the most carefully studied refinements of taste. Apart from their guaranteed efficiency and durability, there is an ingrained

character in them, something presenting unusual attraction, an elusive quality of art, due perhaps to the subtle influence of inheritance and tradition.



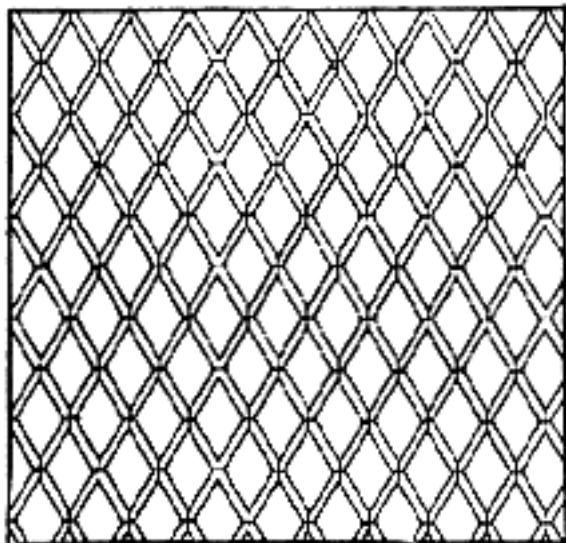
Publishers' Photo Service, N. Y.

Fig. 172

There is some strange mellowing influence that prevails alike upon all men and women who shoot

CHAPTER XXVIII

Review of Military Small Arms



Review of Military Small Arms

MANY references to military arms have been made in these volumes. As the National Rifle Association sells military arms and ammunition through the Director of Civilian Marksmanship, it is in order to describe these weapons of different nations. Military arms are often the means of making very fine sporting rifles—by modeling them to the various ideas that your wishes may dictate. As our best sporting arms are constructed from such weapons, it is very desirable for the student to know them thoroughly, even if they are only to be used for experimental purposes.

The following detailed description is taken mainly from the *Textbook of Small Arms* published by the British Government, and the extracts from that work here reproduced are used by special permission of his Britannic Majesty's Stationery Office, London:

All military rifles of more modern design are breech loaders and are fitted with magazines which will contain five or more cartridges. The breech action, without exception, is operated on the "bolt" system. In this design a hollow cylinder of steel with a solid end is fitted with a handle and knob which is locked in position behind the cartridge in the chamber of the barrel, and together with the metal of the cartridge case, closes the breech against all escape of the gases of the explosion in a backward direction. The pressure developed by the burning powder is between 36,000 and 55,000 pounds to the square inch; therefore a considerable margin of safety may be allowed. The pressure is resisted, taken up, and transferred to the action body by one or more "lugs" which work in cut-outs in the action or receiver and serve as resistance shoulders.

The lugs are part of the bolt and are developed when it is machined to form in the manufacture. From a mechanical point of view, the best designs are those in which they are disposed symmetrically—so that the pressure is taken up evenly—and are placed as near the bolt head as possible in order that the bolt itself shall not be subject to stresses which are bound to be taken up unevenly by a long column of metal free to move within given gauging tolerances, in any direction. The bolt is hollow in order that it may contain the firing pin or striker,

the main spring which actuates it, the cocking piece or bolt head, the sleeve, etc. The bolt is also fitted with an extractor, which is really a hook or claw to engage with the rim or groove on the base of the cartridge case and extract it from the chamber after firing. A safety device, in the nature of a lock to prevent accidental discharge of the rifle, is usually fitted to the bolt sleeve at the rear of the bolt. The receiver body or action, in which the bolt works, is screwed to the barrel. The interior is grooved or broached to allow the lugs to pass when the bolt is worked, and is recessed so that the lugs will be given a substantial bearing surface when in the firing position. The right side of the body is usually cut away to allow the formed cases to eject to that side.

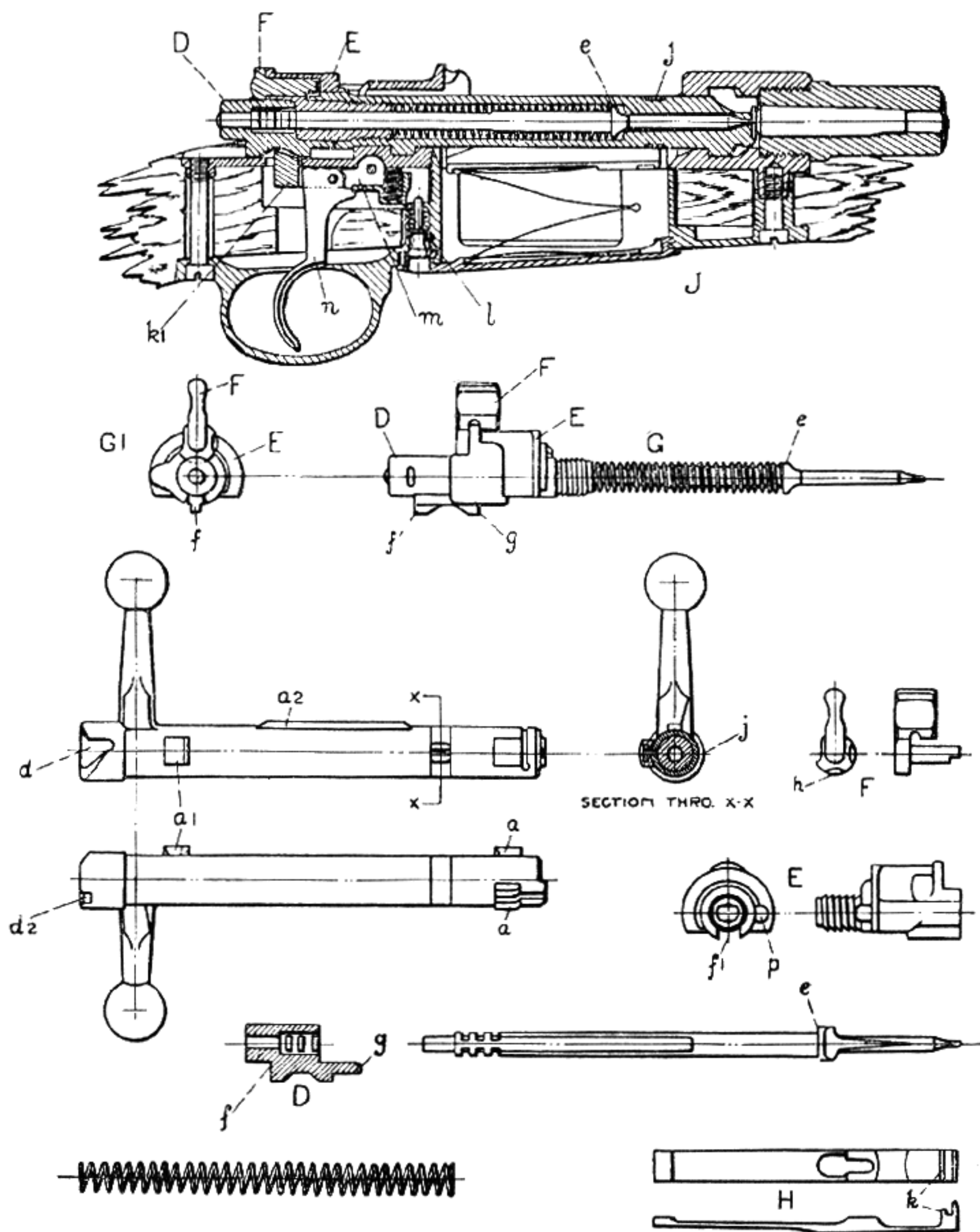
Barrel design and form of rifling in all modern military rifles are very similar, but the real differences will be found in outside contour of the barrel, from a straight taper starting at the muzzle and reinforced at the breech. Various arms have barrels turned in the nature of steps, the object being to break up the barrel vibrations in firing. The barrels vary in length from 24 to 32 inches, and in caliber of bore they run from 6.50 mm. or 0.256 inch to 8 mm. or 0.315 inch, and in weight between 2 pounds 3 oz. and 3 pounds 5 oz. In all but two cases the form of rifling is that which is known as concentric or "Enfield," with four grooves (five in the case of the British short-magazine Lee Enfield). The two exceptions are of segmented or "Medford" form. Of these the Danish Krag has six grooves and the Japanese rifle four grooves. The twist of the rifling is to the right or clock-wise, except in the cases of the Model 1917 caliber 30-06 or Lee Enfield British and French rifles. The Italian rifle has what is called a progressive twist.

The trigger mechanism on military actions, in every case, has what is called a "double pull" or preliminary trigger pull. In such systems, the trigger mechanism is so arranged that after a long light pull the motion is stopped, the firing pin being released by a further short and heavier pull.

In view of the fact that the military breech actions are all on the bolt principle, much ingenuity has been shown in designing them to function with considerable speed, regularity and safety. There

are many and important differences between the various types of these rifles. The main dividing line is between the "straight-pull" actions, in which the bolt is drawn straight back to extract the fired case and pushed straight forward again to feed in a fresh cartridge and lock the breech, and the ordi-

nary "turn-bolt" action, in which the breech is first unlocked by turning the bolt upwards and then the cartridge extracted by drawing the bolt backwards. A new cartridge is fed in and the breech locked again by a reverse movement. Of straight-pull rifles the only ones now in use are the Austrian



Mauser, Model 1904

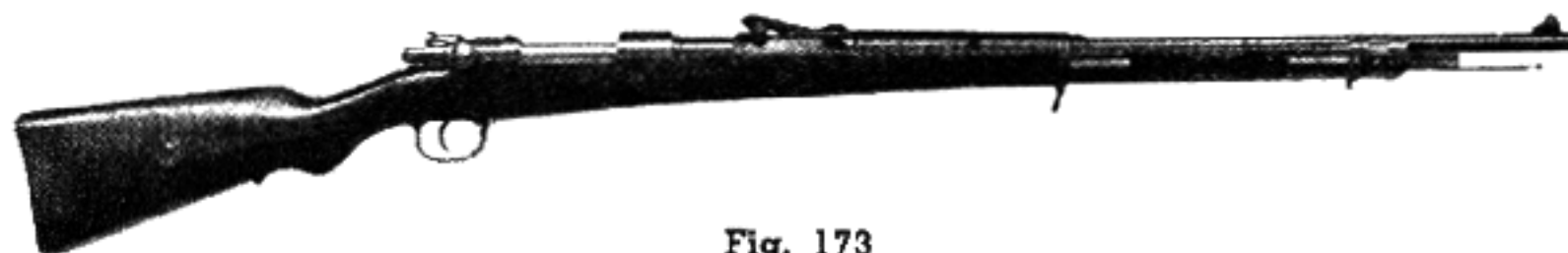


Fig. 173
Mauser, Model 1898 Rifle (Germany)

Mannlicher and the Swiss Schmidt-Rubin. The Ross, once the arm of Canada, is now obsolete.

Turning bolt actions may be divided into three classes: Mauser and Mauser types, Mannlichers, and other types. In the last category are the Lee-Enfield, the Lebel, the Nagant, and the Krag-Jorgensen.

Mauser Rifles — The Mauser action is that most generally in use, more than twenty nations being armed with this type of rifle. Figure 173 illustrates a typical Mauser action and has been reproduced from the descriptive handbook of *The Mauser Magazine Rifle (Model 1904)*.

<i>Mauser Rifles</i>	<i>Model Caliber</i>	<i>Caliber Millimeters</i>	<i>Size Inches</i>
Argentina	1891	7.65	0.301
Belgium	1889	7.65	0.301
Bolivia	1891	7.65	0.301
Brazil	1904	7.00	0.276
Chile	1904	7.00	0.276
China	1893	7.00	0.276
Colombia	1891	7.65	0.301
Ecuador	1891	7.65	0.301
Germany	1898	7.90	0.311
Luxembourg	1896	6.50	0.256
Mexico	1902	7.00	0.276
Peru	1891	7.65	0.301
Portugal	1904	6.50	0.256
Persia	Various old Models		
Spain	1896	7.00	0.276
Sweden	1906	6.50	0.256
Turkey	1905 and other Models	7.65	
Uruguay	1895	7.00	0.276
Yugoslavia	1899	7.00	0.276
<i>Mauser Type Rifles</i>			
Italy	1891 Adopted	6.50	0.256
Japan	Yen 38th Model	6.50	0.256
United States	1903 Adopted	7.62	0.300

The Mauser bolt is of strong and simple construction, in one piece, without a separate movable head. The locking lugs are opposite one another at the front end, *a,a*, illustrated in Figure 173 on the German military bolt (Model 1898); and on the Model 1904 bolt is an extra lug, *a1*, engaging in a recess in the cylindrical part at the rear end of the body. This acts as an additional safeguard in case the front lugs should break. The lever or handle is straight and stands out at right angles from the rear end of the right side of the bolt. The end is formed to a round knob.

At the back end of the bolt is cut a cam-shaped recess *d* which receives the stud of the cocking piece and on turning up the bolt lever slightly withdraws the striker. On the opposite side is a small notch *d2* for the tooth of the safety bolt. The small rib *a2* is special to the German and Model 1904 rifles. It acts as a guide in withdrawing the bolt. When the bolt is closed it lies underneath and supports

the extractor. The face of the bolt is recessed to take the base of the rimless cartridge.

The striker or firing pin has a short point and collar *e* against which the main spring bears. The rear end has three interrupted grooves for connection with the cocking piece. The rear portion of the pin is flattened on two opposite sides to prevent it from turning in the bolt plug. The Model 1889 (Belgian) rifle has a striker differing somewhat from later designs. The rear end is threaded, and a rib formed on the pin takes the place of the flats in preventing the striker from turning. The main spring is of 0.06 inch diameter coiled wire with 29 to 31 coils in the different models. Uncompressed it is about 5 inches long.

The cocking piece *d* is provided with interrupted lugs, so that it can be connected to the striker pin by giving it a quarter-turn. An incorrect connection of these parts is impossible, as the rear groove of the striker and the corresponding bearing in the cocking piece are broader than the two front ones. In the Model 1889 a female thread takes the place of an interrupted lug; on the under side of the cocking piece is a projection *f* which travels in a groove cut for it in the tang of the body. This projection engages with the sear nose when the bolt is pushed forward, so that the bolt travels forward while the striker remains stationary, thus compressing the spring fully for firing. The front top surface of the stud *g* is chamfered to correspond with the sloping surface *d* at the end of the bolt. On turning up the bolt the cam surface *d* forces back the stud *g*, gives a preliminary compression to the spring, and withdraws the point of the striker from the fired cap.

The bolt plug *e* screws loosely into the rear end of the bolt by means of a buttress (reinforce) thread, and closes the opening through which the striker is inserted in assembling. It serves as a seat for the main spring. It takes no part in the turning movement of the bolt, the cocking stud *f* working in the slot *f1*. Peculiar to the German Model and also the Model 1904 is the strengthening of the front part of the bolt plug in semicircular shape. This flange acts also as a shield to protect the user against accidental back-blast. In the German and Model 1904 rifles also there is on the left side of the plug a pin catch *e* which, in a certain position, engages with the bolt and keeps bolt plug and bolt securely locked against accidental unscrewing during the opening and closing movements. In other models the front of the stud *g* on the cocking piece rests in a small slot on the rear of the bolt and prevents the bolt plug from turning when the safety bolt is not holding back the cocking piece. The top of the bolt is drilled with a cylindrical hole for the

bolt of the safety catch *f*, which is shown in position on the assembled firing pin in *G* and *G1*.

The safety bolt consists of a thumbpiece and a spindle which works in the hole in the bolt plug. When the bolt is closed and the thumbpiece is turned vertically, as shown in the illustration, the flange *h* on the safety bolt is brought in front of the top of the cocking piece and forces it back slightly, withdrawing the stud *f* from contact with the sear. On turning the thumbpiece over to the right the cocking piece is still locked as above, but at the end of the stem, where it is not cut away, enters into the slot *d2* on the end of the bolt and locks the bolt and bottom plug together, preventing the former from being revolved. The safety bolt is retained in the two safety positions by the top of the cocking piece bearing on shallow depressions on the flange of the safety bolt. In the Model 1889 (Belgian) the safety bolt is retained in position by a small pin fitted in the under side of the thumbpiece, actuated by a spiral spring and bearing in a groove cut across the top of the bolt plug. This practise is also followed in the Springfield bolt.

The extractor is a strong, broad, long-machined spring *H* terminating in a claw, the front of which is chamfered to allow it to ride over the base of the cartridge when the hook engages into the groove at the base of the cartridge and holds it rigidly against the bolt head. The extractor is provided with an undercut groove which engages on the dovetail projection on the spring band *j*, which revolves in a groove on the bolt. A projection *k* works in a groove at the bolt head, and through this medium the pull of the bolt is transmitted to the extractor. The right-hand lug lies under the extractor in a recess when the bolt is drawn back. In the Model 1889 the extractor is a short spring let into the side of the bolt head between the two locking lugs. It revolves with the bolt, which is an objectionable feature, owing to the fact that the rear end of the barrel has to be weakened by being cut away to afford clearance for the end of the extractor, and also on account of the friction introduced between the extractor and the base of the fired cartridge.

The receiver or action is screwed to the breech end of the barrel. On either side of the bolt way is a channel cut, in which slide the bolt lugs and the extractor. The groove on the right side of the receiver is partly cut away to allow the cartridge to be ejected to the right. At the front end of the action, connected with the grooves, are the recesses for the locking lugs. The rear part of the action, through which the bolt moves, forms a complete cylinder, prolonged behind into a tang which is recessed for the cocking stud to move over it. In front of the cylindrical portion are vertical grooves

to hold the cartridge clip in loading. The tang is drilled and threaded for the rear guard screw, which helps to hold the trigger guard, stock, and receiver together. In the tang is an opening through which projects the sear. In some early models another slot is cut in the action, just behind the magazine way, for a projection on the front end of the sear; this engages in a slot in the rear of the underside of the bolt when the trigger is pressed. The object is to prevent the accidental discharge of the arm when the bolt is not fully in the firing position. In the Model 1889 and also in the Model 1904 a cross groove is cut, just behind the magazine way, for the additional safety lug on the bolt. In the Spanish Model the left side of the action is cut away to give clearance for the thumb in pushing the cartridges out of the clip or charger into the magazine. Some Turkish Models are fitted with a cut-off similar to that of the Lee Enfield, Mark III. It should be noted that during the World War the Turkish army was provided with Mausers of different Models from the standard Model 1890 to 1903.

The bottom of the action body is cut away for the magazine. The Model 1889 and later models have the magazine and trigger guard in one piece and secured to the stock and receiver body by means of screws. These screws are clearly shown in section *j*, which figures the whole bolt mechanism. The five cartridges lie in two columns and are pressed up against the overhanging edges of the magazine by the pressure of a flat ribbon spring secured to the bottom magazine floor plate and the magazine follower. The follower is provided with a raised rib near its left side, which raises the column of cartridges resting on it to the level of the other column and enables the cartridges in both columns in turn to be caught by the advancing bolt and fed into the chamber. The bottom floor plate is held in position by a small stud to the rear of the magazine opening. The stud can be depressed by the point of a bullet, then the floor plate can slide backwards and be taken out together with the spring and follower.

As a war measure the German rifle was provided with a deep curved box magazine to hold twenty cartridges. It could be attached in place of the bottom floor plate of the standard magazine. It was provided with a simple cut-off in shape of a pin which could be inserted from side to side over the cartridge column. In the Model 1889 (Belgian) the magazine is a detachable box of sheet metal, holding five cartridges in single column. The follower is pressed upwards by an arrangement of levers and flat springs.

All Mauser rifles are clip loaders. The chargers

or clips consist of strips of thin sheet-steel with the edges turned inward and reinforced to engage in the cannellure of the cartridge head. The cartridges are held with sufficient firmness in the clip by a spring of ribbon steel, secured by two small tangs which fall into depressions in the clip body. Two small end tangs are turned up, holding the cartridges firmly in the clip body. The cartridges are swept into the magazine by one motion of the thumb, the clip being thrown out by the first forward motion of the bolt.

The trigger mechanism is on the "double pull" system. The sear *k1* projects into the groove cut in the tang and is part of a bar *m* pivoted near the front end of the body. It is actuated by a spiral spring *l* let into it, one end of which bears against the body. The bar portion of the sear has a vertical slot cut in it, in which the trigger *n* is pivoted. On pressing the trigger the forward of the two projections on the upper surface of the arm presses against the body and the sear is depressed, a sliding movement being felt. The leverage is then transferred to the rearmost projection, a slight check is felt, and on further pressing the trigger the sear parts suddenly from the cocking-piece stud and the striker flies forward to fire the cartridge. There is no half-cock, nor can the striker be placed at full-cock without opening and reclosing the bolt.

An arrangement is provided for stopping the

backward travel of the bolt to prevent its being accidentally withdrawn or jerked out. This consists of a lever hinged on the left side of the action. On it is a heel which projects through a slot, into the groove for the left lug of the bolt. The lever is pivoted on a pin and is kept pressed against the body by a small flat spring let into it. The bolt is stopped in its backward travel by the left lug coming in contact with the heel. The retaining-bolt can be swung away from the body so that the bolt can be withdrawn when necessary for cleaning, inspection, etc.

The ejector is pivoted in the same pin as the retaining bolt and forms part of it. It is a triangular-shaped flat piece of steel actuated by a spring inside the retaining-bolt lever. A slot is cut for it in the left locking lug and in the face of the bolt head, so that when the bolt is drawn back the ejector springs into this slot. The base of the cartridge then strikes against the ejector, but as the extractor continues to draw back the right side of the cartridge the latter is swung around and thrown out of the action to the right. There are some small differences in retaining bolts and ejectors—differences of form and not of principle.

Springfield — The United States magazine rifle Model 1903 has an action of Mauser type, but differing from those previously described. A descrip-

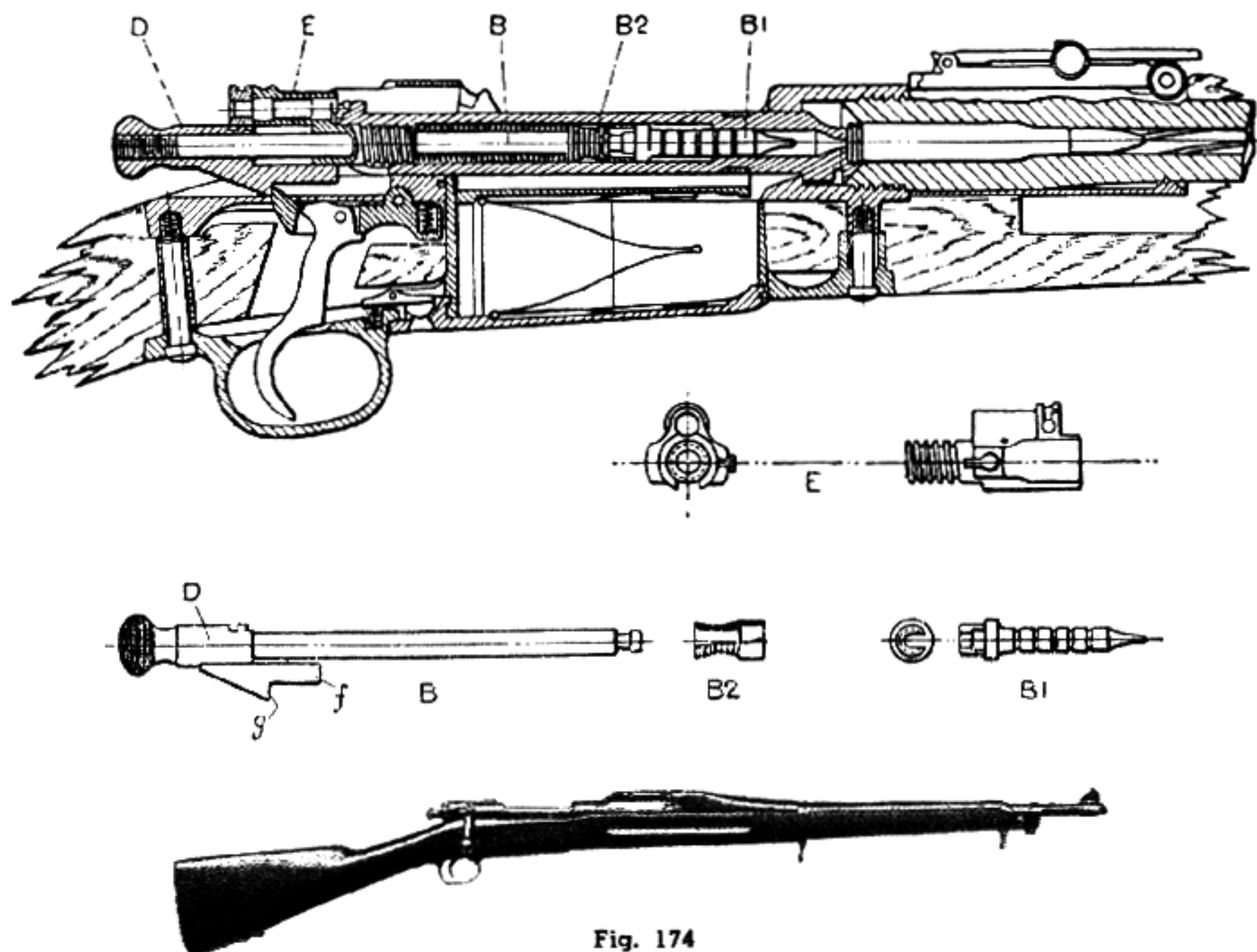


Fig. 174
Springfield, Model 1903 Rifle (United States)

tion is hardly required for the reason that this is our national arm. Those who may want a full description may send to the Government Printing Office and ask for book No. 1923, Description and rules for the management of the "United States Rifle" caliber 30 Model 1903. Figure 174 illustrates the United States Springfield Model 1903 rifle in comparison to other military arms.

Mannlicher-Carcano — The Italian Mannlicher-Carcano, Model 1891, Figure 175, has an action of Mauser type adapted by Mr. Carcano of the Turin Small Arms Factory. The Mannlicher clip system of loading, similar to that employed in the Dutch and Roumanian rifles, is employed to charge the magazine. The action differs from the typical Mauser in the following particular: The bolt lever, which is not at the extreme end of the bolt, projects at right angles about one-third of the length of the bolt from the rear. The rear of the action does not form a complete cylinder, but is cut away at the top to allow the bolt lever to pass.

Under the front end of the body is a transverse rib, following Mannlicher practise, which fits into a groove in the stock and serves to transfer the shock of recoil to the stock. The bolt plug *e* fits into the rear end of the bolt, and a groove *a* inside the rear end of the latter admits the stud *c* entering the slot *b*. The main spring bears on the front of the plug and the striker passes through the hole in the center of it.

The bolt plug acts as a safety arrangement in the following manner: When the plug is in its normal position the stud *c* is resting in the recess at the extreme end of the slot *b*, and when the cocking piece and striker are held back by the sear the main spring tends to drive them forward. If now the bolt plug is pressed forward and turned round, by means of the fingerpiece, so that the stud *c* rests in the recess *d*, the back of the bolt plug bears against the front of the cocking piece and the latter has no tendency to fly forward. If the trigger is now pulled, cocking piece and striker remain at rest. If the stud *c* is turned into the end

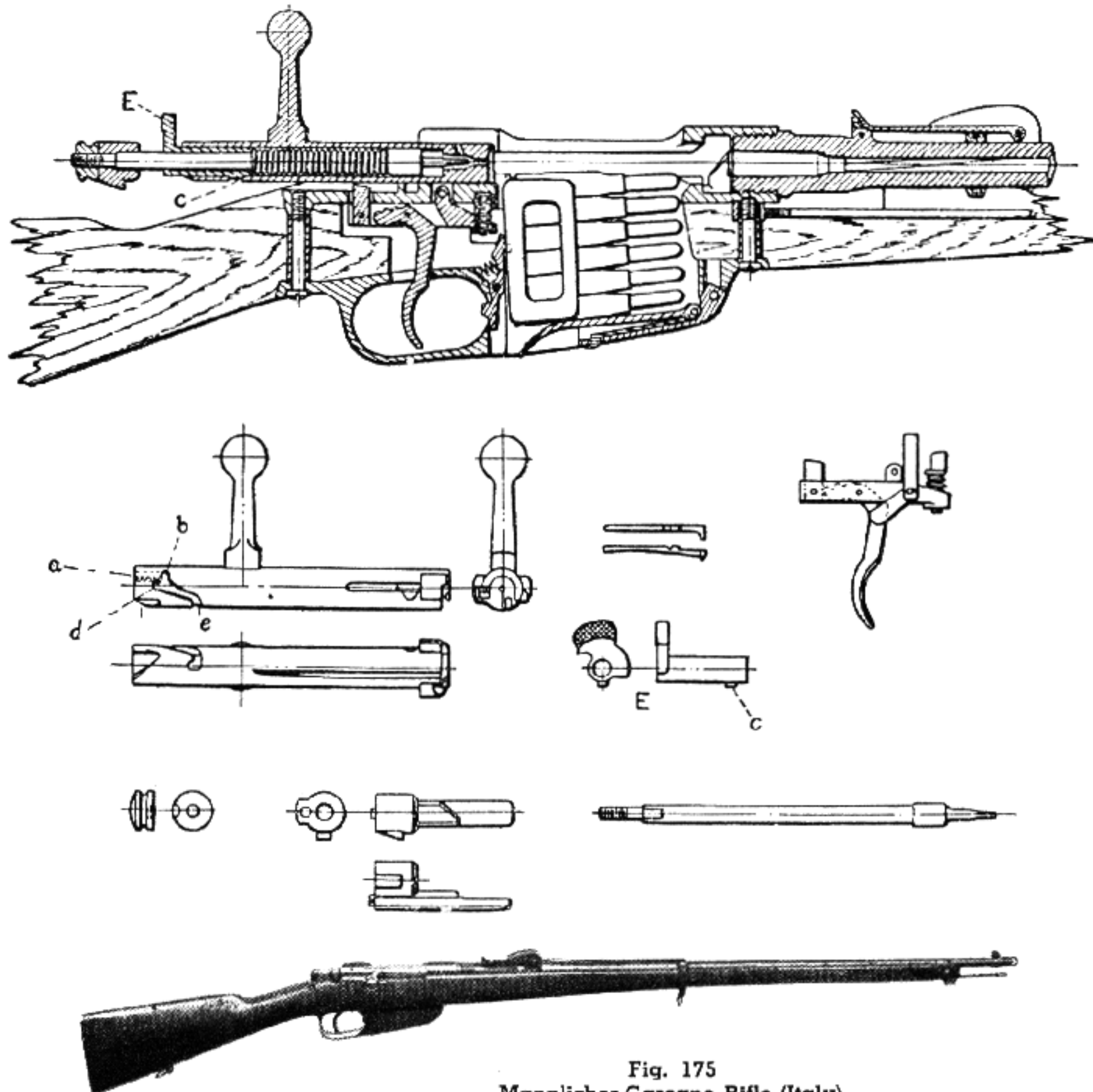


Fig. 175
Mannlicher-Carcano Rifle (Italy)

of the slot *b* and drawn out through the groove *a*, the bolt plug, cocking piece, striker and main spring are withdrawn from the bolt.

The extractor is a medium-length, narrow spring inserted into its groove from the front of the bolt. The extractor revolves with the bolt, which is an objectionable feature. The extractor lies under the right-hand lug, and has a shoulder on it which springs up under the lug and takes the pull during extraction. At the shoulder is a small groove to take the end of a screw-driver or punch in depressing the shoulder when removing the extractor from its groove.

The retaining bolt is on the right-hand side of the action. Its upper end passes through a slot in the right-hand groove for the bolt plug. It is slotted to connect with an arm on the right side of the trigger. To withdraw the bolt the trigger must be pulled when the retaining bolt is lowered and the bolt can pass over it. The magazine holds six cartridges, and is similar to that of the Dutch Mannlicher.

The ejector rests in a bearing in the front of the sear and is pressed upwards by the sear spring. Its top end passes through a slot in the body, enters a groove on the underside of the bolt when the bolt is withdrawn, and strikes against the left-hand lower part of the base of the cartridge, throwing it out to the right.

Japanese — The Japanese Yen 38th Model rifle is of Mauser pattern and differs from typical Mausers in the following manner: The striker and cocking piece are made in one. The striker is of large diameter for two-thirds of its length, and is bored to a depth of 4.2 inches from the rear to take the main spring. A cocking toe is formed on its rear end. In the interior at the rear end are cut two longitudinal guide grooves, disposed at right angles to one another, in which a stud on the locking bolt moves.

On the rear of the bolt the usual chamfered recesses are cut, in order to withdraw the striker from the fired primer on the raising of the lever of the bolt. As there is no bolt plug, these recesses are cut somewhat deeper than in typical Mauser practise.

The locking bolt is in the form of a cylindrical cap on the end of the bolt, with a stem which fits into the striker and bears against the main spring. It can be placed in the safety position only when the action is cocked. To lock the action the locking bolt is pressed forward and then turned to the right, the movement to the right being limited by the travel of a stud, on the under surface of the locking bolt, in a groove in the body. By pressing

forward the locking bolt the main spring is compressed, and by turning the locking bolt a small stud on the rear part of the stem, which had engaged with a guide ledge on the forward end of the locking bolt, engages with a stud on the bolt, which is thereby locked. The locking bolt is held by the weight of the main spring with a stud on the rim of the locking bolt forced into a recess in the groove at the rear of the body. When the locking bolt is disengaged the weight of the main spring is transferred from the point of the stem of the locking bolt to a circumferential rib on the bolt, which engages with a rib on the inside of the cylinder of the locking bolt.

The knob of the bolt lever is egg-shaped.

A bolt cover is provided. It is semicircular in cross-section and is retained in guide grooves on either side the body, in which it moves. It encases the whole of the top of the body when the breech is closed. The bolt lever passes through a hole in the cover and draws the latter backwards and forwards.

The magazine and trigger guard are not in one piece. The box is made of sheet steel and holds five cartridges in two columns. In other respects it is similar to typical Mauser magazines.

Main spring Compression — In all Mauser actions, on the first motion of the lever to open the action the cocking piece and bolt plug are prevented from turning with the bolt, owing to the cocking stud projecting into the groove cut in the tang of the body. The tooth on the cocking stud is forced back by the cam-shaped recess on the rear of the bolt, slightly withdrawing the striker and partially compressing the main spring.

In the Belgian, Spanish, Turkish, and Japanese models, on locking the bolt when there is about an inch of travel before final closing, the cocking stud engages with the sear, so that the cocking piece and striker are held back while the bolt and bolt plug are pushed forward, thus completing the compression of the main spring.

In the 1904 and German Models of the Mauser, and in the Springfield Model 1903 and Italian actions, the cocking stud does not engage with the sear until the bottom of the bolt lever meets the cylindrical portion of the body. The main spring takes its final compression when the bolt lever is turned down. This compression is materially assisted and made easy by the lugs on the bolt traveling along the cam-shaped entrances to their recesses and being thereby forced forward.

Primary Extraction — In all Mauser actions primary extraction of the fired case is attained by the

leverage exercised by the lower end of the lever, at the point of junction with the bolt, moving against an inclined plane cut on the rear face of the cylindrical part of the body. In the Springfield action the inclined plane is a spur or continuation of the lever, formed round the bolt, which works against a cam surface on the rear of the body.

In the Italian action the rear end of the body is not cylindrical but is slotted to allow the bolt lever to pass. The necessary leverage to move the fired case is given by the left-hand lug on the bolt working against a cam surface at the front end of the left-hand groove in the body.

Mannlicher Rifles — Turning-bolt action—Figure 176.

	Model	mm.	inch
Greece	1903	6.5	.256
Holland	1895	6.5	.256
Roumania	1893	6.5	.256

In the Mannlicher bolt the locking lugs are close

to the head on opposite sides of the bolt; but disposed a little further back than those of the Mauser to allow of the fitting of a separate bolt head, which does not rotate with the bolt when it is actuated. The advantages of a separate bolt head are many, and considerably outweigh the advantages claimed for the solid bolt head, the most important of which are strength and the impossibility of the bolt head being lost. In order to get the main spring and striker into the bolt, the front or rear end must have an opening as large in diameter as that of the main spring. These openings are closed either by a bolt head or a bolt plug. A bolt head is lighter and less complicated than a bolt plug, and the extractor can be attached to it and can thus be prevented from rotating with the bolt, and at the same time be of light and simple construction. The disadvantage of having the extractor rotate with the bolt has already been dealt with. Another advantage of the separate bolt head is that if the end of the bolt be damaged by defective cartridges or

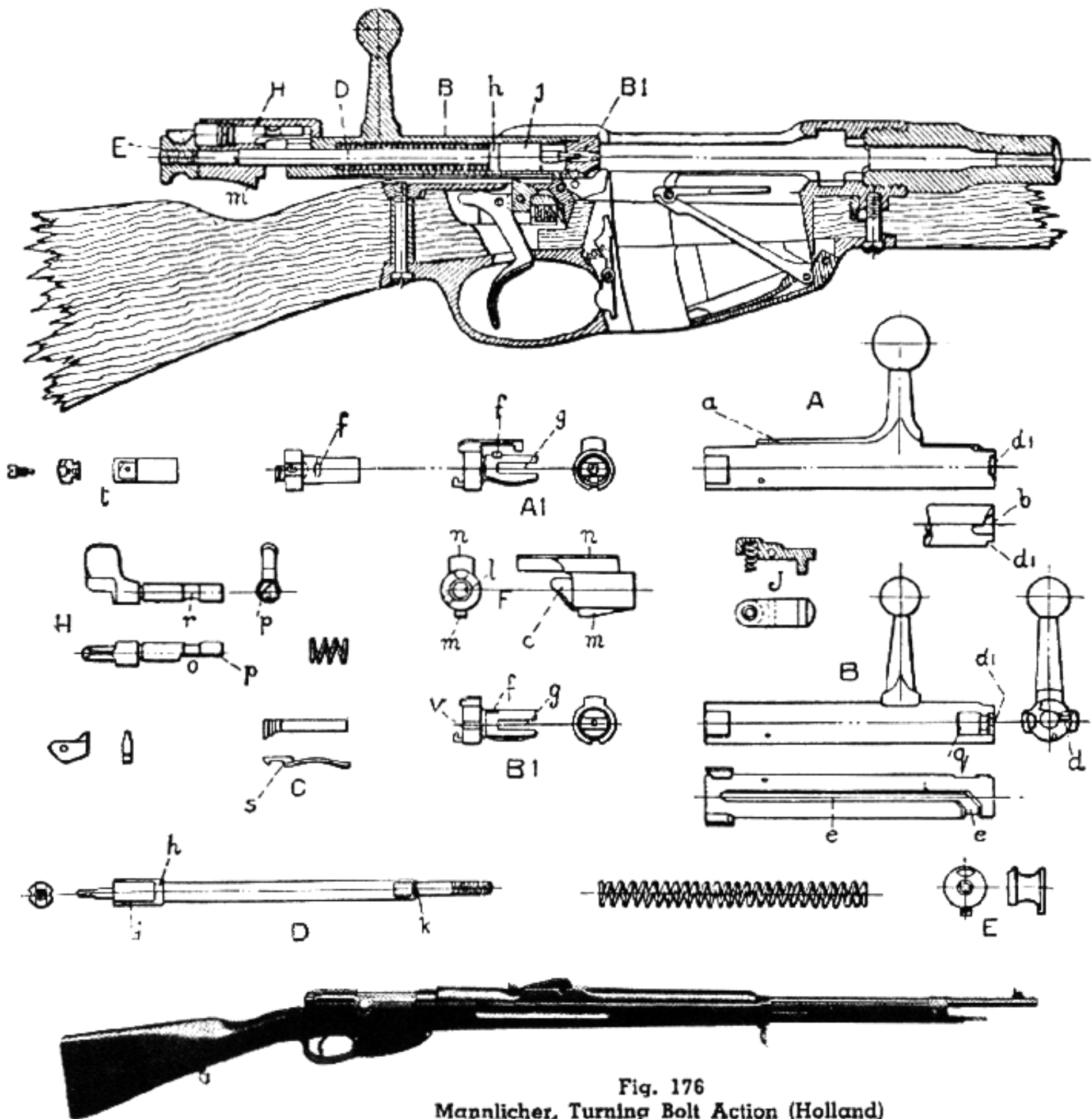


Fig. 176
Mannlicher. Turning Bolt Action (Holland)

in any other way, a repair can be more cheaply effected by exchanging the bolt head than by renewing the entire bolt cylinder.

The disadvantage of a separate bolt head is that the lugs have to be located further back on the bolt to allow for the head and are thus further removed from the barrel and cartridge, and the action body has to be lengthened to allow of proper working of the action. Also, if the bolt head becomes loose, through wear, the shooting of the rifle is impaired.

The Mannlicher bolt is simple in construction and, like the Mauser, can be stripped and assembled without the use of tools. The position of the two locking lugs has already been indicated, and reference to figures *A* and *B*, Figure 176, will obviate further description. *A* represents the Dutch and *B* the Roumanian bolt. The Greek bolt resembles the Roumanian closely, except for differences that will be detailed as they are come to. The Dutch bolt has a strengthening rib *a* in line with the lever. The lever projects at right angles to the bolt about one-third of the length of the bolt from the rear, and terminates in a knob. The knob of the Greek bolt is hollowed out for lightness. It is larger than in either of the other patterns.

There is a cam recess *b* at the end of the bolt, similar to that described in the Mauser bolts and serving a similar purpose. The cocking-piece stud *c* enters it on firing, and the leverage given by the inclined plane on turning up the lever in the first motion of reloading forces back the cocking piece, slightly withdraws the striker, and gives the first compression of the main spring. At the end of its travel along the inclined plane the tooth of the cocking piece rests in a shallow groove *d* in which it is held by the weight of the main spring and prevented from turning when the bolt is withdrawn. On the Greek bolt there is also a projecting cocking-piece stop stud in front of the cam, which prevents the cocking piece being overturned to the right when in the cocked position for insertion in the rifle.

As the striker and main spring are inserted from the front there is no bolt stop. A segmental recess *d-1* on the rear end of the bolt receives the end of the safety bolt. It is larger in the Roumanian and Greek than in the Dutch models. A small gas escape is provided behind the left-hand lug. On the Roumanian and Greek bolts there is a groove *e* to provide a clearance for the ejector fitted to those types. There is a hole in the rear of the bolt through which the end of the striker works.

The bolt heads *A-1* and *B-1*, for the above bolts, are provided with tenons which fit into the front ends of the bolts. The studs *f* work in circular

grooves on the inside of the bolts. The bolt heads can only be withdrawn when the studs are turned, so that there are opposite clearances provided for them. The tenons are slotted at *g* for the flats on the front of the strikers. The extractor *C* fits into a groove on the side of the bolt head.

The main spring consists of 26 coils of .056 wire. The rear end bears against a seating in the bolt cylinder.

The striker, *D*, passes through the main spring, bolt, and cocking piece, and screws into the nut, *E*. In the Greek pattern the attachment is by interrupted lugs. The front end of the main spring bears against the collar *h*. The flat *j* works in the slot *g* in the bolt head and prevents the cocking piece from turning when the stud is clear of the groove in the tang, the bolt being drawn to the rear.

The cocking piece *F* fits on to the striker and butts up against the shoulder *k* on it. It is prevented from turning by the end of a screw *l* bearing on the flat on the striker. The stud *m* travels in the groove in the tang of the body and engages with the bent of the sear. The rib *n* is bored out from the rear for the stem of the safety bolt.

In the Greek Model the under side of the top rib of the cocking piece is grooved on the right side to clear the stop-stud on the bolt, and the striker hold is bored with interrupted rings for attachment to the striker.

The stem of the safety bolt *H* fits in its seating in the rib of the cocking piece. It is operated by means of a fingerpiece. A small spiral spring fits over the stem and keeps the safety bolt pressed to the rear. When the striker is cocked, and the fingerpiece is pointing to the left, the stem of the safety bolt is able to move forward over the bolt, as the half that is cut away, *o*, is underneath, next to the bolt. When the finger-piece is turned over to the right, the small cam, *p*, on the end of the safety bolt, engages the front of the recess *d-1* in the bolt and forces safety bolt and cocking piece back, disengaging the stud on the latter from the sear bent. The safety bolt and cocking piece cannot now move forward when the trigger is pressed. In the Roumanian and Greek pattern the finger-piece can be turned over to the right, and the bolt locked, when the cocking piece is in the fired position. The end of the stem of the safety bolt then engages in the recess *q*, a clearance, *r*, being provided in the stem for the division between the recesses. In the Dutch Model the bolt cannot be locked in the fired position.

The extractor *C* fits in a groove in the bolt head. The shoulder *s* fits against a corresponding shoulder in the bolt head, and takes the strain during extraction. The front terminates in the usual claw.

In the Dutch and Greek Models an undercut stud on the ejector *t* slides backwards and forwards in an undercut groove in the bolt head, its travel being limited by a screw working in a groove. The back of the ejector strikes the retaining bolt when the bolt and bolt head are drawn to the rear. The ejector slides forward, and the front of the stud strikes the left rear of the cartridge, ejecting it to the right. The front edge of the stud is beveled off to enable the base of the top cartridge as it rises out of the magazine to push back the ejector.

In the Roumanian action the ejector is pivoted in a slot on the under side of the body immediately behind the magazine way. It is similar in shape to the ejectors already described for typical Mauser actions. The tail of the ejector works in the groove *e* in the bolt. When the bolt is drawn back so that the tail is at the front end of the groove, it is depressed, and the small tooth on the front being raised into the boltway and into the slot *v* in the bolt head, strikes the base of the cartridge and tilts it out of the rifle, to the right. The bolt head is prevented from turning by the ejector, or, in the Roumanian Model, by a stud which takes its place, working in the left-hand groove of the body.

The retaining bolt *J* is pivoted on a vertical pin on the left side of the body near its rear end. A tooth projects into the left groove in the body and arrests the backward movement of the left lug. In the Dutch rifle it is the ejector that strikes the tooth. A small spiral spring keeps the tooth up to its work. To withdraw the bolt, the thumb-piece on the rear end of the retaining bolt is pressed inwards against the body, when the tooth is removed from the boltway and the bolt is free to move backwards out of the body.

The receiver screws on to the barrel in the usual manner. On either side of the boltway is a longitudinal groove for the lugs on either side of the front end of the bolt. At the front end of these grooves are cam-shaped grooves which lead to recesses above and below the boltway. On firing, the lugs resist the backward pressure of the cartridge case by taking a bearing against the rear face of the recesses. The groove on the right is partly cut away to facilitate loading the magazine and to permit of ejection of the fired cartridge. Behind the recesses the bottom of the body is cut away for the magazine. Behind the magazine way the body does not form a complete cylinder, but is cut away at the top to permit of the passage of the bolt lever. The rear part of the body forms a tang in which a groove is cut for the stud of the cocking piece. Near the front end of this groove is an opening through which the bent of the sear projects. At the front end of the magazine way is a projection, the rear face of

which is grooved to form a guide for the bullets of the cartridges as they rise in the magazine; it also serves to keep the trigger guard at the correct distance from the body. Underneath the front part of the body is a boss which fits in a recess in the stock and transfers the shock of recoil from the barrel and body to the stock. It also takes the front guard screw. In the Roumanian rifle there is a narrow slot just in rear of the magazine way for the ejector to work in.

In the Dutch and Roumanian rifles the magazine works on the clip system. Each clip, which is of sheet steel, with deep sides, contains five cartridges. The clip is placed in the magazine together with the cartridges, which are forced up out of the clip by the action of the magazine spring against a lever termed an "elevator." When all the cartridges have been pushed up out of the clip the clip falls out through the bottom of the magazine, in which a hole is left for the purpose. The advantages of this system are that the loading is easier than when the cartridges have to be swept out of a charger by the action of the thumb, and the clips and cartridges can be easily removed from the magazine when necessary. The disadvantages are that the clips are more bulky and heavier than charges and are more liable to be bent and distorted. The magazine must be made deeper than in the best designs of clip-loading systems, to hold the same number of cartridges, as they lie in the magazine box in single instead of in double column. With a charger extra pressure can be applied by the thumb to overcome extra friction caused by rust or dirt between the charger and the cartridges; but in the case of the clip the strength of the magazine spring cannot be temporarily increased to overcome any abnormal resistance. With charger-loaded magazines, a partially emptied magazine can be filled up with separate cartridges, if desired. With clip-loading the magazine cannot be charged until the empty clip has fallen out of the bottom of the box. In addition, the large hole in the bottom of the box is undesirable in that it is liable to let dirt into the magazine, particularly when firing over a parapet or when firing prone.

In the Dutch and Roumanian rifle the lower part of the box is formed in one piece with the trigger guard. In the Roumanian pattern a small platform is pivoted on to the end of the elevator and actuated by a spiral spring. In the Dutch pattern there is no platform, the end of the elevator being rounded off to work against the cartridges, which are not so well supported as by the platform.

The Schœnauer magazine of the Greek rifle is charger-loaded and is designed on an ingenious rotary system, which, however, presents no ad-

vantages over the more simple charger-loaded box magazines with rising platform and is more liable to become clogged with dirt that cannot easily be cleared from the mechanism.

A rectangular box forming the bottom part of the magazine is fitted into the bottom of the body and held in position by a bottom-fixing plate, pivoted in the center at the bottom of the box; each end of this plate, when revolved, enters radial locking grooves, cut in the front and rear of the downward extensions of the bottom of the body, which forms the top part of the magazine. The magazine bottom-fixing plate is retained in position by a spring which enters a recess in the plate.

In the rectangular box, forming the bottom part of the magazine, a rotary platform is fitted. The platform is bored to receive front and rear axis studs attached to a spiral spring. The axis studs are grooved to receive, and prevented from turning by, two retaining pins, fitted in the axis hole of the platform. The platform is provided externally with five grooves to receive the cartridges.

As the cartridges are charged, the magazine platform is rotated and the spiral spring coiled, its tension being thereby increased (a certain amount of tension is on the spring when assembled with studs to the platform). By the expansion of the spring the platform is rotated, and the cartridges forced up to a cartridge stop projecting into the boltway. The thumbpiece of the cartridge stop projects through a slot cut in the top on the right side of the body, where it is pivoted. When charging the magazine, the cartridge stop is depressed by the cartridges. If it is desired to remove the cartridges from the magazine, the cartridge stop is depressed by pressure on the thumbpiece, when the cartridges are ejected out of the magazine.

The trigger mechanism of all Mannlicher rifles is on the "double-pull" system. Its construction can be clearly seen from Figure 176.

The main spring is given an initial compression and the striker withdrawn from the fired primer by the first motion of turning up the bolt, when the cocking piece is forced back by the action of the cam-shaped recess on the rear of the body cylinder working against a tooth on the cocking piece, which enters a groove at the end of the recess on the completion of its travel. Final compression is given by turning down the lever when the bolt has been returned. During this turning movement the cocking-piece stud engages on the sear bent, and the lugs on the bolt travel along the cam-shaped grooves leading from the grooves in the boltway to their seatings when in the cocked position. The reverse action, when unlocking the bolt, gives primary extraction of the cartridge.

Other Turning-Bolt Actions — The other turning-bolt actions, which do not fall into either of the classes dealt with, are the Lebel (French), the Krag-Jorgensen (Denmark and Norway), the Nagant (Russia), and the Lee (Great Britain). The Lee action is fully described later. The Lebel, Nagant, and Lee bolts have separate bolt heads. The bolt heads of the Lebel and Nagant carry the locking lugs and rotate with the bolt. This system would appear to have no advantages, except for repair purposes, over that in which there is no separate bolt head, as it is desirable that the bolt, especially the front part, should be as solid and rigid as possible. In the Lee action the bolt head does not rotate with the bolt, but the lugs are disposed at the rear of the bolt cylinder. This is not a desirable arrangement, as, on firing, the greater part of the body and bolt are thrown into a state of tension and compression respectively. This strain, acting on the unsymmetrical central part of the body, causes lateral vibrations, which have to be compensated for by displacing the foresight laterally. The unsymmetrical incidence of the strain also has a disturbing influence on the accuracy of the rifle. The British action has, however, advantages which may compensate for the fact that, mechanically, its design is unsound. There is no deep cylindrical portion in front of the action body, as in the continental forms, in which dirt can accumulate. The form of the action and the shape and disposition of the bolt lever allow of extremely rapid fire. It is possible to deliver roughly directed fire at the rate of sixty rounds a minute, a rate which is often attained and sometimes passed in routine tests on the range of the Small Arms Ammunition Inspection Department. With no other action is it possible to attain anything like this rate of fire. Competition has proved that, with good ammunition, and when adjusted carefully, the British rifle is capable of accuracy which compares favorably with that of any Continental Service weapon.

The Krag-Jorgensen has no separate bolt head, but there is one lug only which engages in a recess below the entrance to the chamber. This unsymmetrical arrangement is objectionable because it must give rise to considerable vibrations in a vertical plane.

Lebel Rifle — Figure 177.

FranceModel 1886.....8 mm..... .315 inch

This was the first small-bore rifle to be adopted by any nation, and with it smokeless powder was first used. A later model of this rifle, introduced in 1907, is similar to the 1886 model, except as regards the magazine.

in the body on the right and left of the boltway, and prevent the bolt being forced to the rear on firing. The face of the bolt head is cupped out to a depth equal to the thickness of the cartridge rim; the extractor, therefore, will not rise over the rim of the cartridge until the cartridge is almost home in the chamber. The bolt head is bored out for the striker, the hole in rear being oval to receive the part (24) on the striker. The groove (10) on the bolt for the sear nose is continued for a short distance along the bolt head at (10a).

The main spring consists of 19 coils of wire, 0.05 inch thick, set to a length of 3.9 inches.

The striker has a shoulder (22) for the main spring to bear against, and two slots (23) near the rear end, fit into the T-shaped recess in the striker knob (26). The part that enters into the bolt head is thinned down in front of the shoulder at (24). The point is further reduced in two steps at (25).

The cocking piece *D* has a projection (27) in front, working in the opening between the sides of the body. Underneath the projection is a tooth (28) which is shaped to fit into the cam recess (12) at the back of the bolt cylinder. The bottom front corner (29) of the cocking piece is the full-cock bent. The notch (30) is a second full-cock bent. The notch (31) affords clearance for the bent of the sear, when the cocking piece is forward in the fired position. The top is hollowed out and roughened to form a comb for drawing back, or letting down the striker, but the main spring is too strong for this to be done with safety. The striker passes through the cocking piece, its knob fitting into the recess (33) in the rear end of the latter and being locked with a half turn.

The extractor (20) is a short flat spring terminating in the usual claw, which projects over the face of the bolt head; it is dovetailed into its groove in the bolt head. The breech end of the barrel is beveled off for a quarter of its circumference to afford clearance for the claw of the extractor.

The ejector is a small pin (34) screwed into the body on the left side; it projects into the boltway and works in the slot (11) and (11a) in the bolt and bolt head.

The body has vertical sides which slope inwards at the top. The body is prolonged in front at (2a), and forms a cylindrical reinforce for the barrel. The rear end forms a long tang which is prolonged forwards at (40) between the sides of the body. The bolt slides in a longitudinal groove, cut in the upper part of the body, and the lugs (21) on the bolt head turn into recesses (3) at the front end of the boltway. The entrances to these recesses are rounded off to allow of the bolt coming back during primary extraction. At the front end, be-

low the projection (2a), is an opening (4) for the magazine tube. The bottom of the body is closed by a plate (5), to which are attached the sear and the cartridge elevating mechanism, which are situated below the boltway. The projection (6) on the front end of the plate fits into a recess in the body, and a screw passes through the body and through a screw hole (7) in the rear end of the plate. The body is cut away on the right side to allow of the cartridge cases being ejected to the right. The rear part of the boltway is open on top to allow for the cartridge cases being ejected to the right. The rear part of the boltway is open on top to allow of the passage of the rib (14), on the bolt, and also of the bolt lever, which turns down in front of the shoulder (8). Two recesses, (9) and (9a), are cut in the bottom of the right side of the body for the handle of the carrier axis-pin lever (49).

The trigger mechanism is on the double-pull system and is very similar to that of the Mauser and Mannlicher actions, except that the sear arm is short so that the sear is disposed rather in front of the trigger than behind it, and the spring is V-shaped instead of being spiral. The trigger is little curved and is awkward in shape.

The magazine of the 1886 model is tubular and consists of a longitudinal hole bored in the fore-end, lined towards the rear with a short steel tube. It holds eight cartridges, which are pressed towards the rear by a steel spring consisting of 78 coils of wire .03 inch thick. The spring terminates in a steel plunger which is prevented from coming out of the tube by a small shoulder in the latter. The cartridges are raised to the level of the chamber by a carrier scoop actuated by the bolt striking against a projecting lever. The magazine is loaded by depressing the scoop with the bullet of the cartridge and passing it into the magazine. On the right side of the bottom of the action body a checkered button, connected with the carrier axis pin, projects. When this is pushed to the front the depressor lever is moved so that it cannot be struck by the bolt. The magazine can then be retained full and the rifle used as a single-loader. The magazine of the latter 1907-15 model is of the more usual fixed vertical-box type, holding 5 rounds.

Besides being slow to load, a tubular magazine is objectionable because the balance of the rifle shifts as the column of cartridges is pushed to the rear and the cartridges loaded and fired. The necessary raising platform, also, is complicated and very liable to be jammed by dirt.

On first raising the bolt the main spring is compressed nearly to its full extent by the cocking piece being forced backwards by the cam recess on the

the cocking piece, and has a slot in its under side for the cocking stud to travel in. The top extends over the bolt, traveling in the slot cut in the body cylinder; a groove is cut in this portion of the sleeve, in which a corresponding flange on the rear of the bolt works, and prevents the pressure of the main spring from forcing the sleeve out to the rear.

The extractor (9), which is a long flat spring terminating in the usual claw, is pivoted by a screw to the bolt sleeve, and fits over the bolt rib, when the bolt lever is raised. It has a secondary spring (10) mortised into it, which fits under a projection in the body and prevents the extractor from rising during primary extraction. The extractor claw projects over the face of the bolt-head recess. When the bolt is closed the end of the extractor fits into a recess in the body, but when the bolt lever is raised the projection on the front of the rib of the bolt bears against a projection on the extractor, guiding the latter while the bolt is being drawn back. A slot in the cylindrical portion of the body assists in performing the last-mentioned function. The extractor of the Norwegian rifle is wider than that of the Danish.

There is no retaining bolt, but the lug on the bolt coming up against the resisting shoulder stops the backward movement of the bolt. To remove the bolt it must be drawn back, the extractor lifted so as to clear the top of the body, and the bolt lever turned to the left; this brings the lug opposite the slot in the body cylinder, when the bolt can be withdrawn.

The ejector (11) is a spring, dovetailed into the bottom of the boltway. Its front end projects upwards and enters a groove in the head of the bolt, when the latter is drawn back. On the base of the cartridge striking the ejector, the cartridge is rotated upwards and to the right, and is ejected from the action.

There is no locking or safety bolt in the Danish rifle. The striker can be placed at half and full cock without opening the action. The Norwegian rifle has a safety bolt of the Mauser pattern.

The body has no features calling for special mention, except that the recess (12) for the locking lug is at the bottom of the front end of the body and is readily accessible for cleaning purposes.

The magazine (13) is a horizontal box under the body, closed by a door on the right side. The spring, lever, and platform, which press the cartridges out into the boltway, are attached to the door. When the door is open the platform is held back against it, allowing for the free introduction of the five cartridges it will hold. The magazine can be charged with the bolt either open or closed, and can be replenished at any time by one or more

cartridges. This type of magazine is very slow compared with those which are charger- or clip-loaded. A charger is provided for this magazine, but it is a clumsy arrangement provided with a handle. The handle has to be raised from the side of the charger box and the rifle tilted to the left before the cartridges can be spilled into the magazine. A cut-off is provided by which the cartridges can be prevented from rising into the boltway.

The trigger mechanism is on the double-pull system. The sear is actuated by a flat spring.

The first compression of the main spring is given in the manner described for Mauser rifles, and the final compression by the sliding of the lug along the cam-shaped entrance to its recess.

Primary extraction is given by the bolt lever being forced back by working along the curved surface at the back of the body.

The Nagant Rifle — Three-line—Figure 179.

RussiaModel 1900....7.62 mm..... .30 inch

The bolt of this rifle bears some resemblance to that of the French Lebel but is of far more complicated construction. There is a separate bolt-head (1) which revolves with the bolt (2) and carries two lugs. A connecting bar lies underneath the bolt, holds the bolt-head to the bolt, acts as a guide to the cocking piece, and helps to retain the bolt in the body. When the bolt is closed the lugs are horizontal instead of being one above the other as in Mauser and Mannlicher actions. The striker (3) is in one piece and is actuated by a main spring of 28 coils of .05 inch diameter wire set to a length of 4 inches. The cocking piece calls for no special comment except that it can be pulled back by hand and revolved to the left when it fits into a recess on the rear end of the bolt, which prevents the rifle from being fired or the bolt from being opened.

The extractor is small and fits into a groove in the bolt head.

The magazine is of box form and is made in one piece with the trigger guard. It is fitted with an interrupter (4) to prevent the possibility of double loading. The interrupter is a plate which works in a slot on the left of the body in a manner somewhat similar to the cut-off of the British rifle. On loading the magazine the cartridges are forced down from the charger and press the interrupter outwards and are thus able to pass it. In loading and firing the cartridge next below the top one is held down by a tooth on the plate until the top cartridge has been forced into the chamber and the bolt lever turned down. No other rifle is fitted with this device. The ejector is a projection on the edge of the interrupter.

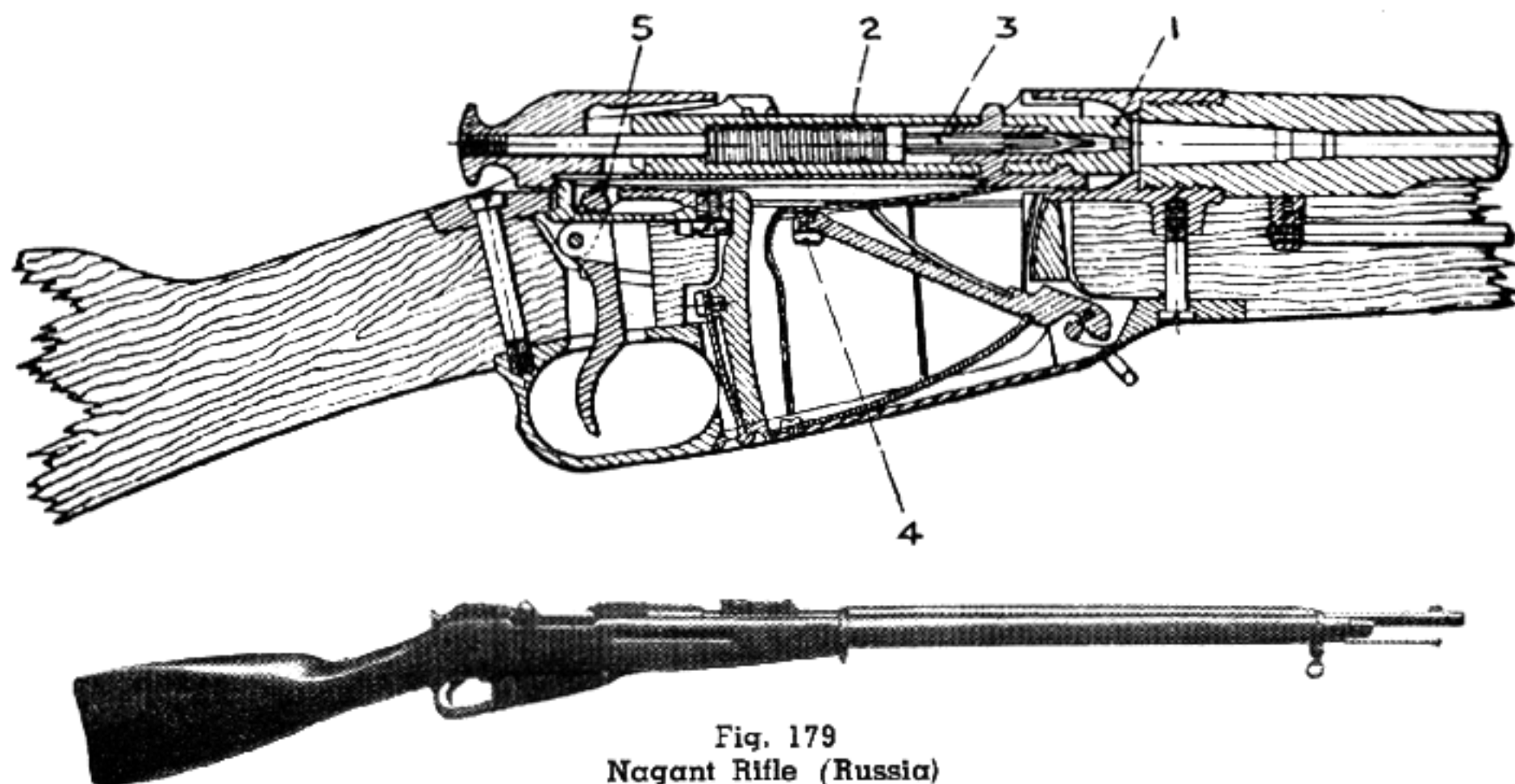


Fig. 179
Nagant Rifle (Russia)

The trigger mechanism gives a single pull. The trigger is provided with a tooth (5) at the top, which projects into the boltway and acts as a retaining arrangement. The trigger must be drawn back to depress this tooth and allow the front end of the connecting bar to pass over it, when the bolt can be withdrawn from the action.

Withdrawal of the striker from the fired cap is arranged for, and first compression of the main spring is given in the usual manner, by the cocking-piece nose working in a cam recess on the bolt end. Final compression of the main spring is given by the final turning down of the bolt and the action of the lugs on the sloped entrances to their seatings.

Primary extraction is effected by the front of a rib on the bolt working along an inclined plane in the body.

Straight-pull Action Rifles —

Austria—

Mannlicher Model 1895.. 8 mm... .315 inch

Switzerland—

Schmidt-Rubin . . . Model 1909..7.5 mm... .295 inch

Compared with turning-bolt action, straight-pull actions are complicated both in design and functioning. There are more moving parts bearing against one another and consequently more friction. In turning bolts, primary extraction is obtained by the direct leverage of the bolt handle being transferred to cam surfaces on the bolt and body.

With a straight-pull bolt this additional leverage is more difficult to obtain, but to a limited extent it can be introduced during the unlocking of the action at the beginning of the backward movement of the bolt handle. In the Schmidt-Rubin, Austrian Mannlicher, and Ross, the locking of the action is effected by rotating lugs. The necessary turning movement of that portion of the bolt carrying the

lugs is obtained during the unlocking of the action, at the beginning of the backward movement of the bolt handle, through the medium of helical grooves. A certain amount of additional leverage for primary extraction is obtained by cutting the lugs and their seatings in the body on a screw pitch. This, however, is not so effective as the direct cam action obtainable with a turning bolt. In theory, straight-pull bolts can be operated a trifle more quickly and are more easily worked without removing the rifle from the shoulder; but it is doubtful if there is any real advantage. Certainly no straight-pull rifle can be worked at the speed of the Springfield. Straight-pull rifles are said to be less likely to jam when exposed to sand and mud, as there is no turning movement to draw deleterious material down between the bolt and the left side of the body.

The Straight-pull Mannlicher — Figure 180. From the Austrian Official Handbook.

In this action the bolt is a hollow cylinder, reinforced at the rear end, where is the lever, terminating in the usual knob. The lever projects at right angles to the bolt. On either side of the bolt are ribs, *a, a*, which work in grooves in the body and prevent the bolt from turning. On the underneath of the front of the bolt are two feathers, *b*, which act as a retaining arrangement by coming in contact with two horns on the trigger when the bolt is drawn backwards. The trigger must be pushed forward to lower the horns and allow the feathers to pass, when the bolt may be withdrawn.

The underneath of the rear reinforced portion of the bolt is cut away for the stud of the cocking piece. The recess for the cocking piece is separated from that for the tail of the bolt head by a collar *d* secured by a screw, the point of which projects into the firing-pin hole, and, bearing against a flat

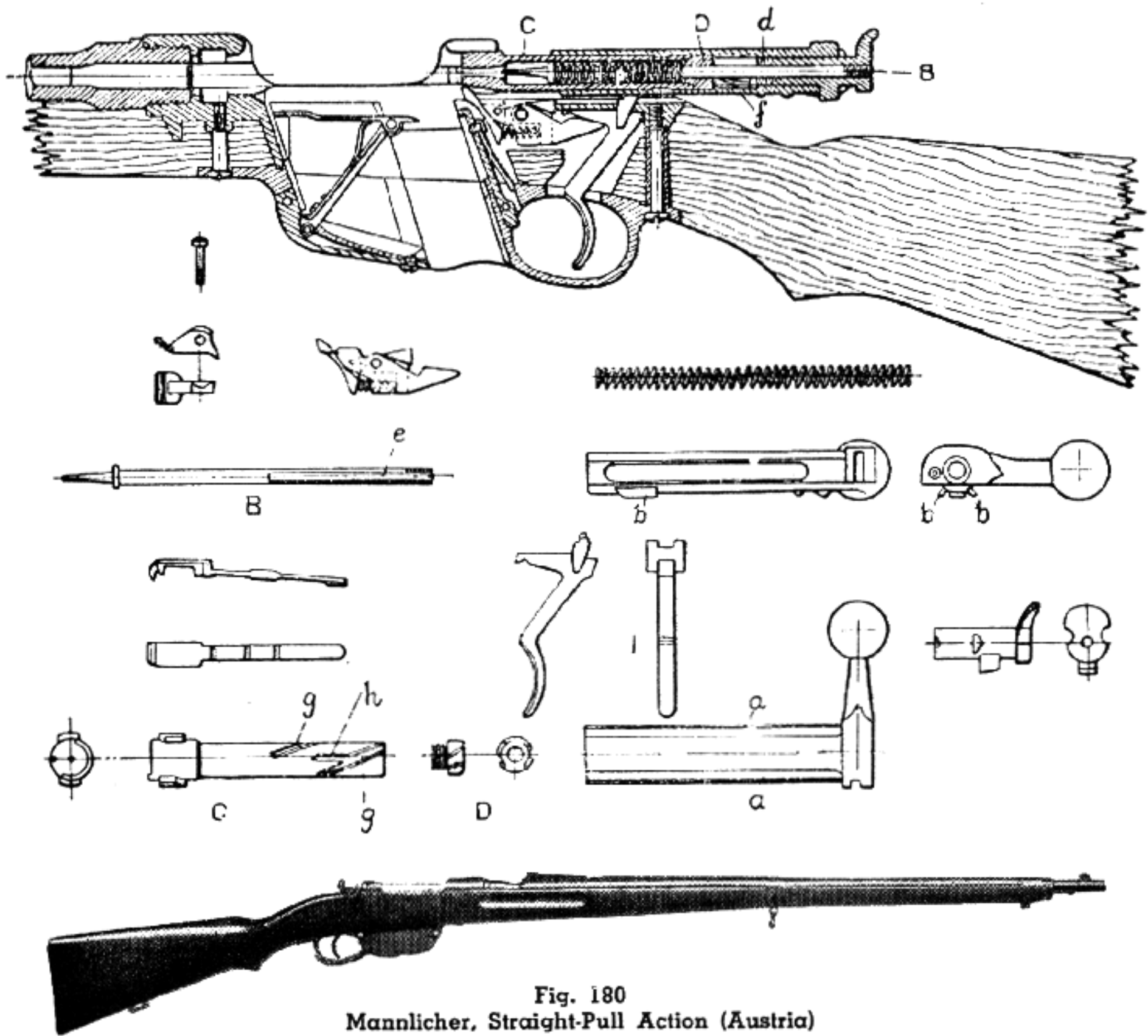


Fig. 180
Mannlicher, Straight-Pull Action (Austria)

e on the firing pin *B*, prevents the latter from turning. The safety bolt is pivoted in the left side of the reinforce. Inside the middle portion of the bolt are two helical feathers, *f*, which work in corresponding grooves, *g, g*, in the tail of the bolt head, and rotate it in opening and closing the bolt. A groove is cut on the inside of the right rib for the extractor.

The bolt head, *C*, consists of a head which projects beyond the face of the bolt cylinder, and the tail which enters the cylinder. The bolt head has cam-shaped locking lugs on either side, which enter the recesses of the body by way of the cam-shaped grooves and support the bolt head in the firing position. A groove is cut in the head for the ejector to work in. The rear end of the tail has two external helical grooves, already mentioned, in which work the feathers in the inside of the bolt cylinder. The helical grooves have each a small groove, *h*, leading out of them in the direction of the length of the bolt, one to the front and one to the rear. The groove to the front is on the top of the tail, that to the rear is on the right side when the bolt is opened.

The bolt head contains the main spring of .04

wire, coiled to a length of 4.9 inches, and the striker. The rear end of the bolt-head tail is closed by a screw plug, *D*, against which the main spring bears, the striker passing out through the plug. The other end of the main spring bears against a collar on the striker. The extractor is a long flat spring, which lies in the right rib of the bolt cylinder. The portion which projects fits over the right locking lug and terminates in a broad claw. The other extremity has a small nib on its under side, which engages in the two longitudinal grooves in the tail of the bolt head above mentioned. When the action is closed, the nib is engaged in the longitudinal groove on the top of the bolt-head tail; when the bolt is drawn back, the nib rises out of this groove, and when the bolt head has turned a quarter of the circle from right to left falls into the other groove. The right lug is then embraced by the head of the extractor and the extractor is drawn back by the bolt. The claw engages the top cartridge in the magazine immediately it is pushed forward by the bolt advancing, and holds it in all the backward and forward motions of the bolt, thus rendering double loading impossible.

The cocking piece screws on to the end of the

striker and works in the rear end of the bolt cylinder. In its left side is a groove in which the locking bolt engages, when it is employed to lock the action with the spring eased. At full cock the locking bolt, when used as a safety bolt, is interposed between the front face of the cocking piece and the rear face of the bolt cylinder; the tooth of the bolt is cam-shaped, and when pushed into position forces back the cocking stud from engagement with the sear.

The body calls for no special comment, except that the tang groove for the cocking-piece stud to work in is undercut on either side to take the feathers, *b, b*, on either side the front end of the bolt. Underneath the front part of the body is a downwards projection which transfers the shock of recoil from the barrel and body to the stock. A similar but larger projection forms the prolongation of the front of the magazine.

The sear consists of two components, the body and the bent; they are both pivoted on the same pin, which passes through the action body. The bent fits in a slot in the body.

The ejector is pivoted to the front of the sear body. Its bottom end is pressed forward by a small spiral spring, the other end of which presses the sear and sear bent backwards. The upper end of the ejector is slightly depressed by the bolt; the spring is partly compressed, and tends to keep the sear and sear bent up to their work.

The trigger is in the form of a bell-crank lever, the long arm projecting downwards through the trigger guard, the short arm terminating in a hook which engages the rear of the sear. At the angle is the cross-piece with the two horns which project into the boltway and prevent the withdrawal of the bolt, as already described. The trigger is not pivoted to the body in any way, but is supported in its groove by the sear.

When the trigger is pressed, the bent of the sear is depressed, releasing the cocking stud and allowing the striker to fly forward; at the same time the front of the sear body is raised into the boltway behind the safety projection on the back end of the under side of the bolt, preventing any backward motion of the latter while the arm is being fired. Further, as the bolt is pushed forward, this safety projection, sliding over the projecting front portion of the sear, prevents the latter rising, and consequently prevents the bent of the sear from being lowered, by pressing the trigger, until the bolt is completely closed.

The magazine and guard are in one piece. The former is clip-loaded with five cartridges, and is similar in most particulars to that already described for the Roumanian Mannlicher.

The bolt is actuated by a straight backwards-and-forwards pull and push. When the lever is pulled to the rear, the bolt cylinder cannot revolve, owing to the ribs on it working in the grooves of the body, and the feathers, in the undercut grooves in the tang. The bolt head, on the other hand, cannot come to the rear until the locking lugs have been disengaged from their recesses in the body, and this is effected by the turning motion given to the tail of the bolt head by the helical feathers in the inside of the bolt cylinder, working in the bolt-head tail. Primary extraction is given by the cam shape of the ends of the grooves in the body in which the locking lugs work. The first motion of the bolt to the rear partly compresses the main spring. As soon as the locking lugs are disengaged from the body they are in prolongation of the ribs in the bolt cylinder, and the whole bolt can then be drawn to the rear.

The Schmidt-Rubin — Figure 181. In this action the body departs from the shape which, with minor differences, has been seen in all rifles already discussed. Behind the magazine way it forms a complete cylinder for a length of $4\frac{1}{2}$ inches and is thus of considerable length and clumsy. On the right side, and forming part of the body, is a smaller cylinder opening into the larger one. The bottom of this small cylinder is slotted for the tooth of the retaining bolt. The main cylinder is slotted for the sear and grooved for the striker stud to travel. This is in place of the grooved tang found in most other rifles. The main cylinder is also grooved longitudinally on each side for the bolt lugs to work in. Those grooves lead into the lug seatings, which are cut on a screw pitch. The rear part of the body forms a short tang, which is bored for one of the three action screws.

The bolt, which is made up of the bolt cylinder *C*, the locking sleeve *D*, and the bolt cap *E*, is operated by means of the action rod *F*. The bolt cylinder is bored out from the rear for the striker and main spring, and is slotted on the right side to admit the tooth, *a*, of the action rod. A circular flange affords a bearing for the front end of the locking sleeve. In front of this flange the bolt cylinder is grooved on both sides to allow it to pass through the turned-in sides of the magazine.

On the left is a deeper groove for the ejector. On top a little to the right is a flat for the extractor. The front end of the bolt cylinder is permanently screwed in. The face of the cylinder is recessed for the head of the cartridge, but the rim of the recess is not cut away at the bottom to allow the heads of the cartridges to rise up at once under the claw of the extractor when loading, therefore double loading is possible. The bolt cap *E* screws on to the

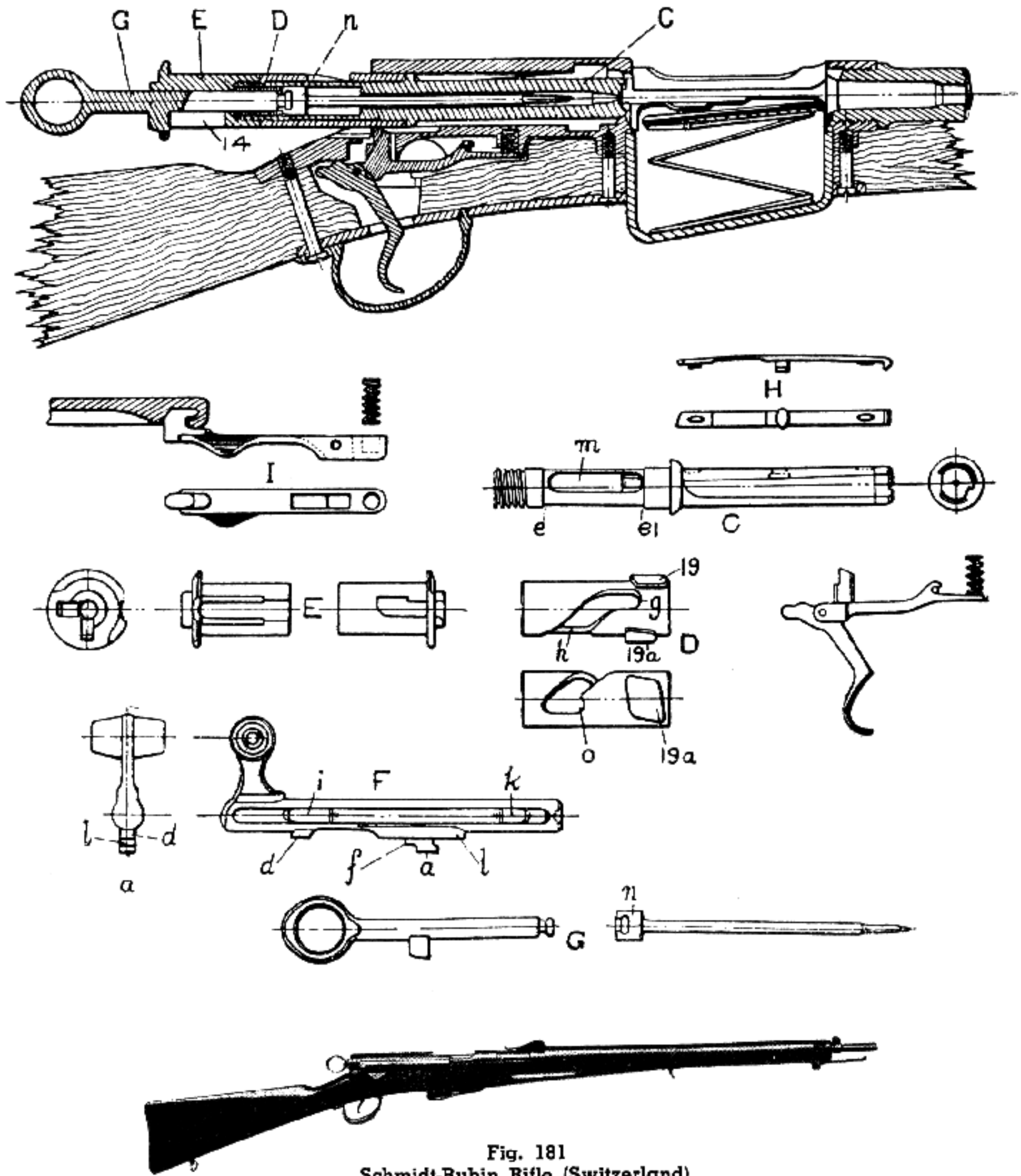


Fig. 181
Schmidt-Rubin Rifle (Switzerland)

rear end of the bolt cylinder. It is bored out for the striker, and has a shoulder inside, against which the rear end of the main spring bears. At the rear end is a broad flange, with a clearance for the action rod. It is slotted out for the striker stud. At right angles to this slot is the safety slot for the striker stud. On the right side is a rib with an undercut groove for the stud *d* on the action rod. The front end forms a bearing for the rear end of the locking sleeve. The locking sleeve fits loosely behind the flange on the bolt cylinder, the diameter of the latter being slightly reduced from *e* to *e-1* to lessen friction. At the front end are the two lugs, which resist the backward pressure of the cartridge on firing. The top lug is slightly in advance of the other, and their front and rear faces are cut with a

screw pitch. A helical slot for the stud *f* on the action rod runs from *g* to *h*. A recess in this slot affords a seating for the stud *j* when the action rod is drawn back. The action rod works in the cylinder in the body. On the right, at the rear end, is a lever for operating the rod, to the end of which lever, on either side, vulcanite knobs are fixed by screws. Underneath is a groove for the tooth of the retaining bolt. Within this groove are two projections, *i*, *k*, against which the tooth of the retaining bolt bears, in the open and closed positions, and holds the action rod steady. On the left a dovetail stud *d* fits in the undercut groove on the bolt cap. The rib *l* works in the slot between the cylinder in the body, in which the bolt works, and the cylinder for the action rod. The stud works in

the helical groove *g*, *h*, in the locking sleeve, which it causes to revolve. The stud *a* enters the bolt cylinder through the slot *m*, and lies in front of the head *n* on the striker.

The striker *G* is divided into two parts; the front part has a short point at the front end, and a head *n* at the other. The rear part has a button at one end, which fits into a suitable recess in the head, and underneath carries the striker stud, which works in the slot (14) in the bolt cap. The striker can be drawn back by means of the ring on the rear end.

The main spring consists of 15 coils of flattened steel wire .06 x .04 set to a length of 2.3 inches.

The extractor, *H*, is a flat spring terminating in the usual claw, projecting beyond the face of the bolt. It is provided with a stud with circular stem and oval head. Near each end are two small projections. To fix the extractor, place the stud in the oval hole in the bolt cylinder, with the extractor at right angles to the latter, then turn the extractor parallel with the bolt, and the head of the stud will lock under undercut grooves, and the projections will spring into seatings cut for them. A shallow recess enables the end to be raised when removing the extractor.

The ejector is a pin with a broad head and flat point, which passes through the left side of the body. It is secured by a keeper screw.

The retaining bolt, *I*, is pivoted underneath the small cylinder on a projection, which fits into the slot through which the axis pin passes. At the front end is a spiral spring which fits in a hole and bears against the bottom of the cylinder. On the rear end is a tooth, which is pressed upwards by the spring into the groove in the action rod. When the latter is fully drawn back this tooth locks into the front end of the groove. To withdraw the bolt push it forward slightly, and depress the tooth by pressing on the thumbpiece.

The trigger mechanism is on the double-pull system and differs but little from those already discussed under turning-bolt Mannlicher actions. The sear bar is pivoted at its forward end and the sear is kept up to its work by a spiral spring disposed vertically. The sear bar is rather longer than usual. The trigger is of the usual shape and is provided with two humps for taking the two pulls. It is pivoted to the rear end of the sear bar.

The magazine is made of sheet steel and holds six rimless cartridges. The bottom is strengthened by a steel strap brazed on. In the bottom are two openings for the escape of dust, which, however, is also liable to find its way in through these openings. The magazine box is inserted through an opening in the trigger guard and is held in position by a spring

catch on the right side of the box engaging on the trigger-guard plate. The platform is shaped to raise one of the two columns of three cartridges higher than the other and present the cartridges in the two columns alternately at the top of the magazine. The platform can be slipped out of the box to the rear and is actuated by a zigzag wire spring with three coils. The magazine can be filled either by the insertion of single cartridges or from a charger. The charger is made of *papier maché* strengthened and protected at the bottom by a tinned iron strip, two tongues on either side of which are turned over to retain the cartridges.

The action of the mechanism is as follows: In the first motion of drawing the action rod to the rear, the tooth *f* moves in the straight path of the slot *g* of the locking sleeve; the tooth *a*, bearing against the head of the striker, begins to draw it back, and the projection *i*, in the groove of the action rod, depresses the tooth *f*, which is constrained to move in a straight line, on account of the rib *l* moving in the slot between the two cylinders, bears against the curved part of the slot on the locking sleeve, and rotates the sleeve, turning the lugs from in front of their seatings into the diagonal grooves in the body. On account of the lugs and their seatings being put on a screw pitch, the entire bolt is withdrawn about $\frac{1}{16}$ inch; this forms the primary extraction. The tooth *f* has now got to the back end *h* of the slot in the locking sleeve, and has drawn the striker fully back. The whole bolt is now free to come back; as it does so, the lugs (*19* and *19-a*) on the bolt sleeve, pass along the diagonal grooves and further rotate the locking sleeve, until the recess at the end of the locking-sleeve groove slips in front of the stud *f*. The latter is pressed forward into this recess by the head on the striker, actuated by the main spring. On continuing the backward motion, the projection in the action-rod groove depresses the retaining-bolt tooth, and the latter then strikes the end of the groove and arrests the backward motion. The dovetailed stud *d* on the action rod, working in the groove on the bolt cap, serves to keep the action rod parallel with the bolt.

On pushing forward the handle of the action rod the retaining tooth in the action-rod groove is depressed by the projection, and the whole bolt mechanism moves forward. When the lugs pass down the diagonal grooves the locking sleeve is rotated, so that the recess *o* no longer retains the stud. When the flange on the bolt cap arrives within $\frac{1}{16}$ inch of the cylinder on the body, the sear bent engages the striker stud and the lugs on the bolt cylinder have arrived at the entrance to their seatings. On pushing home the action rod the

stud *f* passes along the groove in this locking sleeve and revolves the sleeve, placing the lugs in their recesses, and fully closing the bolt. As the bolt is finally closed the extractor claw springs into the groove round the head of the cartridge, which has been pushed forward out of the magazine by the bolt, and the retaining-bolt tooth rises behind the projection in the action-rod groove, and prevents the action rod from slipping back.

By drawing back the striker, and revolving it so that the striker stud points to the left, the latter enters the safety slot in the bolt cap. The point of the striker cannot then reach the cap of the cartridge, and the bolt cannot be drawn back, as the rear face of the striker stud is engaged by the shoulder in the groove in the bolt cap.

The Ross — Figure 182. The Ross was, previously to the early days of the Great War, the arm of the Canadian forces, but is now obsolete. There have been various models, some with solid lugs and some with lugs interrupted as in the breech mechanism of big guns, and with differences in sights and in other particulars.

The essentials of the action are, a bolt (1) and handle machined solid from one piece, and a turning portion (2), carrying the lugs (3) on the front end and containing the main spring and striker.

The lugs, striker and cocking piece, which is secured by a screw thread to the end of the striker, are similar in design to those of the Mauser bolt. The Ross bolt is provided with ribs which work in longitudinal grooves in the body and prevent the bolt from turning. On the inside is a screw thread (4) which engages with a similar screw thread on the turning portion and gives it the necessary turning movement to lock and unlock the lugs. The lugs work in cam-shaped recesses in the fore-end of the action-body in the usual way.

The screw thread on the turning portion is not cut right round it but is on two spiral ribs.

The extractor, which has the usual claw end at the front, is provided with a long tail on which is a lug which engages with the rear edge of the bolt head and takes the pull during extraction. A cam surface works against this lug and causes the claw to grip the case more firmly during extraction.

The trigger (5) is a bent lever pivoted to a frame (6) which also carries the sear (7). When the trigger is pressed the lower end of the sear is forced forward and the nose (8) therefore depressed from engagement with the bent. At the same time the stop (9), which is pivoted on the sear, is raised and engages behind the two lugs (10) on the under side of the bolt, thus preventing the bolt being withdrawn at the same moment as the trigger is

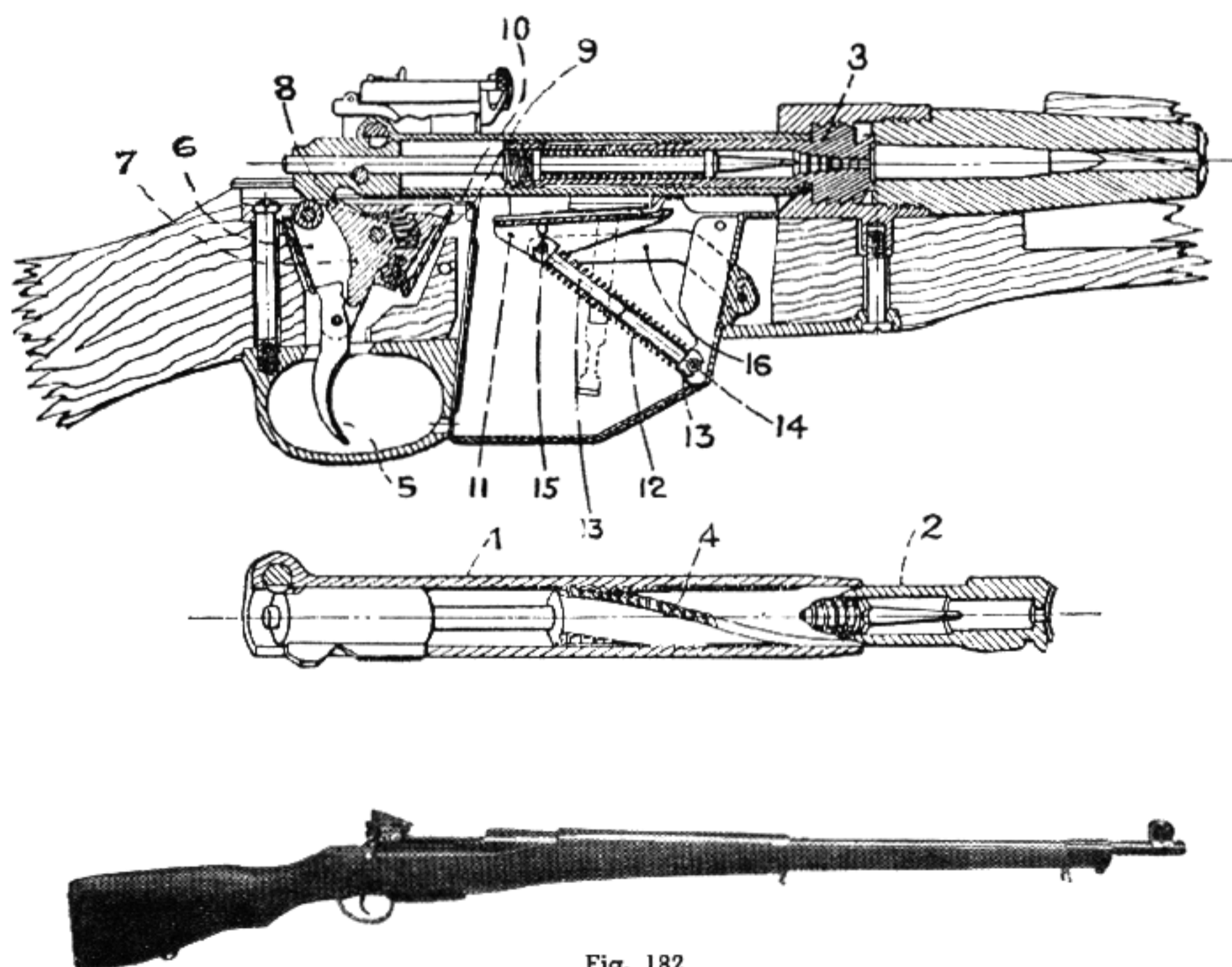


Fig. 182
Ross (Canada). Now obsolete

pressed and serving as additional safety lugs. A double pull in the trigger action is arranged for by two ribs on the upper end of the trigger in the same manner as in the British Mark III.

The magazine consists of a box enclosed in the stock, and retained by the trigger guard. It is provided with means for charger-loading, and is of interesting design. The follower (11) is supported by the spring (12) which works on a telescopic piston or plunger (13) pivoted at (14) and (15). Its movement is controlled by two arms, one of which (16) (that on the far side) is shown in Figure 182. The separate axes on which these arms pivot both in the body of the magazine and in the platform are so arranged that the platform remains parallel to the axis of the rifle throughout the greater part of its movement.

In an earlier model of this rifle no provision was made for charger-loading, but, by means of a lever, the platform of the magazine was connected to a fingerpiece conveniently placed on the right side of the stock to be operated by the fingers of the left hand in the firing position. By depressing the fingerpiece the magazine follower was lowered and cartridges could then be dropped into the magazine with the right hand.

Barrels — The length of a rifle is governed by the length of the barrel with which it is fitted. Barrels as short as 20 inches can be made to shoot well; but a certain amount of length is necessary to give a reasonable handle for the bayonet. The majority of countries use rifles of about 4.25 feet, with barrels measuring about 31 inches. Great Britain and the United States, however, are armed with short rifles just over 3.5 feet long with barrels shortened to correspond. The Swiss Schmidt-Rubin, which was a short rifle in the 1900 Model, has been redesigned with a barrel of 30.75 inches. A well-designed short rifle has the merit of being handier for snap-shooting than a long rifle. It also obviates the necessity of providing a carbine for the mounted services. One arm for all services is a great convenience in details of storing, issue, and upkeep.

The weight of the barrel, within limits, has little effect on the weight of the complete rifle. The British and the United States Springfield rifles are by no means the lightest military rifles. The weight is governed, to some extent, by the consideration that a light rifle gives an unpleasantly heavy recoil with cartridges of the usual military specifications. Most modern rifles weigh, complete, without bayonet, between 8.5 and 9 pounds, yet there is more than a pound difference between the lightest and the heaviest barrels.

The following table shows the barrel length and

weight, and the relation between these dimensions, of a few foreign rifles for comparison with our own service rifle:

Rifle	Bore	Rifle weight lbs. oz.	Barrel length, inches	Barrel weight, lbs.	Lbs. per inch
British	0.303	8-10	25.19	2.156	.083
Springfield	0.300	8- 8	23.79	2.906	.122
Roumanian	0.256	8-13	28.56	3.093	.108
Nagant	0.315	8-15	31.50	3.093	.098
Japan	0.256	8-12	31.30	2.969	.095
Chile Mauser...	0.276	8-13	29.20	2.719	.093
Lebel	0.315	9- 3	31.50	3.187	.115

It will be seen from the above table that the British has the lightest barrel in actual weight and also the lightest barrel relative to its length.

When firing, the barrel commences to vibrate before the bullet has left the muzzle. This vibration exercises a very disturbing effect on the accuracy of the shooting on account of the difficulty of insuring that the fore-end shall influence the vibrations to the same extent for every shot. With a heavy barrel the vibrations are not so severe and the influence of the fore-end is less important.

On account of the heavy pressures set up on firing, but which fall off very rapidly, barrels are made heaviest at the breech end. This increased portion is called the "reinforcement." The effect of this weight of the metal on the external contour of the barrel is exaggerated by the size of the chamber necessary to accommodate the case. The exterior of the barrel from just in front of the reinforcement to the muzzle is usually slightly tapered. In the German, Spanish and Turkish Mausers the barrel is turned down externally in steps, with the idea of breaking up the vibrations on firing. Barrels are browned or blued to protect them from rust on the outside and to give them a dull non-reflecting surface. In some cases the outer contour is slightly increased at appropriate points to afford a seating for the sights.

The degree of twist given to the rifling would seem to be governed a good deal by the individual preferences of the designers. It is essential that it should be enough to give the bullet sufficient spin to keep it end-on in its flight; but usually there is an ample margin beyond the minimum necessary to give stability. In most rifles the twist is about 1 turn in 31 calibers. The most rapid is the French, with 1 turn in 30 calibers, and the slowest the Krag-Jorgensen, with 1 turn in 37.5 calibers. The Italian Carcano rifle is peculiar in that it has a progressive twist.

British Service Rifle — The short, magazine, Lee-Enfield rifle was approved on 23rd December, 1902, to take the place of the magazine Lee-Metford and magazine Lee-Enfield (familiarily known

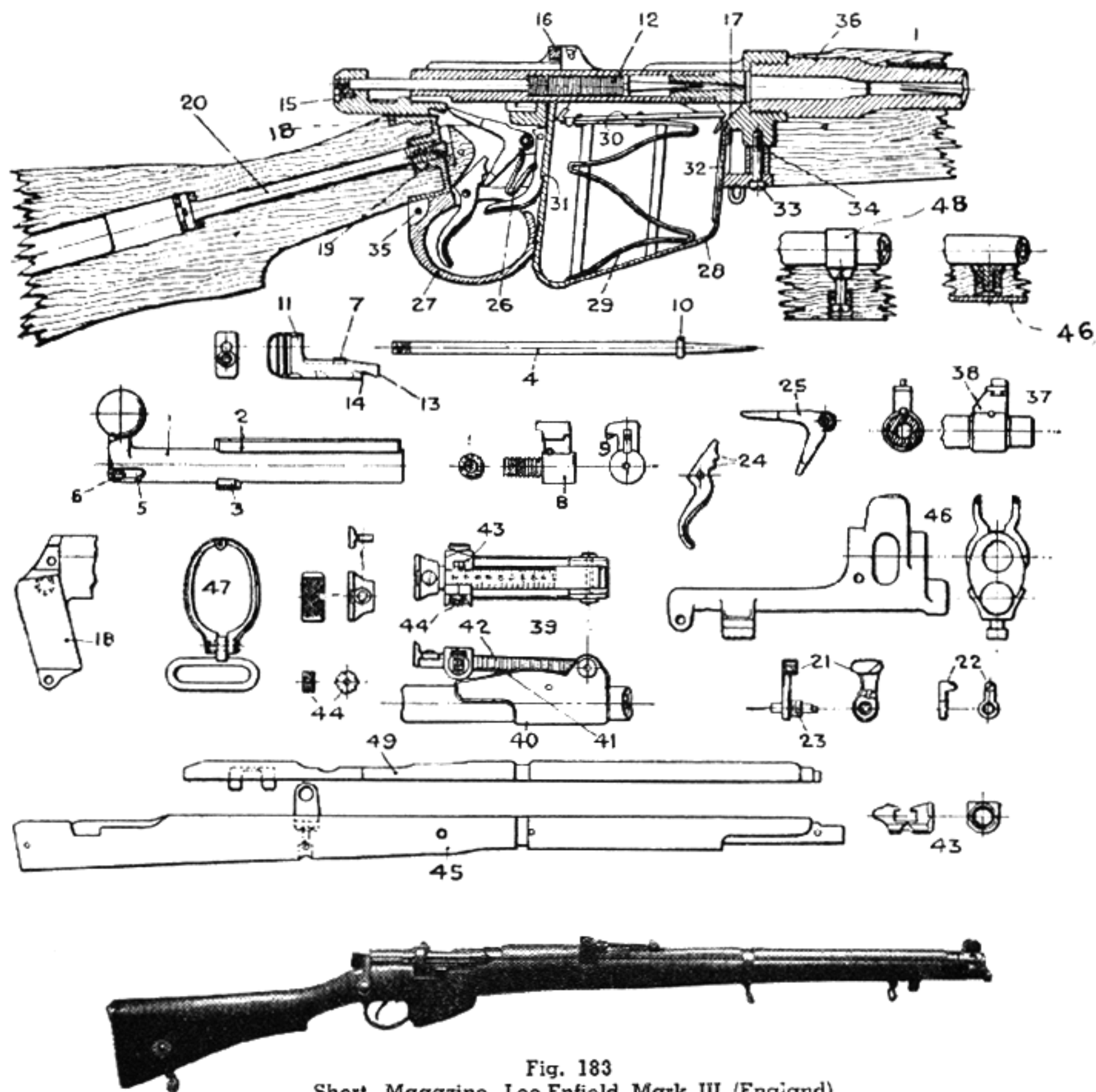


Fig. 183
Short, Magazine, Lee-Enfield Mark III (England)

as the "long rifle"), various marks of which had been the service weapon since 1888. Of the rifle there are six marks, Marks III, III*, and IV now being in use.

- Mark I....Approved 1902. New rifle.
- Mark II....A conversion from long rifle. Similar to Mark I.
- Mark III...Approved 1907. Improvement on Mark I.
- Mark III*...Approved 1908. No cut-off. No long-range sights.
- Mark IV...Conversion from old marks. Similar to Mark III.
- Mark V....Provisionally approved 1922. Improvement on Mark III. Aperture rear sight. (Superseded before being produced in quantity.)
- Mark VI...Improvement on Mark V.

All the above marks have the Lee bolt action, similar to that approved in 1888 for the Lee-Metford magazine rifle, Mark I. Details of the Mark III and Mark III* are as follows (see Figure 183):

The bolt (1) is simple in construction. It is cylindrical and has a bent lever at the rear end, terminating in a round knob for convenience in

handling. The shape and position of the lever are very convenient for rapid manipulation. On the right side of the bolt cylinder is formed a solid rib (2), which works in a slot in the rear of the body and acts as a guide when the bolt is worked backwards and forwards. On the opposite side to the rib, and having its rear face level with the rear face of the rib, is a solid lug (3). The lug and the rear face of the rib engage against appropriate bearings when the bolt is locked and support the bolt on firing. The disadvantages and advantages of having the lugs so far removed from the face of the bolt-head have been discussed. The rear faces of the rib and lug are cut on a screw pitch corresponding to the slope of their seatings on the body. On turning down the bolt this gives the necessary leverage to force the leverage for primary extraction on turning up the bolt. The bolt cylinder is bored out to take the striker (4) and main spring. The rear part of the boring is constricted to the diameter of the striker, to form a seating

for the rear of the main spring and to act as a guide for the striker. Underneath the rear end of the bolt cylinder is a recess (5) formed by a long groove on the right and a short groove on the left, connected together in front by a cam-shaped face and separated by a stud (6). On raising the bolt lever the cocking-piece stud (7), which is resting in the right-hand or long groove, is forced backwards by the cam-shaped face until it rests in the left-hand or short groove, thus partially compressing the main spring and withdrawing the point of the striker from the face of the bolt head. This is necessary to prevent the striker point from firing the cap of the next cartridge as it is fed upwards from the magazine and pushed forward into the chamber.

The bolt head (8) has a tenon which screws into the bolt cylinder. On it is a solid projection which has a hook (9) on its right side which engages with a rib on the right side of the body and prevents the bolt head from turning with the bolt cylinder. On the side of the bolt head is a hole to allow for the escape of gas in event of a blow-back or burst case. The projection on the bolt head is slotted to take the extractor, which is a short steel bar with the usual claw at the end. It is pivoted on a screw at the rear of the slot and is kept up to its work by a small V-spring let into the slot above it.

The striker is in one piece and has a collar (10) against which the front end of the main spring bears. The front face of the collar seats against the rear end of the bolt-head tenon in the "fired" position and thus limits the protrusion of the striker. Originally there was, in front of the collar, a small stud which fitted into a recess cut for it in the rear of the bolt-head tenon. This stud was later discarded, but both the modified and unmodified types of striker are still in use in the service. The end of the striker is screw-threaded for attachment to the cocking piece (11).

The main spring (12) is of coiled steel wire set to a length of $3\frac{1}{2}$ inches.

The cocking piece has a long tongue projecting to the front and lying against the under side of the bolt when it is assembled. The front end of the tongue forms the full bent (13) and a groove cut across it the half bent (14). A stud (7) on the upper side of the tongue works in the two grooves already mentioned in the rear of the bolt cylinder. On the left side the tongue is recessed in two places for the locking bolt to engage in. The rear of the cocking piece was originally formed with a circular projection, cut away on the left-hand side and roughened to serve as a grip for finger and thumb when cocking without operating the bolt. The Mark III* rifle was fitted, as an alternative to

facilitate manufacture, with a cocking piece which had its rear end formed as a flat piece, grooved on each side to give a grip for finger and thumb. Both these types of cocking piece are now interchangeable in the Marks III and III*.

The bolt may be easily stripped for cleaning and examination. The striker-keeper screw (15), which retains the striker in position in the hole drilled and tapped for it in the rear portion of the cocking piece, having been removed, the bolt head is unscrewed. Those strikers which are fitted with a stud on the front face of the collar can be unscrewed by means of the bolt head, but to avoid the possibility of damage to the bolt-head tenon this method should not be employed, and the special tools with which armorers are provided should be used.

The body is cut away on the right side for the greater part of its length to allow the projection on the bolt head to work backwards and forwards. The hook on the projection of the bolt head engages in a slot or rib, which is cut away at the rear end just sufficiently to allow the hook on the bolt head to be free. There is a small retaining catch forming a continuation of the rib at this point. When the bolt is drawn back as far as possible the hook can be forced up over this catch and the bolt removed from the body. The retaining catch is a small spring secured by the rear-axis screw on the right side of the body. The rear of the body does not form a complete cylinder, but is slotted out at the top to afford passage for the rib on the bolt and at the bottom for the bolt lug and cocking pieces. The right-hand side of the rear of the body forms the right resistance shoulder for the rib on the bolt, and opposite this on the left side is the slot into which fits the bolt lug, the rear face of the slot forming the resistance shoulder on this side of the body. It is cut on a screw pitch to assist in forcing the cartridge home in the chamber and in the final compression of the main spring when the bolt is turned down into the locked position for firing. The recess for the lug is at the rear end of the body, opposite the resistance shoulder; the entrance to it is cut on an incline in the usual way to give the leverage necessary for primary extraction.

In front of the resistance shoulder, at a sufficient distance to give clearance for the bolt-head projection when the bolt is being removed, a charger-guide, in the form of a bridge (16), is riveted to the left and right sides of the body. Immediately in front of the charger-guide, the left side of the body is cut away in a semicircle to allow the thumb to sweep the cartridges out of the charger into the magazine. The front end of the body is a complete

cylinder, into which the barrel screws. As no space has to be provided for the lug recesses, the bolt head enters a little distance only into this cylinder, which is not much recessed and is readily cleaned. Beneath the barrel chamber the action body is sloped off (17) to provide a way or guide for the cartridges entering the chamber from the magazine. The right side of the body is slotted to take the cut-off. There is no tang as in Continental actions. The place of the tang is taken by a socket (18), which is part of the body and projects downwards. Into it the butt fits, and in the center of it is a hollow, threaded boss (19) for the stock-bolt (20). The rear end of the body, including the upper surface of the socket, is grooved to allow passage for the lug and cocking-piece tongue. The usual opening beneath the body is provided for the magazine.

At the rear end, on the left of the body, two holes are drilled for the locking bolt (21) and locking-bolt safety-catch (22). The locking bolt is a stem, fitted with a roughened thumbpiece by which it may be actuated. The stem fits into a hole in the body leading into the groove for the cocking-piece tongue. The end of the stem is cut away so that when the thumbpiece is in the forward position the cut-away portion is level with the floor of the groove for the cocking-piece tongue and the cocking piece can pass over it. When the thumbpiece is drawn to the rear the solid portion of the stem rises in the groove and engages in one of two recesses cut in the cocking-piece tongue, according to whether the latter is in the cocked or fired position. The bolt can thus be locked fired, or cocked. When the stem of the locking bolt engages in the front or cocked-position recess, it draws back the cocking piece slightly, removing the bent from contact with the nose of the sear. On the stem of the locking bolt, close to the thumbpiece, is cut a steep-pitched thread (23). On this thread works the arm of the safety catch. On the end of this arm is a short stem which fits in the hole entering the boltway of the body. When the thumbpiece of the locking bolt is in the forward position, this stem is within its hole and clear of the bolt in the boltway. When the thumbpiece is drawn to the rear, the threads on the locking-bolt stem and safety-catch arm push the stem forward so that its end enters the short groove on the end of the bolt and prevents the latter from being rotated and drawn back. By the combined action of locking bolt and safety catch, both cocking piece and bolt are positively locked against any possibility of accidental opening or discharge.

The ejector is a small screw which projects slightly into the boltway on the left side. On drawing back the bolt the back edge of the rim of the

cartridge case catches against the end of this screw and is thrown out of the rifle to the right. In practise this action only takes place in the case of a bulletted round, when the case is held on the bolt face until the bullet is clear of the breech. An empty case, being shorter and therefore being clear of the barrel sooner, is normally thrown out to the right by the action of its rim frictioning against the sloping portion of the groove hollowed out in the left side of the body immediately behind the breech.

The trigger mechanism is on the double-pull system already described in the account of Continental rifles, but differs from them in most particulars, save for the provision of two ribs (24) on the upper part of the trigger. The sear (25) is a two-armed, bell-cranked lever, pivoted to the projection beneath the body on the same screw which holds the retaining catch. It is pressed to the rear and upwards by a U-shaped spring (26) which also serves to keep the magazine-catch up to its work. The long upper arm passes through a hole in the body into the groove for the cocking-piece tongue, and engages with the full bent on the latter when the bolt is pushed forward. The short arm projects downwards. The trigger is pivoted on a pin which passes through the trigger guard (27). The two ribs are on the front surface of the upper part of the trigger. On pressing the trigger the lower of the two ribs engages with the short arm of the sear and causes the latter to revolve on its axis until the end of the long arm has come close to the edge of the bent. The pull during this movement is light, as the rib is close to the trigger pivot and great leverage is obtained. The fulcrum is then transferred to the upper of the two ribs, which, being further from the pivot, affords less leverage, and a stronger pull is therefore necessary to make the sear move the small remaining distance which releases the cocking piece and allows it to fly forward. The motion imparted to the sear by the motion of the trigger acting through its upper rib is, however, more rapid, and the sear is thus drawn smartly off the bent.

The action of the bolt mechanism has already been indicated in the description of the parts. The complete sequence is as follows:

On raising the bolt lever the cocking piece is prevented from turning with the bolt by the fact that the tongue is engaged in the groove in the body. The bolt head is prevented from turning by its hook engaging with the rib on the right side of the body. As the bolt is turned, the cam face at the end of the two grooves on the rear of the bolt forces back the stud on the upper side of the tongue of the cocking piece. This draws the end of the striker clear of the end of the bolt head and par-

tially compresses the main spring. As the turning movement continues, the sloping face of the lug working against the sloping face of the recess in the action causes the whole bolt to move to the rear, effecting primary extraction. When the bolt has been turned as far as it will go, the rib touches the left side of the body and is opposite the gap in the rear of the body. The lug is now in the groove for the cocking piece. The bolt can be drawn back until the projection on the bolt head strikes against the resisting shoulder. This acts as a retaining arrangement. The stud on the cocking-piece tongue has now fallen into the recess in the front end of the short groove on the bolt and the cocking piece cannot revolve and is retained in position for entering its groove in the body. On pushing forward the bolt the full bent of the cocking piece engages the end of the sear, and the main spring is further compressed. As the bolt is driven forward the stud between the long and short grooves on the bolt passes the stud on the now stationary cocking piece. On turning down the bolt, the bolt is forced forward by the action of the sloping faces on the rear of the lug, and the rib working against their bearings on the body. In the complete action of closing the bolt the free forward travel is 3 inches; the travel after the sear has engaged with the bent, when the pressure of the main spring has to be overcome, is $\frac{1}{2}$ inch, and the final forward movement, on turning down the lever, $\frac{1}{8}$ inch. When the action is cocked, the stud on the cocking-piece tongue lies in the long groove in the body, and the cocking piece and striker are free to fly forward when the sear is released from the bent by pressing the trigger. Should the trigger be pulled when the bolt is not completely closed, the stud on the cocking-piece tongue strikes against the stud between the two grooves on the bolt and either causes the bolt to close, automatically, before the striker point reaches the cap of the cartridge, or else the two studs meet full face and the striker is prevented from flying forward. If the action is then closed by hand the sear falls into the half-bent and the action is locked owing to the two studs lying side by side, preventing the rotation of the bolt. It is possible to cock the action fully by drawing back the cocking piece.

The magazine (28) is a detachable sheet-steel box, strengthened by two flutings on either side. It contains ten cartridges in two columns which are fed up as required by the action of a zigzag ribbon steel spring (29). The platform (30) is so formed that the left side is higher than the right. The left-hand column of cartridges is thus presented to the bolt first and then the right-hand column, cartridges being pushed forward alternately from each

column until the magazine is empty. The sides of the rear end of the box are extended slightly upwards and turned in to retain the cartridges. In the No. 1B (stamped with the figure 4) magazine there are small inturning projections made by turning over the top of the sides of the box in front. These serve to keep the platform in position when the magazine is empty. In earlier marks of magazine a stop clip is pivoted on the right side of the box, in front, which helps to keep the platform in position when the magazine is empty and keeps the bullet of the upper cartridge of the right-hand column in position when the magazine is full. This clip can be drawn down to the front when the magazine has been detached from the body, and the platform and spring can be withdrawn for examination and cleaning. The spring is secured to the No. 3 platform by a tongue of metal turned over on the right-hand side and by two rivets. In earlier marks it is secured by two tongues of metal on each side. Downward-turned tongues of metal on the front and on the left-hand side at the rear of the platform serve as positioning guides. A small turned-down tongue on the right side at the rear serves the same purpose. At the back of the box is a rib in which is cut a tooth (31) to engage in the magazine retaining spring catch. In the No. 1A and 1B (stamped 3 and 4) magazines there is also a small auxiliary spring which bears against the front of the trigger guard. Into the front of the box is hooked and secured the magazine platform auxiliary spring (32) which serves to keep the front end of the platform at a proper angle when the magazine is full and also protects the front of the box from being dented by the points of the bullets.

The cut-off is pivoted to a vertical screw in the projection on the right side of the body. It works in a slot parallel to and below the rib on the body for the bolt-head hook. It is provided with a cylindrical thumbpiece, bored out for lightness and ribbed on top for the thumb to grip. It is spring-tempered and set to press upwards, a small projecting flat on the upper surface acting as a catch against the side of the body and holding the cut-off open or shut. In the shut position the cut-off holds down the cartridges in the magazine out of the path of the bolt and acts as a platform for single loading. The hole in the rear of the cut-off is for convenience in manufacture only. In the Mark III* rifle there is no cut-off. In none of the marks is any provision made to indicate that the magazine is empty, as is provided in the Springfield rifle and in some Continental arms.

The trigger guard is attached to the body by a screw (33) passing up through a collar (34) let

into the fore-end in front of the magazine, and by a small transverse screw (35) passing through ears on the bottom of the socket of the body.

The barrel which screws into the body in the usual manner is strongly reinforced at the breech end, which is formed into a flat on its upper surface known as the Nock's or "Knox" form (36), from an old-time gun maker named Nock, who first devised this method of insuring the correct breeching up of barrel to body necessary to bring the sights vertical. It is 25.1 inches long overall and weights 2 pounds 2½ ounces. This is the lightest barrel used in any service arm.

The rifling is of the Enfield figure, with five grooves of .0065 inch mean depth. The width of the lands between the grooves is .0936 inch. The twist of the rifling is one turn in 10 inches, left-hand. The left-handed twist was originally adopted in order to compensate for the drift due to the rotation of the earth in the Northern hemisphere. It also has the effect of twisting the butt of the rifle away from the firer's cheek instead of against it.

The foresight (37) is of the "blade" pattern and consists of a plate dovetailed into the foresight block (38) at right angles to the axis of the barrel. It is capable of lateral adjustment. The foresight block is formed with a band which fits the barrel and is kept in position by a key and cross-pin. It is set approximately .015 inch left to counteract the lateral throw of the rifle due to vibrations set up on firing. The backsight (39) is attached to a bed (40) which encircles the barrel, to which it is fixed by a cross-pin in the middle. It is also supported by the sight-spring screw. The sides of the bed are raised to form a ramp (41). The leaf (42) is a solid piece of steel pivoted to the bed in front and kept in position by a spring fitted into the bed. It can be turned over on to the hand guard and rebounds into correct position when it is brought past the vertical. It is graduated from 200 to 2,000 yards. On the top left side of the leaf are lines representing every 25 yards. On the top right side the lines represent every 100 yards. The odd figures from 300 to 1,900 yards are omitted. A slide (43) fitted with a spring catch and a fine adjustment worm-wheel (44) enables the sight to be set at any elevation. The right side of the leaf is cut with screw-thread notches, and in these the fine adjustment is released, and the slide may be moved quickly along the leaf by the action of the thumb only. The periphery of the worm-wheel is divided by 10 thumbnail notches, the distance between each notch representing 5 yards in range, *i.e.*, 5 notches equal 25 yards, or one division on the left side of the leaf. One complete revolution

of the fine-adjustment worm-wheel moves the slide 50 yards.

A wind gauge was originally fitted on the rear end of the leaf, but has been discarded. It was held in position by the wind-gauge screw. The scale was marked in divisions representing 6 inches' deflection on the target at 100 yards. Each quarter-turn of the wind-gauge screw represented 1 inch of deflection for every 100 yards of range at which the sight was set. At each quarter-turn a friction spring engaged in a nick inside the head of the screw, checking its rotation. A U-shaped notch was cut in the top edge of the slide, and the face was roughed to prevent the reflection of light.

In the Mark III* and in the later Mark III rifle there is no wind gauge. Its place is taken by a cap which is attached to the leaf by means of a screw. It is provided with a U-notch and roughened on the face. There are two patterns of backsight caps which differ slightly in form.

Long-range sights were provided in the earlier Mark III giving elevations from 1,700 to 2,800 yards. The backsight consisted of an aperture attached to the left side of the body. It was carried on a bar terminating at the upper end in a cup-shaped button through which a peep-hole was bored. It was pivoted on the stem of the locking bolt and kept in position by a spring. The foresight, known as the dial sight, was attached to the left side of the fore-end, and consisted of a dial on which the ranges were marked, a pointer, and a bead which acted as a foresight.

No long-range sights are fitted to the Mark III* rifle or to the later Mark III.

The stock is in two pieces. The fore-end (45) is held to the barrel by a nose cap (46) and outer band (47), which are fitted with swivels. The swivel of the nose cap is a piling swivel, *i.e.*, cut away in the center. A swivel is also fitted on the butt. Naval-service swivels are made slightly larger than for land service. The barrel being comparatively light, accuracy is liable to be detrimentally affected by a badly fitting fore-end. In the assembled rifle there are three important metal-on-wood bearing points where even bearings must be insured. They are as follows:

- (1) The thrust of recoil is received by the stock, through the medium of the rear lugs on the body, on the resistance shoulders formed a little in front of its rear end. It is essential that the thrust should be taken up evenly on both sides.
- (2) The barrel must be held firmly down on the fore-end at the reinforce. This is effected by the fore-trigger-guard screw, which is

fitted with a collar which limits the amount of "crush" which can be obtained on the wood by tightening. It must be noted that in the case of a shrunk fore-end there is a danger of the screw being screwed up tightly against the collar without pulling the barrel down tightly on the fore-end. Careful fitting is therefore necessary. It is also important to remember that, since the trigger is mounted on the trigger guard, a loose fore-trigger-guard screw may affect the "pull-off" of the rifle by allowing the front end of the trigger guard to drop, and thus slightly affecting the relative positions of the trigger and the tail of the sear.

- (3) The barrel is caused to bear lightly on the woodwork $\frac{1}{2}$ inch in rear of the inner band (48) by means of a spring acting through the medium of the latter.

Between (2) and (3) the woodwork is hollowed out so as to be clear of the barrel, and from the inner band forwards the barrel is held away from the fore-end by the fore-end spring stud, the hole in the nose cap being slightly oval in form to give the necessary clearance.

The foregoing is a brief description of the service stocking. For match shooting under N. R. A.* conditions, with private rifles, certain other methods have been evolved. These other methods have for their object the increased weight of the barrel and the damping of the vibrations set up on firing in order to attain a relatively high standard of accuracy for the special conditions of target shooting. They consist, briefly, in adopting some means of packing the barrel between the fore-end and fore-hand guard. The service stocking was evolved with the object of insuring a consistently satisfactory standard of accuracy under service conditions.

A backsight protector formed with two upstanding ears, roughened on top so as not to reflect the light, is let into the fore-end and secured by a vertical screw and nut.

The nose cap completely encircles the barrel at the muzzle and is provided with a tang which projects backwards under the fore-end and carries the piling swivel at its rear end. Immediately in front of the piling swivel is a sword bar for the attachment of the pommel of the bayonet, and in front below the muzzle is a boss on which the ring of the bayonet cross-piece fits. The sword bayonet is thus fixed underneath the rifle to the nose cap

only, and does not touch the barrel. The nose cap is provided with high wings roughened on top, which protect the foresight. It is pierced on either side beneath the wings for lightness.

The hand guard (49) extends the full length of the barrel and is divided into two parts by a saw-cut opposite the backsight bed. This is for convenience in fitting and removing.

The rear portion fits over the barrel and is held in position by means of a spring riveted on to it. The front end of the hand guard is strengthened by a sheet-steel cap which fits under a recess in the nose-cap. A groove is cut in the correct position for the jointed outer band, a slot being formed to give clearance to the hinge. The hand guard does not touch the barrel, as the groove is of greater diameter than the barrel. An inner band is carried permanently on the barrel; it is grooved out so as to touch the barrel in two places, and is fixed in the groove of the fore-end in rear of the lower band by means of a screw, the head of which bears against a strong spiral spring.

The butt is attached to the socket on the action body by means of a stock bolt (20) that is inserted through a hole drilled longitudinally from the butt end. It is made in three ordinary lengths, long and short butts being marked by the letter L or S stamped on the wood on the top of the butt. For special use during the Great War, butts shorter than the ordinary short butt were made. These were termed "bantams" and stamped with the letter "B."

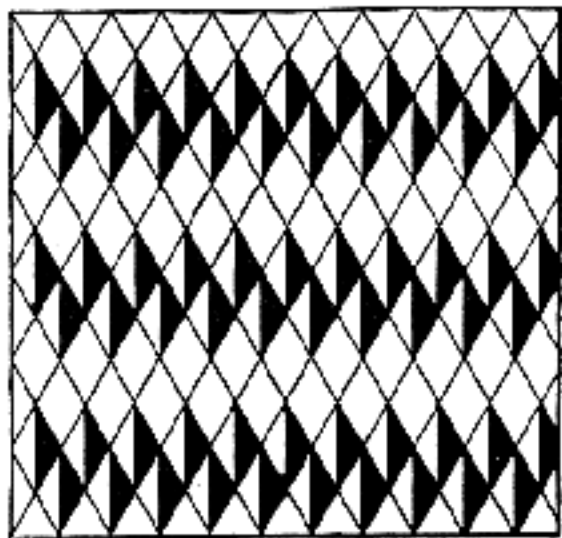
The butt plate is of brass, forgeable alloy or malleable iron. It is finished polished or zinc electroplated, according to the materials employed in manufacture. It is fitted with a trap for the insertion of oil bottle and pull-through. A marking disc is fixed with a screw to the right side. The "grip" is of a special "semi-pistol" shape.

The rifle, short, magazine, Lee Enfield Mark V was an improvement on the Mark III, but altho a certain number were produced in 1925 none were issued, and it was later discarded in favor of the more fully developed Mark VI. The Mark V differed from the Mark III in several particulars, the chief of which were (1) the adoption of an aperture backsight located on a specially-designed bed on the body behind the bridge charger-guide; (2) the making of the hand guard in one piece completely covering the barrel. The Mark VI is the outcome of experiment, since the Great War, but as yet has not been produced in quantity.

*National Rifle Association of Great Britain.

CHAPTER XXIX

Glossary of Chemicals and Substances



Glossary of Chemicals and Substances

INASMUCH as chemistry plays an important part in the manufacture of ammunition and firearms, some elementary information on this subject will be helpful for the student who wishes a general understanding of what is necessary in compounding various acids for browning or bluing, and in the handling of other substances used in the building of a firearm. With a definite understanding of the names of chemicals and the formulæ given in other chapters, he will be able to carry his experiments to any desired length. It is much like the glossary of mechanical terms used by gunmakers—a separate book could be written on the subject—but with this as a foundation, the reader will find a world of facts suited to the many needs that may arise in the course of his gun work.

Acids—

Acetic Acid—A colorless pungent liquid, usually obtained by the destructive distillation of wood, or by the oxidization of alcohol with ferments. The acetic acid of commerce is an aqueous solution containing 33 to 36 per cent of glacial (pure) acetic acid. Vinegar contains 4 to 12 per cent.

Boracic Acid—A colorless crystalline compound, obtained largely in volcanic lagoons of Tuscany, Italy, and found in chemical combinations such as borax.

Carbolic Acid—A white crystalline deliquescent compound with a burning taste, and an odor resembling that of creosote; contained in the heavy oil of tar from which it is distilled. It is a caustic poison. Known also as phenol.

Gallic Acid—Acid produced in yellowish-colored crystals, derived from nut galls or oak apples. Soluble in water and alcohol. Nut galls are an important ingredient in the manufacture of good black ink.

Hydrochloric Acid—Known in commerce as muriatic acid. The only known compound of chlorine and hydrogen. Obtained when equal quantities of chlorine and hydrogen are mixed and exposed to the diffused light of day. The gases combine and form an unaltered volume of hydrochloric-acid gas. The acid may, however, be more easily prepared by heating sodium chlorid (common table salt) and sulfuric acid in a flask. This acid is a colorless gas, 1.269 times heavier than air; it fumes strongly in damp air, combining with the moisture, and has a strong acid reaction. It is very soluble in water, one volume of the acid at 15 degrees dissolving 454 volumes of the gas. This solution is the ordinary hydrochloric or muriatic acid of commerce.

Hydrofluoric or Fluoric Acid—Used to etch glass. The gas and solution are dangerous substances. The gas is poisonous, and the acid, if dropped on the skin, produces severe burns. Keep in wax or bakelite bottles.

Muriatic Acid—So called because it was formerly thought to be an oxid of an unknown element, murium. Also called hydrochloric acid.

Nitric Acid—Formed by the action of sulfuric acid on ni-

trates and other means. The pure acid is a colorless, fuming, corrosive liquid. Ordinary commercial nitric acid is yellowish in color. This acid is very active, dissociating very readily in water, and also having strong oxidizing qualities. It attacks most metals and certain other elements. It yellows and corrodes various organic compounds. Known also as aqua fortis, or strong water. Used to etch metal.

Oxalic Acid—A white crystalline poisonous compound found extensively in the vegetable kingdom; also made by the decomposition of sugar, etc., with nitric acid. Also called salts of lemon.

Picric Acid—A yellow crystalline compound obtained by the action of nitric acid on phenol, and by other means.

Pyrogallic Acid—Obtained from gallic acid by heat.

Salicylic Acid—A white crystalline compound contained in many plants, and also made from phenol.

Sulfuric Acid—A colorless, very corrosive, oily liquid compound. Originally made by distilling iron sulfate (green vitriol), hence its name, oil of vitriol. It is the most important acid used in the arts. Do not confound it with sulfurous acid (sulfur dioxide), which is simply the fumes of burning sulfur combined with the oxygen of the air. The burning brimstone match gives forth sulfurous acid.

Tartaric Acid—A colorless crystalline compound occurring largely in the vegetable kingdom, either as a potassium or calcium salt. Usually prepared commercially from argol, which is the crude tartar found at the bottom of wine casks.

Acetone—An inflammable liquid with a biting taste, obtained by the destructive distillation of certain acetates, citric acid, starch, sugar or gum. Used in making chloroform; a solvent for fats, camphor and resins, and powder residue.

Alcohol—

Ethyl—Grain alcohol. Obtained by fermentation and distillation of rye, wheat, etc.

Methyl—Wood alcohol, wood spirits, carbinol; distilled from wood.

Denatured—The addition of 10 per cent wood alcohol "denatures" it according to law. For general commercial use benzine is added, the first-mentioned article being allowed to manufacturers of varnish, etc., only under special permit. Hence, denatured commercial alcohol is not so desirable for many uses that a wood finisher finds for alcohol, owing to the presence of the benzine. In Great Britain, denatured alcohol is known as methylated spirits.

Absolute—Absolute alcohol is that which is entirely free of water, a condition not obtainable by ordinary distillation, and effected only by the use of some dehydrating substance such as quicklime. Commercial absolute alcohol contains about 1 per cent of water and is used only for special purposes. As used in the U. S. Pharmacopœia, alcohol means a solution of 91 per cent by weight of ethyl alcohol and 9 per cent of water.

Proof Spirit—Or dilute alcohol: 45.5 per cent by weight of alcohol, 54.5 per cent of water.

Amyl—Amyl alcohol is the principal constituent of fusel oil, etc.

Alizarine—An orange-red crystalline compound formerly obtained from the madder plant, but now made from the coal-tar product, anthracene.

Alkali—Anything that will neutralize an acid; for example, lime, magnesia, ammonia, soda, potash.

Alkanet Root—The root of a species of bugloss. It gives a fine red color to alcohol and oils, but a dirty red to water. Used very successfully when mixed with linseed oil to darken light woods.

Aloes—An intensely bitter resinous substance consisting of the inspissated juices of the leaves of several species of aloes.

Alum—Sulfate of potash and aluminum. Potash alum.

Ammonia—A colorless gaseous compound of hydrogen and nitrogen. Aqua ammonia or ammonia water is a solution of gaseous anhydrous ammonia in water. It should contain 10 per cent of the gas by weight; the "stronger ammonia," 28 per cent. Ammonia is very soluble in water, liquefiable and solidifiable by cold and pressure; it is strongly alkaline and combines readily with acids to form ammonia salts.

Ammonia Persulfate—Comes in a powder form and when mixed with ammonia and distilled water makes a very good cleaning solution, especially for dissolving metal fouling.

Ammonium—

Phosphate—A combination of ammonia and phosphoric acid.

Sulfate—A salt formed by the union of ammonia and sulfuric acid.

Chlorid—Sal ammoniac.

Carbonate—A variable mixture of ammonium bicarbonate and ammonium carbamate.

Annato—Also spelled anotta, arnotta, and annotto. A red coloring substance obtained from the pulp of the seed vessel of the plant *bixaorellana*. It dissolves in alcohol and can be used to darken light woods.

Anilin—An oily poisonous basic liquid, colorless when pure; now chiefly made by the reduction of nitrobenzene. It may be regarded as ammonia in which one hydrogen atom has been replaced by the radical phenyl. In commercial language anilin (or anilin oil) for blue, signifies pure anilin; anilin for red, a mixture of anilin and o- and p-toluidin; and anilin for safranin, anilin containing o-toluidin.

Antimony Trichlorid—Butter of antimony. A compound obtained as a soft, white, fuming crystalline mass by dissolving antimony trisulfid in hydrochloric acid and distilling. Butter of antimony enters into most formulas for furniture polish, because it is a good cleanser, not affecting the luster. It is highly corrosive.

Aqua Regia—Meaning "royal water." Certain metals such as gold and platinum, and many metallic compounds such as certain sulfids which do not dissolve in either nitric or hydrochloric acid separately are readily soluble in a mixture of these two acids, especially upon warming.

Arsenic—White and red arsenic are used in coloring.

Arsenic Chlorid—Also used in the ingredients to color brass, copper, etc.

Barium Chlorid—A salt obtained by fusing barite, a native sulfate of barium, with calcium chlorid.

Barytes—Sulfate of baryta. Most important of the salts of barium. Barytes is commonly known as heavy spar.

Benzene—Obtained by distillation from petroleum.

Benzoin Gum, or Gum Benjamin—A gum extracted from the tree, *styrax benzoin*, which grows in the East Indies. It fuses at a gentle heat. Can be dissolved in alcohol and employed as a varnish to take the place of

white shellac in finishing. It gives an agreeable odor when warmed by the heat of the hands.

Bismuth Chlorid—Used to color metals when mixed in proportions of other ingredients.

Bismuth Oxochlorid—A metallic salt used in certain bluing solutions.

Blue Vitriol—Sulfate of copper, also called blue stone. A salt formed by sulfate acid in combination with copper. It is soluble in cold or warm water. Used in bluing solutions and for coating steel when mixed with sulfuric acid to give a copper appearance to the surface.

Bone-black—Animal charcoal or bone-black is made by heating bones and animal refuse in a closed vessel. Used to coat work where fine points are exposed in hardening.

Brazilwood—A number of tropical American trees yield dyes such as the sapanwood, peachwood, limawood, camwood, barwood, brazilwood, and red sanders or sandalwood. These produce red or purple dyes.

Brunoleine—A preparation used to give the appearance of age to oak, or to make imitation old oak. To make it, boil 7 parts linseed oil with 2 parts litharge and 2 parts red lead in a large kettle until the pale red liquid is converted into a thick brown mass which becomes solid when cold. Reduce this solid body into pieces; pour 16 parts of turpentine over it and dissolve by stirring or by the use of heat. This is filtered through linen, and the clear liquid obtained is mixed with 3 parts of wax turpentine solution. If necessary, color with a solution of asphaltum in turpentine for a lively brown tone.

Campeachy Extract—Logwood extract.

Camphor—A solid concrete substance. *Laurus camphor* or Indian laurel tree grows in the East Indies, China, Japan and the Island of Sumatra. This substance dissolves in alcohol, ether, oil, and acetic acid. Used in making sulfur casts, etc.

Catechu—That mostly used is called Bengal catechu and is an extract of the wood of either of two East Indian acacias. Gambier catechu is from an East Indian shrub. Cutch is from several tropical Asiatic plants. The wood, leaves, or fruits are used in obtaining the coloring matter, by decoction and evaporation.

Carbon Disulphid—A clear liquid which, when not perfectly pure, has a very offensive odor. Dissolves rubber, etc.

Carbonate of—

Magnesia—The white magnesia is a varying mixture of carbonate and hydrate, made by precipitating a hot solution of magnesium sulfate with sodium carbonate.

Potash—Commercially known as pearl ash and potash.

Soda—Known in commerce as soda ash. Made on a large scale from sea salt.

Carmine—There are several carmines. Made from the cochineal insect. Carmine lake is made from carmine and alum. Indigo carmine is of the same class.

Caustic Soda—Sodium hydroxid. Made by boiling lime and carbonate of soda together with water and evaporating down the clear solution.

Charcoal—Used when powdered to blue small parts, willow charcoal being the best. Also used in the making of black powder.

China-wood Oil—Tung oil. Described at some length in Chapter XII, Volume I.

Chlorid of Lime—Calcium chlorid. A mixture of calcium and calcium hypochlorite; bleaching powder.

Chlorid of Sulfur—Sulfuryl chlorid. A colorless, slightly fuming liquid, obtained by direct union of sulfur dioxide and chlorine by sunlight and otherwise. Treated with water, it decomposes, forming sulfuric chloranhydrid.

Coconut Oil—Used in the mixture of oils such as sperm, etc.

Collodium—Collodion. A viscous liquid consisting of a mixture of alcohol and ether in which soluble guncotton or pyroxyllin is dissolved. On evaporation of the solvents, the pyroxyllin remains in a tough adhesive form, in which condition it is used for photograph films, etc.

Copal—The concrete juice of a tree growing in South America and the East Indies. Strictly speaking, it is not a gum or a resin, but rather resembles amber. It may be dissolved in linseed oils with heat a little less than sufficient to boil the oil. The solution diluted with oil of turpentine forms a transparent varnish used on some forms of stock work.

Copperas—Sulfate of iron or green vitriol. A salt made by decomposition of iron or iron pyrites in oil of vitriol, dissolved in water and other ingredients. The basis of some bluing solutions.

Corrosive Sublimato—Or bichlorid of mercury. Made by the action of chloroform and quicksilver, forming a deadly white powder. Used in most bluing solutions.

Creosote—An oil liquid, colorless when pure, but usually colored yellow or brown by impurities or exposure. It is obtained by the distillation of wood tar, especially that of beechwood. A similar substance is obtained from coal tar. Creosote is obtained from creosote oil by purification.

Cupric Chlorid—Chlorid of copper. Formed when copper is brought into chlorine gas, or when copper oxid is dissolved in hydrochloric acid; it forms green needle-shaped crystals, soluble in water and alcohol. Used in bluing solution.

Cupric Sulfate—Sulfate of copper, blue vitriol, blue-stone. Largely made by dissolving copper oxid in sulfuric acid. It crystallizes in large blue crystals.

Cyanid Chlorid—A white substance which is produced in moulds and also powder. Highly poisonous. Used in case-hardening.

Dammar—A resin obtained from various pinaceous trees of the genus *dammara* in Australia, New Zealand, and the East Indies. *Dammar alba* is from the *Amboyna* pine; *dammar Australia* is from the *Kauri* pine. *Batavia dammar* simply means that it came from the principal shipping point of that name. The so-called *Batavia dammar* is considered to represent the best.

Distilled Water—Use only the pure distilled water in all chemical mixtures.

Digest—To extract soluble substance, as from bark, etc., in alcohol; to soften by heat or moisture.

Dragon's Blood—The true dragon's blood of commerce is obtained from the Malayan rattan palm, from whose fruit the resin exudes. Socotrine dragon's blood, from the island of Socotra, is probably the "cinnabar" of the ancients. Used for tinting varnishes and staining wood and marble.

Epsom Salts—Magnesium sulfate. Obtained mainly from the mines at *Kieserite*. Formerly obtained by boiling down the mineral waters of *Epsom*, England.

Ether—Obtained by the distillation of alcohol with sulfuric acid, hence also known as sulfurous ether. A powerful solvent of fats, oils, resins, etc.

Ether, Nitric—Made by distilling equal parts of strong nitric acid and alcohol with a few grains of urea. It is a liquid; colorless, having a sweet taste and insoluble in water.

Ferric Chlorid—A brown salt used in bluing solutions.

Fusel Oil—An acrid, oily liquid of vile odor, accompanying the making of potato spirits, corn spirits, etc. It consists chiefly of amyl alcohol, hence is known also as amyl alcohol.

Fustic—A light yellow dye obtained from the wood of a tree growing in Mexico and West Indies.

Gamboge—An orange-red resin which becomes bright yellow when powdered. The best comes from Cambodia, Siam.

Glauber Salts—See sulfate of soda.

Glycerin—A sweet syrupy liquid, colorless, odorless, and obtained by the saponification of the neutral fats and oils, which are composed of glycerin with various acids. It is a by-product of soap and candle factories.

Gum—Any of a number of amorphous, tasteless substances, exuded in most cases by plants, and hardening on exposure to the air. Their chief constituents are certain carbohydrates, as arabic acid, bassorin, etc. Some (tree gums) form clear solutions with water, while others (vegetable mucilages) swell up in water into a glutinous mass. All are soluble in alcohol. They may be true secretions, or transformation products of cellulose, as in cherry gum, etc. Loosely, any of various plant exudations, including the gums proper, resins, gum resins, etc.

Gum resins are essentially a mixture of gum and resin, usually obtained by making an incision in a plant and allowing the juice which exudes to solidify by evaporation. Gum resins are, in accordance with their composition, partially soluble in alcohol. Some substances commonly called gums are gum resins; they usually originate as excretion products in special canals or glands. See also Resin.

Henna, Tincture of—From the leaves of a thorny tree or shrub of Asia there is obtained a reddish orange dye, called henna, or alhenna.

Indigo—Made artificially from naphthalene. Formerly made entirely from the indigo plant. The indigo coloring did not exist in the plant as such, but was obtained by decomposition of indican, which contains, besides indigo blue, various other substances unless specially purified.

Indigo Carmine—The sodium or potassium salt of indigo in disulfuric acid (indigo extract). Sold usually in the form of a paste.

Iron Acetone—A liquid formed by the action of acetic acid on iron filings.

Iron, Sesquichlorid of—Perchlorid of iron or permurate of iron. Made by dissolving rust of iron in hydrochloric acid, and then crystallizing. It forms red crystals. Soluble in water and alcohol. Very corrosive; used in bluing solutions.

Japan—A varnish used in Japan and obtained by tapping a tree called the varnish tree. In the painting trade, japan means a drying agent. There are various kinds; brown is the kind generally used by house painters for adding to paint to assist its drying; of course there are several qualities or grades of brown japan. Black japan is really a black varnish used by coach painters. Coach japan is a good-quality drier used by coach painters. The color of a drying japan depends upon the siccative agent used and the amount of boiling the liquid receives. The dark japan is a quicker drier than the light tints. Japan gold size is light in color, but a strong drier. It all depends upon method of manufacture. For the wood finisher, the dark japans are usually the most useful.

Kilo—A prefix meaning thousand, used in forming names of units of measurement, as in kilogram, kilometer, kilowatt. A "kilo" is 2.2 pounds.

Lacquer—Nitrocellulose is an essential ingredient of special solutions called lacquers. These are extensively used for coating finished metal parts.

Lead Acetate—Sugar of lead. A drying agent, used in making "patent drier." A colorless or white crystal salt with a sweet astringent and metallic taste, made by dissolv-

ing lead in vinegar, and in other ways. It is an irritant poison.

Lime—A caustic, highly infusible substance, white when pure; obtained by burning limestone, oyster shells, etc. Known also as quicklime. Calcium oxid. Lime slaked with water is calcium hydroxid. Lime slaked in the air is carbonate of lime.

Linseed Oil—Made from crushed flaxseed; used on gun stocks. There are two kinds, the raw linseed oil and the boiled.

Litharge—A yellowish-red substance obtained by heating lead moderately in the presence of air, or by calcining lead nitrate or lead carbonate. Practically the same as red lead.

Logwood—The heartwood of a Central American tree. It is very hard, and of a brown or brownish red color. Imported in logs hence its name. Logwood chips and extract are used in dyeing. Barrels are sometimes boiled in logwood to produce a deep black after bluing.

Madder—A plant of the genus *rubia*, one species of which is used to dye red.

Magnesium Chlorid—A fusible salt obtained by evaporating magnesia dissolved in hydrochloric acid with an equal quantity of sal ammoniac; on fusion, the latter salt volatilizes, and the magnesium chlorid remains behind.

Malaxating—To soften by kneading, rubbing, mixing, or by stirring some thinner substance.

Manganate of Soda—A salt of manganic acid. Various manganates are formed as green masses by fusion of manganese dioxid with alkalies, oxids, or carbonates. Those of sodium (manganate of soda), of potassium (manganate of potash), and of barium are perhaps the best known.

Manganese, Sulfate of—A beautiful rose-colored salt, used to give a fine brown to woods.

Marble Dust—Simply crushed and pulverized limestone. Large quantities are used in making what is called "putty."

Mercury, Quicksilver—A fluid metal which congeals at about 40 degrees below zero Fahrenheit. Boils at 660 degrees, and forms a colorless dense vapor. It is used in barometers and thermometers, and in alloy with tin in coating mirrors. It unites with chloroform, forming calomel and corrosive sublimate. The only acids that act upon it are sulfuric and nitric. To make it unite with the latter, it must be heated. Used to remove lead fouling from rifle barrels, and to harden lead bullets.

Muriate of Iron—Called chlorid or iron. Made by dissolving iron chips in hydrochloric acid and crystallizing by evaporation, crystals of green color being the result. Used at times in bluing solutions.

Neat's-foot Oil—A pale yellowish fixed oil made by boiling the feet and shins of neat cattle. It consists almost wholly of olein and is used as a fine lubricant and leather dressing.

Nitrate of Silver—Made by dissolving silver in nitric acid and evaporating the solution to crystals. Will dissolve in warm water. It is used for indelible ink and photography. Also in the coloring of different metals when mixed with other ingredients. In contact with organic matter, it turns black.

Niter, Sweet Spirits of—A solution of nitrous ether. Contains a high percentage of alcohol. Used in bluing solutions.

Oil of Amber—Amber varnish.

Oxalate of Tin—An oxalate is an ester of salt of oxalic acid.

Ozokerite—Mineral wax. A waxy, translucent substance or natural paraffin, occurring usually in coal measures, sometimes in large quantities.

Paraffin—A wax produced in distilling wood, lignite,

coal, etc., and occurring in the earth as ozokerite, either as a solid deposit or as a constituent of petroleum. Pure paraffin is white or colorless, odorless and without taste. Chemically, it is perfectly inert.

Pearlash—Carbonate of potash. An alkali obtained from the ashes of trees by leaching. When evaporated to dryness in iron kettles, it is called potash, but when calcined to burn off the coloring matter it is called pearlash.

Persian Berries—The dried berries of various European and Asiatic species of *rhamnus*, producing, with tin salts, a yellow lake.

Petroleum Ether—A term sometimes used to designate 62-degree benzene.

Phenol—A colorless or pinkish crystalline substance produced by the destructive distillation of wood, coal, etc., and from the heavy oil from coal tar. Its odor resembles that of creosote. Generally called carbolic acid.

Plaster of Paris—So called because originally brought from a suburb of Paris. Made from gypsum. When gypsum is moderately heated it loses its water, and becomes plaster of Paris. This, when moistened takes up two atoms of water again and sets to a solid mass.

Potash—Caustic potash. Potassium hydroxid. Prepared by boiling one part of carbonate of potash with 12 parts of water, adding slaked lime prepared from two to three parts of quicklime. In this reaction calcium carbonate (chalk) is formed, which falls to the bottom as a heavy powder, caustic potash remaining in solution. The clear liquid, which should not effervesce on addition of an acid, is evaporated in a silver basin to dryness, fused by exposure to a stronger heat, and cast into sticks in a metallic mold. This prepared caustic potash is a white substance soluble in half its weight of water, and is highly corrosive to the skin.

Potash, Prussiate of—There are the red and yellow prussiates, the latter being non-poisonous.

Potassium Bitartrate—Cream of tartar. Used to color metals.

Potassium Chlorate—Used in bluing formulas.

Potassium Chlorid—Used in different formulas.

Potassium Cyanid—Used for case-hardening.

Potassium Nitrate—Saltpeter. Used in coloring steel and in solutions.

Potassium Permanganate—Used to color woods, and for snake bite, etc.

Pumice—Pumice stone. A highly vesicular volcanic froth, which became stone upon cooling. The color is white, gray, yellowish, or brownish, but rarely red. The imported is best for rubbing with, being free from grit, from which the American article is not sufficiently free.

Quercitron Bark—The bark of a large timber oak of the Eastern United States, whose foliage resembles that of the red oak; its inner bark is yellow.

Resin—Any of various solid or semi-solid organic substances, chiefly of vegetable origin, yellowish to brown (usually), transparent or translucent, and soluble in ether, alcohol, etc., but not in water. Resins soften and melt on heating and burn with a smoky flame. Chemically they differ widely, but all are rich in carbon and hydrogen and also contain some oxygen. Many are oxidation products of the terpenes and are produced as exudates from plants either alone or as mixtures with essential oils (oleoresins), with gums (gum resins), etc., being chiefly excretion products. Some are obtained from alcoholic extracts by addition of water, and some are made artificially as by the action of caustic potash on aldehyde. The chief constituents of the natural resins are certain copals, dammar, guaiacum, lac, mastic, rosin, and sandarach.

Rosin—The residue from the turpentine still. Known

also as North Carolina copal. Its better name perhaps is colophony.

Rose Pink—Whiting dyed with a decoction of brazil-wood and alum.

Rose Madder—An alumina lake of madder or alizarin, of a pale rose color.

Rottenstone—A friable siliceous stone, the residue of a siliceous limestone whose calcareous matter has been removed by the solvent action of water. Also called tripoli powder. Used for fine wood finishes.

Sal Ammoniac—Ammonia and its compounds are now obtained mainly from the ammonia liquors of gas works. Adding hydrochloric acid to the liquid and evaporating the solution produces the sal ammoniac of commerce. Quicklime and sal ammoniac give chlorid of lime. Used in soldering, etc.

Sal Soda—Washing soda. Sodium carbonate. Soda crystals. Carbonate of soda.

Salt—Table salt. Sal culinaris. Chlorid of soda. It is from this that almost all the other sodium compounds are prepared.

Sandarac—A resin that exudes from trees growing in Africa. Fusible by heat and soluble in alcohol. Used in varnishes.

Saturated Solution—When water has taken up all of a solid that it can hold in suspension, as of salt, for instance, it is said to be a saturated solution.

Savogran—A commercial cleanser containing certain alkaline substances.

Shellac—Lac is a resinous substance produced mainly from the banyan tree of the East Indies. It is also the product of an insect.

Silver Nitrate—Prepared in the form of small fusible stones like crystals, by dissolving silver in aqua fortis or nitric acid.

Soda—Sodium, a metal, silver white, and soft at ordinary temperatures. When thrown upon water it floats, and rapidly decomposes the water with disengagement of hydrogen, soda being formed. The compounds of sodium are very widely diffused; every particle of dust contains some; sea water contains nearly 3 per cent of sodium chlorid or common table salt. Sodium carbonate (see carbonate of soda) is made on a large scale from sea salt.

Soda Ash—Same as carbonate of soda.

Sodium Chlorid—Common table salt. See salt.

Sodium Bicarbonate—Bicarbonate of soda. Baking soda. Saleratus (acrated salt). Obtained by exposing the crystallized carbonate of soda in an atmosphere of carbonic acid gas. Heating will convert it again to the carbonate form.

Sodium Nitrate—Used in bluing solutions and other means of bluing steel.

Spermaceti—See Wax.

Spirits of Wine—See Alcohol.

Stannous Chlorid—Obtained by dissolving tin in hydrochloric acid; it separates in needle-shaped crystals, when the solution is concentrated. In commerce known as tin salts. Used in dyeing as a mordant.

Stearin—A constituent of many animal and vegetable fats and oils. Tallow owes its firmness to the presence of stearin. Olein is the liquid or oily part, and stearin the solid part of oil or fat.

Steatite—Soapstone, a variety of talc.

Stick Lac—The resin in its natural state; seed lac when broken up, cleaned of impurities and washed; shellac when it is melted and formed in thin flakes. United with ivory black, or vermilion, it makes sealing wax. Dissolved in alcohol it makes lacquers and varnishes.

Sulfate of Copper—Blue vitriol. Bluestone is the common name, as it comes in large blue crystals. Made by dissolving copper oxid in sulfuric acid.

Sulfate of Hydrogen—Hydrogen sulfate, known in commerce as brown oil of vitriol. Thick oily liquid, combining with water with great force, and used in the laboratory as a drying agent, as it absorbs moisture rapidly from the air. Great heat is evolved when this acid is mixed with water, and care must be taken to bring the two together gradually, otherwise an explosive combination may ensue. Many organic bodies, such as woody fiber and sugar, are completely decomposed and charred by strong sulfuric acid.

Sulfate of Soda—Glauber's salts is the commercial term.

Sulfate of Zinc—Used to color metals, etc.

Sulfur—A mineral of yellowish color, often called brimstone. Soluble in turpentine, fat oils, bisulfuret of carbon, and hot liquor of potassa. With oxygen it forms sulfuric acid and sulfuret acid, and with the metals it combines as sulfurets or sulfides. It is an essential ingredient in the making of black powder. Used in tempering oils for springs and sulfur casts.

Sweet Oil—Oil from the olive.

Talc—A soft mineral of a soapy feel; usually whitish, greenish, or grayish in color. Soapstone and French chalk are varieties of talc. Talcum powder is a toilet article composed of powdered talc and a perfume.

Tannin—Chemically, tannic acid.

Tartar, Salt of—Potassium carbonate, an especially pure form, is made by heating cream of tartar. Cream of tartar is purified tartar. Chemically it is acid potassium tartrate, or potassium bitartrate. Tartar is the crystalline sediment of wine casks.

Tea—Used to age ivory.

Tincture—The finer and more soluble parts of a substance separated by a solvent.

Tincture of Ferric Chlorid—"Tincture of iron" used in bluing solutions.

Turmeric—A vegetable dye, a yellow, and there may be used in its stead, answering the same purpose, Persian berries or quercitron bark.

Turpentine—An olio-resinous substance flowing from several species of pine, larch, and fir trees. Oil of turpentine is obtained by distilling the crude turpentine.

Verdigris—Copper acetate. A dark green salt, poisonous. Obtained by action of acetic acid on copper. Formerly used in paint, but besides being poisonous, it was liable to fade, blacken, and react with other substances.

Water Bath—To prevent the overheating or burning of a substance that is to be boiled, it is placed in a vessel which is placed within a second vessel containing water, and the water, upon heating or boiling, heats the first vessel's contents sufficiently and without endangering it from overheating.

Water Glass—Soluble glass. Silicate of soda. Silicate of potash. A substance consisting of silica which has been liquefied by extreme heat and pressure, in connection with potash or soda, potash giving potassium silicate, and soda sodium silicate, the latter being the more generally used by painters. It is a sirupy liquid, soluble in water.

Wax—Beeswax is secreted by the bee, and used in the making of the honeycomb. A dull yellow solid wax of agreeable odor; melts at 142 to 148 degrees Fahrenheit. Can be purified and bleached white, in which condition it is tasteless, odorless, and somewhat brittle. Insoluble in water, partially soluble in boiling alcohol, and miscible in all proportions with fats and oils (turpentine of course). Used to a large extent in finishing oils for stocks, and coating surfaces of metals for etching. Carnauba wax is obtained from

the Brazil wax. It is yellow in color and brittle. Used in making candles. Ceresin wax is an amorphous substance, the insoluble part of cherry gum. Japan wax is obtained from the Japan wax tree, a Japanese sumac. A fragrant green wax from the bayberry or wax myrtle is called myrtle wax. Paraffin wax—see Paraffin. Spermaceti is a yellowish or white wax, solid, obtained from the oil of the sperm whale.

Whiting—Calcium carbonate. There are various forms: crude, commercial, gilder's bolted, English cliffstone, Paris white, Spanish white. All whittings are made from chalk, but differ in grade or quality, according to amount of

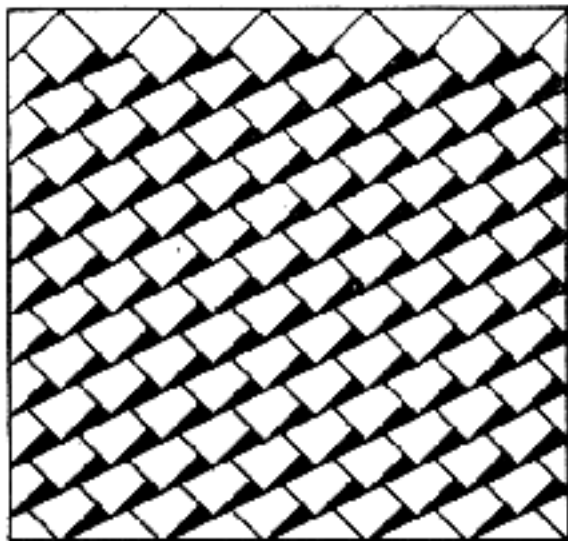
preparation in the making.

Woad—A coloring matter from the woad plant, *isatis tinctoria*, resembling indigo, consisting of the powdered and fermented leaves of the plant. Its essential constituent, indigotin, is identical with that of indigo, which has largely superseded it in dyeing.

Zinc Chlorid—Chlorid of zinc. A white soluble deliquescent substance formed by burning zinc in chlorid, or by dissolving zinc in hydrochloric acid.

Zinc Sulfate—A soluble salt, crystallizing in long prisms, and commonly called white vitriol.

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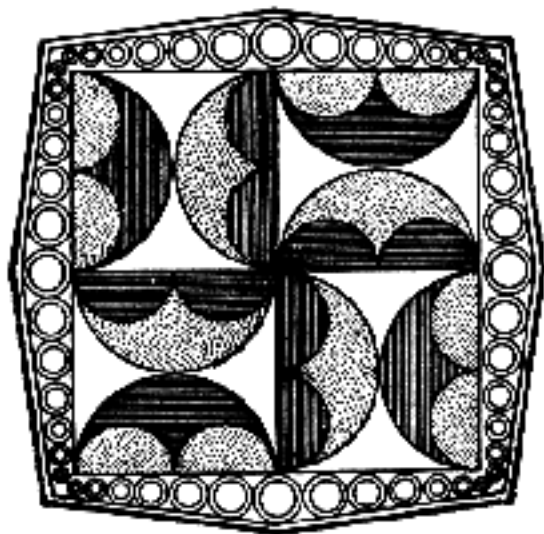
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The Modern Gunsmith Supplement



THE MODERN GUNSMITH SUPPLEMENT

Latest Developments, up to 1941, in Metallurgy, High-Velocity Projectiles,
the Merits and Defects of the Garand and Other New Semi-Automatic
Weapons, and Some Recent Inventions

By
JAMES VIRGIL HOWE



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PREFACE

AS THIS two-volume work on gunsmithing has been extensively used by all lovers of firearms in our country and in several foreign countries, and has, in its entire circulation, exceeded three editions, the author and the publisher have felt it their moral obligation, in return for such distinguished interest, to use their best endeavors to render the work as complete as possible for those in whose behalf it was primarily designed. With this in view, much of the work has been revised in the large books, and this supplement is now added as an incorporated part, bringing the subject more fully up to the present advanced state of the art of gunsmithing and gunmaking than has been done in any similar book in this country or abroad.

The present supplement contains a number of new chapters on phases of the subjects which the progressive state of firearms development has rendered permanent since the first great European war. Among these are various aspects of practical metallurgy, notably in the art of increasing velocities, in the ability to ream gun barrels with greater precision and without injury to the metal surrounding the bore, in producing the most ideal finishes to metal and wood, in handling the new automatic military weapons, and in gauging the wind in testing small arms. High velocity is a subject but little understood. This is true not only of the average sportsman but also of military engineers; yet the subject is one of so much importance to all nations in wartime and to all riflemen who wish to secure greater range and killing power in their weapons, that we have greatly enlarged this chapter. The new chapter, also, on "Gun Barrels, Their Steels, and a Safety Analysis" has been prepared with greater care than usual and will, it is hoped, give the sportsman and target shooter a clear and intelligent understanding of the strains and stresses to be found in all gun-barrel steels, and of their proper treatment at the hands of the experienced rifleman and gunmaker.

We have aimed here, as in the main volumes, to furnish a full view of the most useful gunsmithing knowledge and its most important practical applications; but we have sought to avoid the error that mars too many of the attempts to render our art easy of comprehension—that of setting forth nothing but what is so barren and superficial as to be of little service to either the professional gunmaker or the learner. Addressing ourselves to the more advanced technical field of gunmaking, and keeping constantly in view the practical applications as well as the modern improvements, we have been careful to give to each additional chapter a space proportional to its value in relation to its objective. To render difficult gunmaking plain and intelligible to the young shooter of military age, and to enrich his mind with such knowledge as may at once inspire a love and a habit of using small arms on the rifle and pistol range, has been the author's aim; it has been his desire also to furnish practical suggestions to many who are dissatisfied with themselves and with the weapons they are continually firing, and who lack the essential knowledge that would make them perform efficiently and thus enable them to secure higher scores—or promotion in the ranks.

Besides the men who are about to be pressed into military service, we have had constantly in view two other classes of readers—first, gunsmiths who must be trained and educated in the service and who may desire to continue the study of gunsmithing as a means of livelihood after their honorable discharge; and, secondly, practical target shooters and sportsmen, who consult a work of this class for principles which they can employ in judging all weapons that they own or expect to purchase. In conclusion, we truly believe that the present supplement, although of small dimensions, will be found to contain an unusual amount of such information as is required by the ballistic engineer and the gun mechanic, and that the two-volume work and this supplement together deserve, therefore, a place in all their libraries.

J. V. HOWE

*Wayne Oak Plantation, Virginia,
January 10, 1911*

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The Modern Gunsmith Supplement

CHAPTER I

Some Matters of Major Importance

THE spectacle of destruction furnished by Europe's dictators, with their threat of death to all who may oppose their dictatorial power, has affected the peace of our own nation, compelling us to prepare for action in the event that their designs may reach to the Western Hemisphere, which we must defend; and to defend it we shall require thousands of technical and mechanical experts similar to those which *The Modern Gunsmith* has produced since its publication in 1934.

The Modern Gunsmith, it is true, has inspired hundreds of sportsmen to become successful gunmakers and gunsmiths, and these can give a good account of themselves when called upon to do so; but how can we secure the thousands of mechanically minded men which we now require in keeping a large mechanized army in the field? What means shall we employ to find the mechanical geniuses who can be used in our large munition plants, or how shall we produce the necessary number of gunmakers, gunsmiths, tool- and die-makers, machinists, and men to handle or repair aircraft engines and instruments, in order that a large army and navy may be kept in operation?

The first answer to these questions, of course, is that we always have to find our men of mechanical ambitions, not to make them; we cannot manufacture them, any more than we can manufacture the iron ore of which all weapons of war are made. But it is possible to find both the right ore and the right men, and to educate these men. A certain number of mechanically minded infants are born annually in every country, greater or less according to the nature and advancement of the nation; but only a fixed number annually, not increasable to any great extent. Without a doubt it is possible to find two or three Edisons at this moment in some of our industrial centers or in government employment; but we are not using their particular talents in war industries, where they could do the most good; indeed, we may only be oppressing and destroying their ambitious spirits. And the mechanical gift

usually is not combined with other talents; your born gunmaker, if you do not make a gunmaker of him, will never become a successful doctor or chemist; and the special gifts of such a man are seldom detected by the heads of the average industrial organization. They fail to recognize the fact that variety, not specialization, develops the human brain.

Through variety we create a certain degree of intelligence, which we can make use of only by setting it at its proper work; if any attempt is made to use it otherwise, the result is the dead loss of so much human energy.

Now that we are in urgent need of such men, how are they to be discovered? Easily enough! To desire to employ them, is to discover them. The needs of the War Department today are for mechanics—gunmakers, tool-makers, and instrument-makers in every important government arsenal, aircraft engine factory, navy yard, and in industries that are working on war orders and cannot find men of such talents; therefore they must train men who are able to fit in where they can accomplish the most good. Many who have studied *The Modern Gunsmith*, namely, sportsmen, shooters in general, and gun hobbyists who have used this book in their home workshop—farmers' sons, salesmen, clerks, and ambitious apartment-house dwellers whom the urge to use tools has made mechanically minded, and others in all walks of life—would make excellent apprentices to supply the great demand for mechanics. To complete the education of such men, schools are urgently needed; but these schools must not be entirely regulated by formal political laws, nor should the teachers be selected from the rank and file of manual-training instructors. Not only should these teachers be finished masters in their particular fields; they should also be able to find out what their pupils are adapted for in the field of mechanics.

After passing through the school he has selected, the student must be given secure employment.

This is a matter of chief importance, for even under the present apprentice system the young men who have real mechanical ability generally make mechanics of themselves, whether in the field of gunmaking or in similar industries.

Having provided these young men with the right kind of school and the proper employment, and having encouraged them with judicious praise, one thing more remains to be done for them in order to prepare them for complete success in the work they have chosen; namely, to make, in the complete sense, gentlemen of them; that is to say, to take care that their minds receive such training that in everything they undertake, whether upon weapons, aircraft engines or a locomotive, they shall see and feel that they are putting forth their best efforts, and are treating the work they do in the most gentle and human manner. Unfortunately, in the education of the average mechanic, the calm and gentle part of his being has been the most neglected. Too frequently one may perceive some jarring defect in his nature, some element of degradation in his treatment of machine tools and fine precision instruments, owing to the want of a more gentle training and the liberal influence of the right kind of books.

There are many other points of nearly as much importance as this, which must be brought to light with reference to the development of genius in the inventive field. We must look for these men in the various mechanical trades. Many of them may not possess the rank of genius, but they are men who are ready and willing to develop their creative talents to higher purposes, especially that of producing

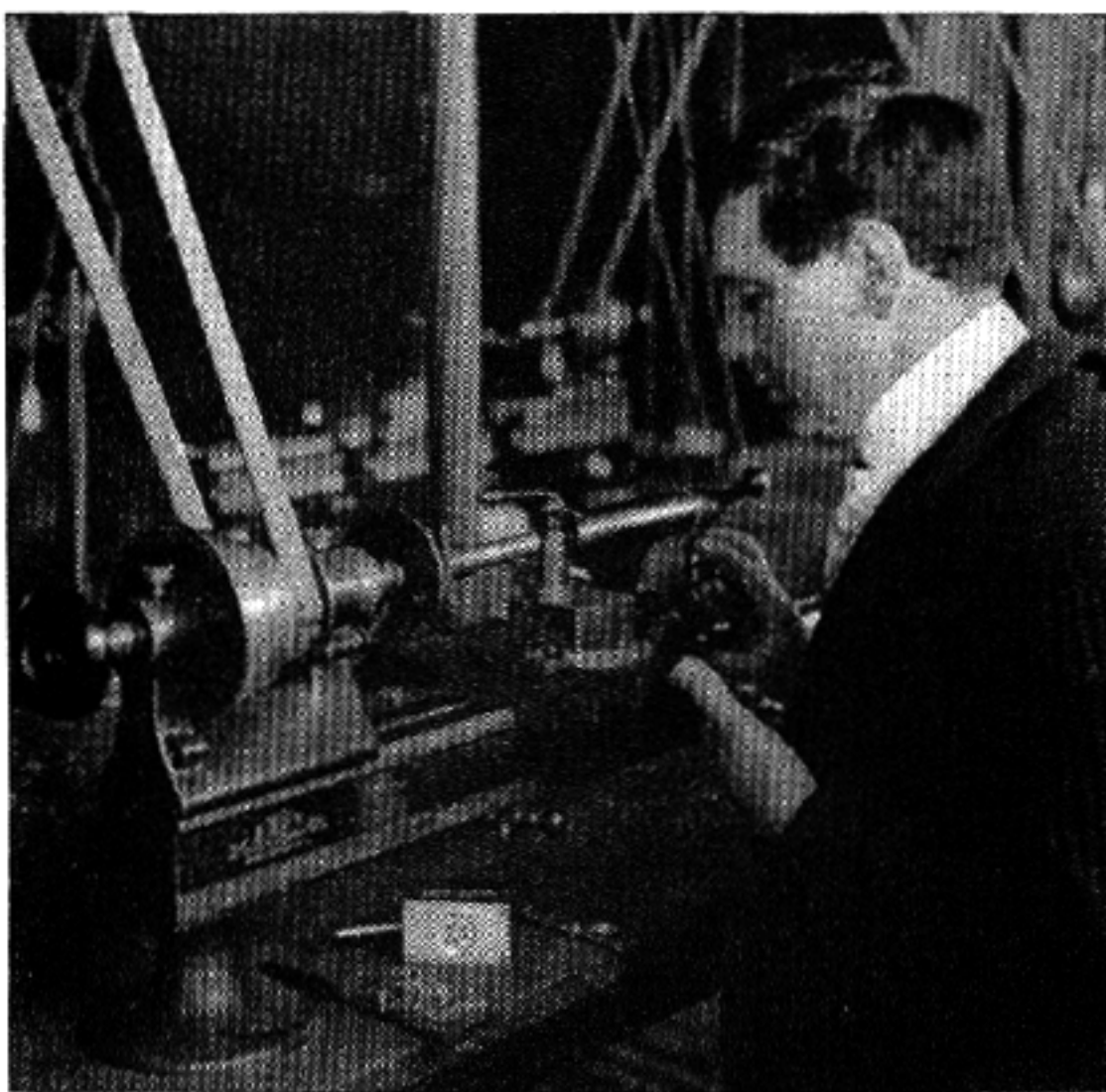


Fig. 1

It is the ambition of every gun inventor to own a bench lathe

more efficient weapons for our own defense. Mechanical geniuses, interesting as they are when discovered, should be placed in key positions, especially where weapons and tools are in need of improvement. But mechanical geniuses are born, not made, even by our best technical instructors. Teach as much as we can, yes; but we must first teach the same thing to all: how to make correct observations of all things mechanical, and more especially of sight impressions.

A very difficult subject to teach, this, perhaps, for it must be combined with the proper brand of inventive imagination, the most important element in the whole range of technical training. We must be taught to think as we make observations; and it does not matter how much imagination we possess if we do not know how to use it. What is needed, in these days of war preparation, is to be able to see in the dark—foresight, that is the greatest gift of all.

Certain it is that our immediate business, in such a school as we have described, will prosper more by attending to the mind than to the use of the hands in the beginning courses. We can do more good by simply endeavoring to enable the student to use his inventive imagination as applied to mechanical work. This, especially for those who are destined to labor afterward upon fine precision work, whether upon weapons or instruments, is the most valuable preparation the student can have. He must begin observing without any sense of effort before he can apply his mind to mechanical observation as a business. All gunmakers have been amateurs in the beginning, however early in life their first serious work may have been performed, and all amateurs have begun by watching mechanical things as idle people window-shop. We are first enticed by the pleasure of irresponsible imagination, and afterward led into the work by a sort of accident. Between the ease of irresponsibility and the ease of mastery there lies a difficult passage, that season of apparent failure when the imaginative power is impeded by the straining of the attention.

Invention is simply mechanical imagination at work on a given task. The distinction between the inventive imagination and the common power to think out mechanical improvements lies simply in the capability of discipline.

To this it may be answered that the idea which would be considered the source of the real invention usually comes to us involuntarily, as for example, when a gunmaker hits upon a new and original rifle sight at a time when his mind is occupied with a barrel problem. We are aware of this, but we do not consider that the real inventive power is to be sought for in the original idea, which is often of

the most extreme simplicity, and is not infrequently borrowed from another source without any kind of acknowledgment. Sketches of first ideas, both by research engineers and inventors, are frequently so crude that they give one no conception of the work the perfected invention is to perform; the inventor only sees his way as he proceeds. What he does is to make some sort of attempt and see what he can make of it by the trial-and-error method—with the aid of his inventive ability. Then comes the real test, which is the working out of the idea so as to present it in its exact proportions, and with the most vivid appearance of reality when all its component parts are assembled, whether it be a machine or a gun. To accomplish this, he "sets his wits to percolate"; that is, he makes his imagination obedient to his will. The everyday sort of man seems to have no imagination in mechanics because he is unable to apply his disconnected dreamings to a definite purpose.

When the real gunmaker gets hold of a good practical idea, he applies his mind to the business of invention in this way. He is not able to invent at a moment's notice, but he knows that in the course of time, he will certainly be able to work out the requisite amount of detail. An arrangement is made between a sportsman and a clever gunmaker by which the gunmaker promises to deliver a new type of shotgun with features in the action and locks which are patentable. At the time when the promise is made, he is ignorant as to the locks and details of action design, but he knows that by the application of his imaginative power he will be able to form the action and locks to the proper proportions. An uninventive sportsman might see almost as much of the shotgun's action after his first glance at some crude sketches made by the gunmaker, but the difference is that he would never see anything more.

It is my belief—and I hope that many will accept it, as it comes from one who has made numerous improvements in small arms, ammunition and diesel engineering—that invention is imagination which can be made to work; therefore, it must follow that real inventors will work at inventing improvements just as they would at anything else, and those who "wait for inspiration" are those who are the least likely to be honored. Does not experience generally confirm this? Setting aside the general belief that men of genius are conceited individuals (an error that can only arise from ignorance of the toil involved in work which seems so easy), and looking at the real facts of the case, do we not find, when we know them personally, that they labor just like other professional engineers?

We may even go further and say that if there is

a difference, it is in favor of the men who possess mechanical genius, for they work more than common mechanics, because they have a much finer appreciation of what they are doing, and take pleasure in performing it and seeing their creation finished and working. Consider the amount of experimental work performed by Eli Whitney, Blanchard, Edison, Steinmetz, Pope, and Wright! In some cases it is true that the great labors of men of genius have been performed under the stimulus of necessity, but we do not find that wealth leads to wasting precious hours in their case. Browning, the inventor of the automatic rifle and machine gun, and Henry Ford continued to work long after they had become rich men. It is easy to acquire knowledge, but invention we bring with us, to develop it in great or little measure, as these men did, for they developed it while young and never allowed it to die within them.

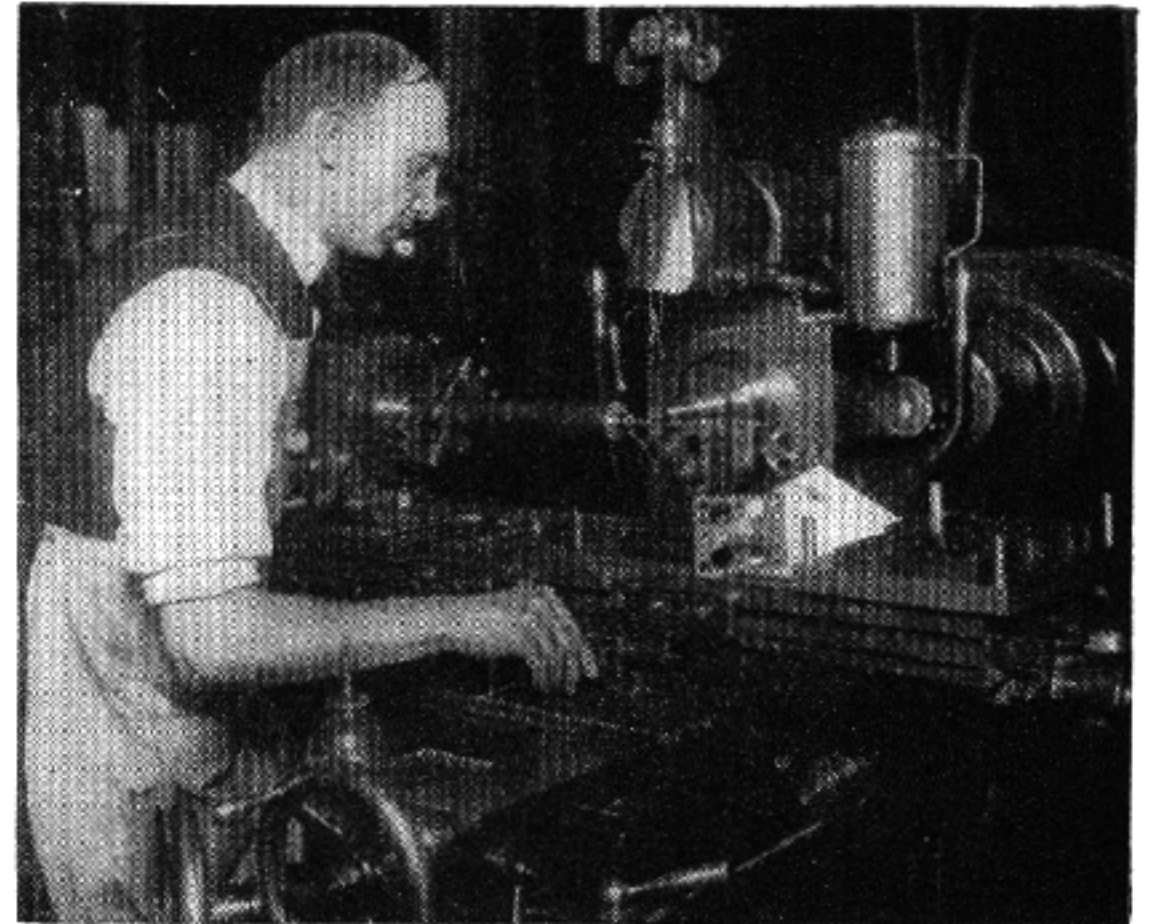


Fig. 2

It is also the desire of every guncraftsman to own a milling machine

Invention in firearms and ammunition, as in every other mechanical art, requires a certain amount of freedom of action, especially in gun and ammunition experiments; and this freedom involves a working condition of a peculiar kind, which has led to the belief that firearms inventors are an especially gifted race. If he were bound down to rigid factory supervision, the gun inventor would be unable to perform the best which is expected of him. All inventors working upon firearms select steels which have great strength, and if the material does not possess strength in its easily workable state, they can easily specify the proper heat treatment after a part is completed. Their education in the metallurgical art enables them to do this, for the recog-

nized men of invention have always done it, and their strong successors are likely to continue the practise, always applying, too, the proper sense of proportion to the things they invent.

That is why hundreds of young men study engineering in all its branches in many technical schools. Too often, however, these young men, not having a well-developed sense of proportion, do not make the best mechanical engineers after graduation.

The term "proportion," in arithmetic, denotes the ratio one number or distance bears to another, and is essentially a concept of linear relations. A "sense of proportion," of course, permits one to estimate fairly well whether one gun barrel is double, one half, one quarter, or one third the length of another, but it certainly is not limited to that. There appears to be some appreciation of the squares and cubes of quantities, especially in measuring gunpowder, although this may, to a great extent, depend upon one's experience.

It is interesting to contemplate how far a gunsmith may go in his reliance on judgment, or sense of proportion, without being led astray. Dimensional analysis is a convenient tool for such investigation, and has the advantage of revealing those fundamental relations which, in so many cases,

make it possible to design guns "in proportion" or by "rule of thumb" successfully.

It is safe to say that whenever a new gun is designed which involves geometric similitude, the mechanical engineer's sense of proportion is of inestimable value, but that, conversely, where geometry is not involved directly, the mechanical engineer is apt to guess the wrong answer unless he makes use of theory, or research, or both. Unfortunately, the highly trained technical person is only rarely endowed, to any high degree, with that fine sense of proportion, clarity of vision, and creative ability which is an attribute of the successful "practical" inventor or research engineer. Indeed, I fear that too much intensive technical training tends at times to becloud and suppress the most desirable characteristics of a successful gun designer; and too much logical thought tends to crowd out the more artistic and spontaneous creative thinking that is also necessary in gun and ammunition design. Be that as it may, the engineering department of an arms and ammunition factory is usually faced today with the problem of persuading these temperamental individuals to work in harmony. The gun inventor is fortunate who possesses the talents for creative invention and yet has a strong technical background.

Iron and Steel in Nature and in Guns

THE importance of conveying to the non-technical gun hobbyist and sportsman a working knowledge of metallurgy, as a foundation upon which to build a clearer understanding of the chapters to follow, cannot be overemphasized. Only by carefully arranging, classifying, and subdividing these fundamentals according to their respective importance to the gun lover, can each phase of metallurgy and the treatment of steels be clearly understood. Reference to various treatises on steel-making—metallurgy in relation to the proper heat treatment of metals—will demonstrate that for many reasons few, if any, have presented the fundamentals of steels and their action in general gun-making. Therefore, these chapters have been dedicated to the task of dealing with that subject in simplicity, for three reasons: First, because there is an apparently widespread demand for such information in readable form. Second, because to educate properly is to present the fundamental facts first, and let the arbitrary details be relegated to their relative position in the technical background. Third, we have been accused of not saying enough in the second volume of *The Modern Gunsmith* about steels, their treatment, and their relation to the gunmaker's art by hundreds of enthusiastic home craftsmen and shop mechanics.

We did not understand at first that this subject was of such vital interest, and even when writing what we did upon the subject, five or six good reasons for eliminating those chapters completely occurred to us; but what was written only whetted the appetite for more, it seems; for we live in an age in which metals of all kinds play a major role in industry. Gun enthusiasts are divisible into two distinct classes: those who are capable of comprehending the fundamental principles of metals, and those who are not. The first class, who are the minority, entered into our mind at the time the large volumes were written; but the second class were never considered, even though they were the majority, for we thought that any explanation in the matter of heat treatment of steels would be wasted upon them. We have learned at last that it is the latter class who really need considering, for it is these men who are bewildered about the fundamentals of metallurgy, especially in the proper

treatment of their gun barrels when shots will not group in the center of the ten ring. Metallurgy, in all its branches, has a sort of influence upon all shooters who are more or less mechanically minded. It would take volumes to define all the details so that the layman could really understand, but if a young man understands some of the elementary principles of metals, he is already far above those in the mechanics class.

Iron Rust and Its Value—You all probably know that the yellow stain often seen on the banks of a running brook, and around the edges of a spring, is iron in a state of rust; and when we see rusty iron in other places we generally think, not only that it spoils the places it stains, but that it is spoiled itself—for rusty iron consists of ferric hydroxide, an oxide formed by corrosion.

Iron in such a state of rust cannot be employed for most of our needs; and because we do not care to use a rusty gun barrel instead of a highly polished one, we imagine rust to be a great defect in the metal from which it is made, and conclude that gun barrels should be made from steels which are not subject to rust. But this is not the case; on the contrary, the most useful quality of steel is its tendency to get itself into that condition. Rust is not a fault in the iron, but an accomplishment; for in that condition it fulfils its most important functions in the universe and its most useful duties to the human race. We may say, indeed, that iron in a rusted state is Living; but when melted, and when a specimen is removed from the bar and polished to explore its structure, it is Dead.

In the mixed air that we breathe, the part which is so essential to animal life, as you know, is oxygen. The nervous power of life is a delicately arranged structure, but the supporting elements of the structure cannot be nourished without the help of oxygen. The air we breathe is the very same air which the iron breathes when it gets rusty. It takes the oxygen from the atmosphere as eagerly as we do, although it uses it differently. The iron keeps all that it gets; we, and other animals, part with it again; but the metal absolutely keeps what it has once received; and the yellow oxide which we so often despise is, in fact, just so much pure iron,

in so far as it is iron and oxygen combined. The main service of the iron and all other metals, to us, is not in making guns, tanks, cookstoves, and hunting knives, but in enriching the ground we feed from; for iron constitutes $4\frac{1}{2}$ per cent of the earth's crust, and is one of the various substances, in the form of oxides, that are most needful to our very existence. All these are nothing but metals and oxygen—metals with oxygen put in them—but they are in such a disintegrated, unrecognizable state that the unobserving person will never detect their presence. Sand, clay, lime, and the rest of the earths—potash and soda, and the rest of the alkalis—are all metals which have experienced this vital change, and have been made fit for the service of man by their permanent unity with oxygen.

Is there not something significant in these facts, considered as one of the lessons furnished by inanimate creation? Here we have our hard, bright, cold, lifeless metal when made into steel—good enough for guns and battleships, but not for food. You may think that iron is wonderfully useful in its pure state, but how would we react if all the fields, instead of growing grass, grew nothing but iron nails? Or if the whole earth, instead of being rich with green forest between the level fields as far as the eye could see, showed nothing but the image of a vast furnace district like that around Pittsburgh—a globe of black, lifeless metal? It would be that, if the elements of which it is made did not breathe the oxygen from the atmosphere. And as metals breathe, the crusts of the harder substances naturally fall into the class of oxides, or dust, planting themselves again in the earth from which they are extracted for our commercial uses.

Steel Alloys—Thus far the same interest attaches to all the physical elements of which steel is made; but now a deeper interest attracts our attention to another element—carbon, that which gives steel its hardening qualities. The addition of carbon to iron wrought revolutionary changes in the art of steelmaking. It was in 1000 A.D. that the charcoal hearth process of making iron brought to light this effect of carbon—followed later by a carburizing process in which charcoal was used to give steel its desired carbon content. Whenever an analysis is made of steel of modern manufacture, the elements listed below in their proper order are usually found, with their functional value and their effects when incorporated in steel.

IRON

Found as a metal in meteors. Occurs as iron ores; namely, hematite, magnetite, limonite, siderite, etc. It constitutes $4\frac{1}{2}$ per cent of the earth's crust.

CARBON

Found in wood, coal, graphite, diamonds, and is a vital element of all plant life and of all animal bodies.

Used extensively in the form of cast iron, in steel-making, and in all organic chemical compounds; namely, dyes, flavors, gasoline, etc.

It is steel's principal hardening element (except those of an alloy content). It is the most vital element which gives steel its qualities of hardness.

MANGANESE

Found as manganese ores, and manganiferous iron ores.

Used in steel-making and in glass-making.

It has strong hardening features, giving steel its toughness and great wear resistance. Our best rifle barrels are made from manganese steel.

NICKEL

Found as sulphide ores.

Used in steel-making, cast iron, nickel-copper alloys, magnetic alloys, etc.

It has great toughness, hardenability, and corrosion resistance.

It is the alloy which gives steel great strength and fatigue-resisting qualities.

CHROMIUM

Found as chromite, etc. All chromium ores are oxides.

Used in steel-making, in cast iron, chromium plating, tanning, and in color and paint pigments (chrome yellow, etc.).

In steel it has stainless properties, heat-resistance, abrasion-resistance, and hardenability.

MOLYBDENUM

Found as molybdenum sulphide and calcium molybdate.

Used in steel-making, cast iron, paint pigment, and for plates and grids for vacuum tubes.

It gives steel a high-temperature hardness, and hardenability in the annealed state. The barrels used on the Garand automatic rifle are made from a steel with a molybdenum content, known as S. A. E. 4150. The amateur should avoid using this type of steel for rifle barrels, because of his inability to secure a satisfactory finish to the bore.

SILICON

Found in sand, quartzite; in fact, 7 per cent of the earth's crust is this element.

Used for making glass, Portland cement, carborundum, etc., as compounds.

Used in the making of steel, and in cast iron as a dissolvent element.

In steel it is a deoxidizer, and is gifted with special properties. Basic open-hearth alloy steels usually contain between 0.15 and 0.30 per cent of silicon. Electric and acid open-hearth steels usually contain 0.15 per cent of silicon as the minimum range.

SULFUR

Found in its pure state; also found with iron (pyrites) and in other minerals.

Used in making free-cutting steels, gunpowder, rubber, lubricants, bleaching compounds, sulfuric acid, etc.

In all alloy steels it is generally considered an im-

purity; when used in a free-cutting steel up to 0.30 per cent, it raises the value of the metal's machinability.

PHOSPHORUS

Found in phosphate rock (calcium phosphate). It is also an important constituent of bones.

Used to make fertilizer, and in free-cutting steels.

In all alloy steels it is considered an impurity, and when found in large amounts it lessens the ductility of steel; but when used up to 0.20 per cent in rust-resisting steels, and in the presence of copper, it resists the effects of weather upon the metal.

COPPER

Found as metallic copper, as sulphides, and as an oxide.

It is one of the metals most widely used in pure form. It is used in steel, coinage, household and industrial uses, copper plating, etc.

In steel it has corrosion-resisting properties, and is used occasionally in certain grades of steels as a hardening agent, and when 4 per cent is used, it produces very effective hardening results.

ALUMINUM

Found as the mineral "Bauxite," which is the commercial name of this metal. It is also found in clays and rocks in a very wide range throughout the world as a metallic element.

When used up to 1.50 per cent in steel it is an alloy for surface hardening by nitrogen—in a furnace constructed for that purpose. It is also alloyed with copper. The oxide is used as an abrasive and as a refractory.

In steel it is used as a grain refiner and as a deoxidizer.

TUNGSTEN

Found largely as an oxide compound, calcium tungstate.

Tungsten steel is the steel *par excellence* for cutting other metals, and is known as high-speed tool steel.

Used for lamp filament, it is made into wire by drawing it through diamond dies as small as 0.0005 inch.

In steel it has many special uses. It also provides stability at high temperatures. Some of our best reamer steels are of a low tungsten content.

VANADIUM

Found as various oxides and as sulphide ores.

Used in steel-making. It is a toughening agent and refines the grain size of steel; when used in a larger percentage it is a hardener.

In this slight review of the functions of the alloys of modern steels, it will be observed that they all impart a strengthening power to the metal. Thus nickel, added to steel, raises its strength without sacrificing its ductility, and intensifies the effects of other alloy elements, particularly chromium. Chromium raises the ultimate strength, and gives steel its hardness and toughness, thus keeping grain growth down to a minimum. Molybdenum raises the ultimate strength, hardness and toughness, and,

like chromium, minimizes grain growth at a high normalizing temperature. The tables of the S. A. E. numbers will be found in Chapter VI, Volume II, and should be used as a reference in connection with this table of information.

But the most important point to remember is that the oxides would never have existed had it not been that the oxygen first turned them into dust. The pure alloys have no special part in steel-making, and they never occur in nature at all except in meteoric stones fallen from the skies. In the necessary work of preparing the nation for war, great tonnage of steel is used; but if the alloys in the form of oxides had never breathed the oxygen from the atmosphere, we would still be using cast-iron cannon, cast-iron rifle barrels, and wooden ships would still be upon the seven seas.

Problems of the Metallurgist—With the discovery of the alloys the steel industry moved rapidly forward, and following in its path is the shadow of obsolescence, creeping over and obscuring the weapons and ships of yesterday's hope. The nation and its weapons may both be obscured if either fails to keep pace with the needs of warfare. Yet, our nation has within its power that which will prevent it from falling behind—the vision to penetrate the darkness, see what is ahead, and adjust its pace accordingly.

Today the science of warfare is in the spot-light, bringing about recognition of its importance. Upon the shoulders of the metallurgist, mechanical engineer, and research engineer falls the burden of the responsibilities accompanying this recognition. It is their task to demonstrate their ability by improving the products of which they are the masters. Their success will be in proportion to their vision.

The metallurgist, the mechanical engineer, and the research engineer are as essential to modern industry as the engine is to the airplane. But, unless modern industry can be made to appreciate the value of the "engine to the airplane," the shadow of obsolescence will fall upon all three engineers.

Therefore, upon all three rests the further responsibility of convincing the war industries of their value, by the intelligence they display in solving the heat-treating problems of those industries. This task will be less difficult if they will avoid complex explanations of "phenomena" pertaining to engineering problems in their contacts with army officers and perhaps with more inexperienced men at the head of some particular war industry. This can best be done by the application of logic, because logic is simply fundamental "horse sense" in any kind of language.

Gun Barrels, Their Steels, and a Safety Analysis

CLASSIFYING S. A. E. numbered steels, and explaining to gun hobbyists and sportsmen in general how one differs from the other, is almost as difficult for the metallurgist as classifying the human race is for the psychologist. Like human beings, steels follow the same master pattern; their variations in physical detail merely reflect the influence of progressive scientific development.

Gunmakers, like psychologists, may agree on the fundamentals of their professional problems, but few agree on their solution. Therefore, while the number method used by the S. A. E. to classify steels and their approximate heat treatments may not be agreed with in detail by those who have to work out their individual heat-treating problems, it is felt by that society that the clarity of its method justifies its use by the nontechnical reader. The difficulty is amplified by the fact that it is necessary to deal with problems correlating metallurgical fundamentals with traditionally established coined words, trade names and phraseology which, in themselves, are sometimes more descriptive than accurate. Every attempt has been made to set forth the classification and subdivision of various steels and their approximate heat treatment for industrial needs in a sufficiently broad manner to permit different opinions and authoritative views to be given their due recognition. It is not the purpose of this chapter to pass judgment on the firearms manufacturer, or to agree with any specific statements the steel-makers may make. Rather, our purpose is to accomplish the essential function of any educational text, namely, to present the law of safety limits in a gun barrel to the sportsman (who is not usually at fault when a gun barrel blows apart) in an interesting, nontechnical form.

In attempting to classify the various barrel steels used by the gun manufacturers, many complications arise, due to the large number of companies making firearms, not only in our own country but in Europe. This is true, even though one grade of steel is used for all calibers by the makers of firearms, as in the case of the U. S. Springfield Armory before the Garand automatic rifle was placed in production. However, it is believed that this chapter and the next one will clarify the subject for the sportsman and give the gun manufacturer material for thought.

It is not too much to say that the founders of the great arms companies of the United States, the names of which are now household words throughout the nation, were all amateurs at one time. In the days when those companies were formed, steels were just steels to them. When they purchased a piece of steel, they expected nothing more than a piece of chisel steel, tool steel, spring steel, machinery steel, and all of the poorest grades. But today more than a hundred different S. A. E. steels are listed. From these are selected about forty different numbers that are used in the automotive industry alone. Many of these are of the finest quality, and have given us certain standards according to which we may now select our steels for the making of the various component parts of our firearms. There is a reason for the selection of each kind listed in the *S. A. E. Hand Book*. Some steels give greater strength (as we have already proved) for actual weight, others will not corrode when exposed to the powder gases or to the elements. There are special alloy steels which, after they have been given the proper heat treatment, show no wear after long use.

In order to obtain the best in steels for the manufacture of firearms components, including gun barrels, or for that matter any of our industrial needs, the assistance of a metallurgist from one of our leading steel mills should be sought. Such men are willing to assist not only the sportsman who may have only a small experimental gun shop, but also the large industrial plant; for he will be able to assist both with the proper selection of steels and with the solution of all heat-treating problems; also to advise regarding all special requirements for individual parts, if practical.

Defective Gun Barrels—Unfortunately, I cannot help casting my memory back over the number of high-velocity gun barrels I have seen blown apart, and the shotgun barrels and actions which have been set before me split open from ahead of the chamber to the muzzle. Many of these accidents were due in part to the sportsman's carelessness; some of these guns which blew apart, however, had defects that were readily found in the metal itself.

Such blemishes existed in many gun barrels made

less than a century ago, and there must always be a few guns whose defects will never come to light until an obstruction is lodged in the bore, unknown to the shooter. Perfection can exist only in the imagination; and doubtless an exploding gun barrel either kills or seriously injures its owner. Yet a chemical analysis of the defective metal will prove that it had been considered safe: it contained the requisite amount of carbon, manganese, silicon, and not too much sulfur or phosphorus. But, just as



Fig. 3

The slag elongation in the direction of which Damascus, stub twist, wire twist, etc., were welded. This is the reason why so many of these barrels go "bad" when a heavily loaded cartridge is used

many a sportsman mingles for years with his associates, his character unrevealed, until suddenly he is found to be "bad," so this gun barrel is found to be bad inwardly and outwardly. The chemist had made a thorough chemical analysis of that particular heat of metal at the mill, and appeared to have fulfilled his duties faithfully. But place the bad barrel under a metallurgical microscope, and then the exact reason for its failure to perform its duty becomes as clear to the trained metallurgist (the man who studies the internal architecture of metals) as it does to the physician that the poison found in the stomach of a lifeless patient was the cause of his death.

Let us suppose that, after the barrel burst in the hands of the sportsman, we have removed from the breech a small specimen, and formed it into a $\frac{1}{2}$ -inch cube.

After cutting out our specimen with a hacksaw,

we finish-grind one side, and mount it in a piece of bakelite one inch in diameter by three-fourths of an inch in length, and then the ground surface is highly polished. The polishing operation consists of removing all grinding marks by the aid of various grades of fine emery paper, starting with grade number 1 and finishing with number 4/0. This last is a hand operation, and is followed by a buffing operation on a vertical metallurgical polishing machine, in which a very fine kitten's-ear buff is used charged with a very fine polishing compound. Of course, the side of the specimen that is polished is the side in which the steel bar has been drawn, and which would naturally be from breech to muzzle, i. e., lengthwise of the tube. We are now aware that the surface of the metal appears in its best clothes, so to speak, without a spot or a minute scratch to mar the mirror-like surface. It is like the ordinary target shooter whom we meet occasionally at Camp Perry—at times one can hardly recognize him. Shooting clothes have been removed and he is clean shaven and dressed in his best. This part of the barrel, in other words, is difficult to recognize without its external coat of blue.

Although a specimen of polished steel appears quite homogeneous to the unaided eye, microscopic examination of a polished surface which has been lightly etched with acid shows the internal structure to be complex. The study of the internal structure of metals, and the effect of such structure on the properties of metals, is the science of metallography. The use of the microscope is not the only means by which the structure of metals can be studied, but it has been one of the most effective.

Before the cube of barrel steel is ready to have its picture taken, it must be given an etch to make the structure visible under the microscope, in order that we may examine the nature of its internal design. As the old-fashioned commercial photographer so often suggested, we are asking it to "Look natural, please."

The treatment consists simply in subjecting our specimen to the action of a chemical compound which attacks the different components of the metal; in short, we are immersing the face of the specimen in a solution of nitric acid and alcohol for a few seconds, usually between eight and twelve seconds. This is known to the profession as the 5 per cent nital etch. The solution first attacks the junctions of the different crystals in the metal, and then the crystals themselves, coloring some brown or black, but leaving others white. The cube has now lost some of its polish, but the whole framework or structure lies plainly before us. To the sportsman or layman the polished surface of the

metal shows practically no change, though it is a little less brilliant, and a slight grayish appearance is visible to the unaided eye.

To elaborate further: The structures of steels are found to be closely related to their physical properties. The study of structure is, therefore, useful in determining the practical applications to which the steel may be subjected. Even when the relationship is not completely understood, satisfactory performance sometimes can be associated with *suitable* structures, and unsatisfactory performance with *unsuitable* structures.

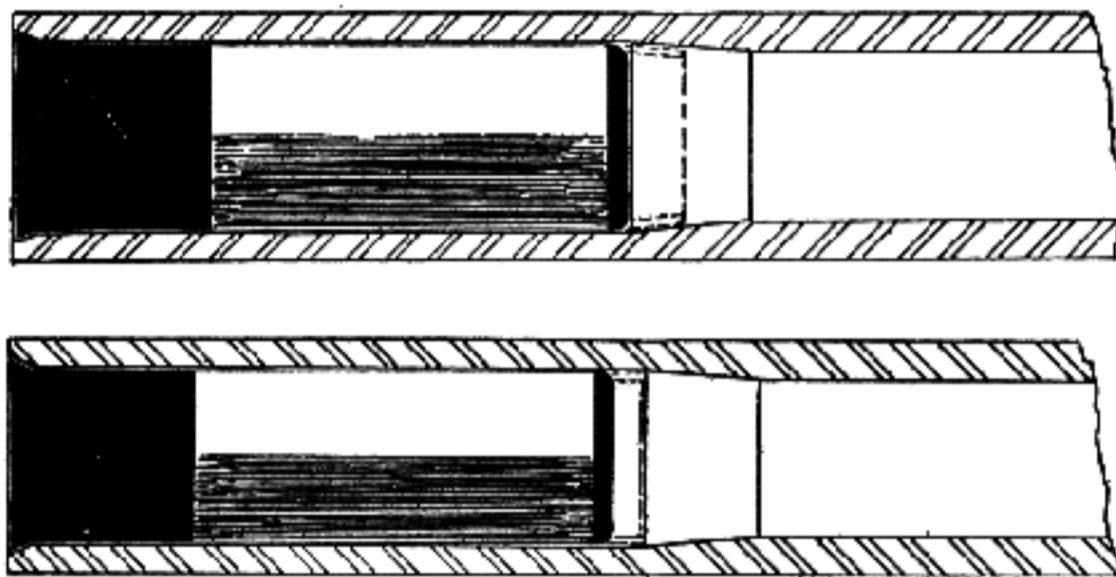


Fig. 4

Top—The position of a 2 $\frac{3}{4}$ -inch shotgun cartridge in a 2 $\frac{1}{2}$ -inch chamber. The dotted lines show the crimp as it opens out into the cone

Bottom—The correct position of a 2 $\frac{3}{4}$ -inch cartridge in its proper length of chamber. It is also the cause of many of the old guns' going "bad"

In order that we may detect the suitable and unsuitable structures of our barrel specimen, we must be aided by the microscope. Through a number of lenses and prisms from the objective to the binocular eyepiece, the metallurgist can look at this piece of barrel steel under a linear magnification of from fifty to three thousand diameters. This means that a spot measuring 0.010 of an inch across, and to be explored by the 100 \times objective piece in position, will appear one inch in diameter to the eye of the observer.

A picture can be now obtained, if desired, in the usual technique of photography by throwing the image of the structure upon a photographic film in a camera attached to the microscope.

Examining the photograph thus taken, we notice light and dark areas, the former pure iron or ferrite, the latter pearlite, named from its resemblance to mother-of-pearl when seen through the microscope for the first time. We shall not linger here with ferrite and the other technical names of steel's chemical composition, but shall leave them to the metallurgist, for they will be of no further use to the sportsman or gunsmith, except that they may create a desire to study the subject. Those who are

interested will find many books that will give them all this information.

We do not intend to convey the idea that all prevailing ills in gun barrels may be viewed through the microscope. Gun-barrel steels should be left to the metallurgist and his indispensable etching compounds, for today he is able to detect all the sins of barrel steels at the mill before they ever reach the gun manufacturer. Of course, he may not detect a few tenths of 1 per cent of sulfur or phosphorus which may make a barrel go bad. A seemingly small amount of sulfur will make a barrel steel brittle if worked hot, and phosphorus will cause it to fracture from a sudden shock, as in the case of an overloaded cartridge when the barrel is cold. These two, sulfur and phosphorus, are the two evils that the metallurgist attempts to keep down to a minimum at the steel mill if the steel is to be classed as "good" barrel steel.

Neither do we wish to convey the idea that all barrel steels are bad, nor that all fractured gun barrels are due to faulty bars of steel. Let us suppose, for the sake of illustration, that a bad bar of steel occasionally slips in among the good ones. That is the one to be dreaded, not only by the steel manufacturer, but by the maker of firearms. For after it has left the mills there is no possible way to distinguish this physically incompetent bar of metal or its source of weakness, and it may never be detected during the process of manufacturing the barrel. If the defective bar is not discovered by the barrel-maker, and is allowed to pass through all the sequence of operations to which a gun barrel is subjected, it will finally appear in the complete rifle or shotgun. Our modern inspection methods are so efficient, however, that such a bad piece of steel is seldom found in a high-velocity rifle; for rarely does one ever survive the final stages of its operations without being detected either by the inspector or by one of the machine operators. But there is still a million-to-one chance that a bad bar of barrel steel may never be detected.

Danger of Altered Barrels—A high-velocity gun barrel, after being properly heat-treated, should stand a pressure of 130,000 pounds, or 65 tons, to the square inch, before the yielding point is reached; whereas, the maximum established pressure of a high-velocity cartridge in the Model 1906 class is but 26 tons per square inch. This surely gives a good gun barrel a great margin of safety. But on the other hand, if the caliber .300 magnum cartridge is chambered in the U. S. Model 1917 Enfield rifle, meant for the caliber .30-06 cartridge, the change is very apt to make a bad gun barrel blow open, particularly if the metal should contain any small pipes,

segregations, or abnormal changes in the structure of the metal from the surface to the bore near the breech. Perhaps many such rifles have been changed over to use the more powerful cartridge? Those making such changes may not know that the steel produced at the end of the First World War was not so carefully selected as gun-barrel steels are today. Those who have changed such guns are creatures of infinite limitations, limited by their health and sex, and their incomplete education in handling firearms. Of course, to that class, a certain range of sentiment comes along with one of those guns, especially if it was bought in the days when it could be purchased for \$7.50. Now that the sale of all arms and ammunition has been discontinued by the D. C. M. (Director of Civilian Marksmanship), the sale of all military rifles should remain closed to those who must be continually changing calibers on this class of weapons; and those who already possess such made-over guns should be ready to reserve a room for an indefinite period in some hospital—or space in some cemetery.

Your guns, however, are not to remain in a state of inactivity because you may think them unsafe or inaccurate after glancing over this and other chapters. On the contrary, it is only necessary to recall the fact that the makers of firearms today eliminate all defective material by a thorough inspection in their laboratories, which proves that the mastery of gun-making is quite complete. Upon rare occasions, carelessness may enter into the making of a rifle barrel, causing it to be inaccurate, even as carelessness enters into the lives of those who use them. It is not enough to be acquainted with the facts as stated, for gun knowledge only begins when the character and behavior of metals are known to the sportsman. The sportsman should also know that all steels selected for gun barrels must be given the proper heat treatment, not only at the mills where they are made, but also after the barrel has been forged and straightened; for it is then again scientifically heat-treated for the proper hardness and machinability, so that, when completed, it shall have strength where needed.

Requirements of Good Steel—It now remains for us to direct our attention to the fact that, among all thoughtful and experienced gunmakers of the past half century in the United States as well as in Europe, no phase of firearm construction has been the subject of more forethought than the producing of accurate rifle barrels. Gun barrels have been made as inclination dictated, often from the free-cutting steels which were used in the black powder days, and at the present date upon cheaply made caliber .22 boys' rifles. They have been made of

every known chemical composition in which $3\frac{1}{2}$ per cent of tungsten was part of the content, alloys of which have played the major part since the First World War with a view to securing a tough steel for the service of the sportsman. But this fact should never be forgotten: That while regular shotgun, rifle and revolver steels will bear strains of more than 50 per cent against excessive loads in a cartridge case, they will expand and blow apart whenever a slight obstruction has been accidentally left in the bore. Whenever a gun barrel is severely strained by the effects of an obstruction, if not blown apart, it loses that degree of safety, for the molecular structure of the metal has been changed and so injured that the final bursting of the barrel is but a matter of time. This is especially true of a gun barrel in the high-velocity class. Whenever a shotgun has been found to be badly strained in the breech action, or bulged in the barrels, the whole gun should be destroyed in justice to those who may incidentally use it.

The requirements of a good barrel steel today, whether used upon a rifle, shotgun or target revolver, call for special physical properties, namely, tensile strength, yielding point, elongation, reduction of area, and the necessary hardness governed by the machinability of the metal. For the hardness inspection, either Brinell or Rockwell standards are accepted; but we prefer the Rockwell instrument to take our hardness tests upon steel specimens, mainly because of its simplicity and the direct hardness readings upon a dial.

To secure all these qualities in a gun barrel, it is necessary to select our steel from the list of the S. A. E. (Society of Automotive Engineers) standards, specifying electric furnace steel of airplane quality. This may serve to account for the fact that T-1350 would be the most logical material for the gun-barrel experimenter. It is manufactured by the Timken Roller Bearing Company, Canton, Ohio, and possesses all the desirable qualities in the physical charts, being a steel capable of taking a very fine interior finish, provided perfect cutting reamers are used. When desiring to use a nickel steel, we would naturally select 2350; or if not satisfied with a nickel content, we would select 3150, which is a steel of a nickel-chromium content; if a molybdenum content is desired, we select 4150, which will withstand shock and fatigue, but is a hard steel to work; that is, it is not a steel to remain stable after being heat-treated, nor, at times, can a good finish be secured on the surface of the bore. It does not always remain stable when slightly heated; that is, the structure of the metal will not remain set when a barrel has been fired a number of times, particularly if the barrel is of light construction, as I have ex-

perienced. I have very good grounds for believing that a number of such bars of steel as I have named are ordered from time to time by gun hobbyists who have small shops; if I am correct, they must specify that the bars thus ordered shall be heat-treated at the mill at a hardness of 28-32 Rockwell "C" scale.

In the manufacture of automatic guns, such as shotguns and rifles, one of the most important con-

siderations is the selection of the proper grade of steel to permit the weight of the breech mechanism to be of light construction and at the same time assure adequate strength and wear-resistance for dependable performance. In addition, the steels selected must respond readily to machining methods and heat treatment; and good impact and fatigue strength are essential to withstand recoil from modern high-velocity loads. One great reason why we select 2350, a 3½ per cent nickel steel, for such types of weapons, is that the high physical properties of such an alloy steel are extremely useful in the making of such guns.

There is hardly a steel used today, where strength and fatigue are the main issue, that is not an alloy steel. Common cast iron alone is too soft for any firearm construction. Carbon and manganese are the chief chemical elements for most rifle barrels (as we have already pointed out), but too great a percentage of carbon makes steel too brittle, whereas, too great a percentage of manganese makes it too hard to work. But with a slight addition of manganese over the standard practise, so that the chemical composition would read: Carbon range 0.45-0.55 per cent, manganese range 1.00-1.20 per cent, nickel range 1.25-1.75 per cent, the steel would be toughened remarkably for rifle barrels. The use of such a nickel-manganese steel in the making of special rifle barrels will mark the beginning of a new era of better accuracy, and of bullet stability over long ranges for target shooters.



Fig. 5

Free ferrite or sulphide of manganese, which is often found in all types of steel. It is hard to secure a desirable internal finish when this is in evidence

Gun-Barrel Stresses and Strains, and Their Treatment

PHYSICIANS are constantly warning us to control our diet, regulate our habits, have our teeth thoroughly examined three times a year, and consult them immediately when certain symptoms of serious illness are observed. Being human, we eagerly confess our loyalty to these warnings on our sick bed, and just as quickly condemn them as silly when our recovery is complete. Too frequently we struggle along, knowing we are not 99 9/10 per cent perfect, but do nothing about it until the doctor reaches our bedside, then go into a cold sweat when he whispers to the family: "Operation," "Hospital," "Stop worrying," "Be brave."

Regrettable though it may be, the same human frailty extends itself into the sportsman's and target shooter's activities upon the range. There it is referred to in theory as: unbalanced bullets, unequal powder charges, too great a headspace, unequal pressure of wood against the barrel, uneven bullet-jacket metal, variable winds, and a world of other faults mentioned in sporting magazines. Regardless of the number of theories expressed or the fact that they relate to gun barrels instead of the human body, they are all manifestations of the same human weakness. How often, in the firing trials of new guns, do the symptoms of coming or apparent "illness" go unnoticed or ignored in the hope that the barrel will settle down and "adjust itself"!

The first tangible indication of inaccuracy in a new rifle barrel often is its failure to keep target groups centered, yet careful observation may have indicated poor accuracy before groups really began to change. So in the outline of a gun barrel's accuracy problem it is well to start with the discussion of "stresses and strains" and from there lead to the manifestations which, if recognized, will often indicate the logical treatment of the steel's molecular structure to prevent any further poor shooting results. The metallurgist, like the physician, must have the knowledge which will constantly warn his patrons of the meaning of their symptoms. If a new rifle shoots poor groups, it does not mean "expected trouble"—the trouble already exists.

Normally, a study of the problems of stresses and strains in a gun barrel is conducted by considering, first, the cause of the barrel's failure to shoot good groups; second, the effects of such cause upon the

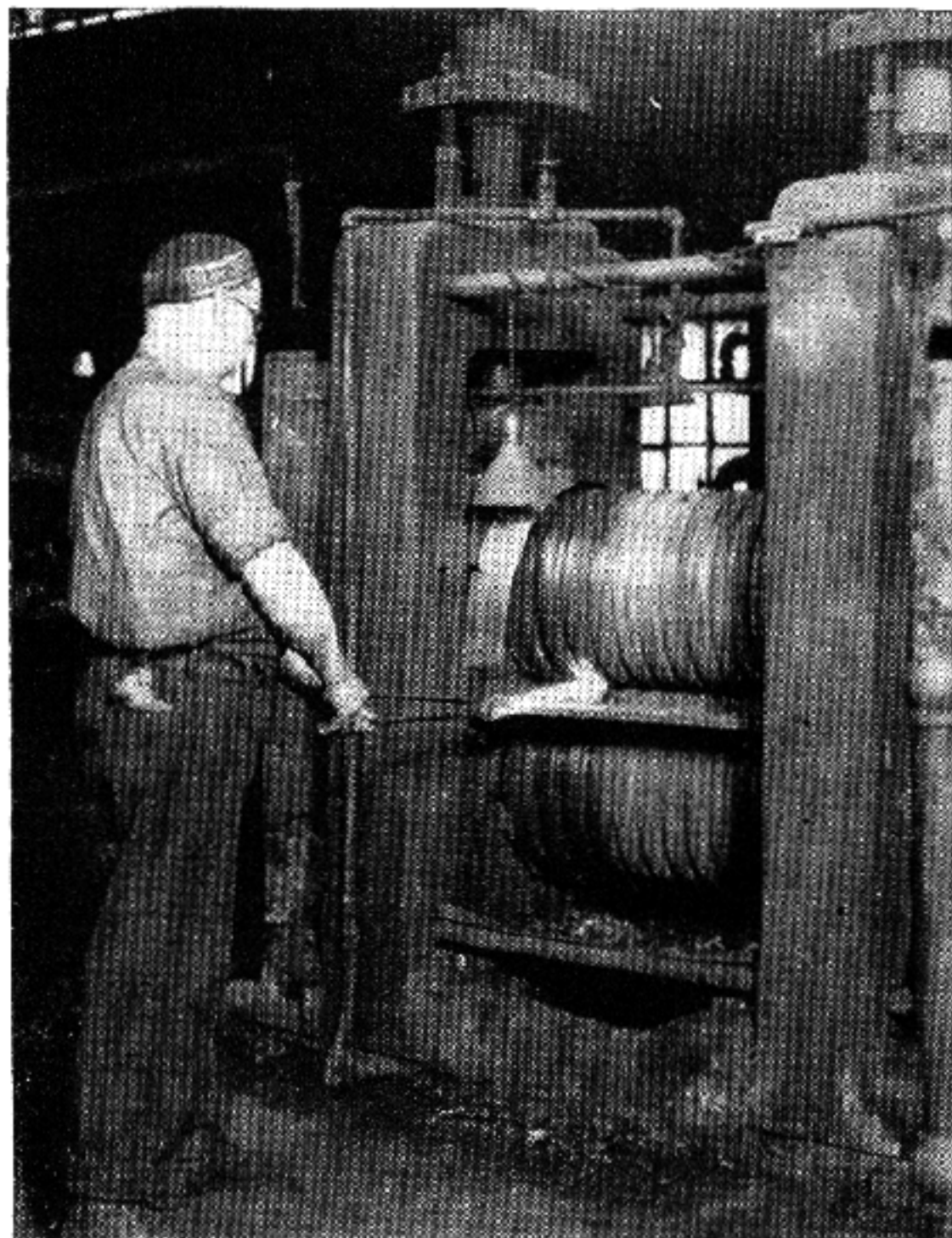
shooter; and third, the results or the actual failure to secure good groups. However, it is believed that this chapter will have more practical value if this study is conducted in the reverse order; so we will begin by considering the "results" or the failure of the barrel to remain stable.

Why Gun Barrels Fail—Everyone interested in shooting, and in guns in general, is probably familiar with the fact that powder gases are converted into instantaneous energy when confined in the chamber of a gun barrel, after being created by a simple ignition agent—the primer. A cartridge is introduced into a chamber, an explosion occurs, a bullet is forced along its path, and velocity is transposed from a projectile at rest through a cylindrical engraved surface—the bore. This is an old familiar story, but the sequence of these actions in relation to each other may well bear further investigation, for it is upon this sequence that the first important variations of barrel accuracy hinge. A clear understanding of these conditions is essential if the shooter is to meet and overcome inaccuracy problems involved in shooting at targets over long ranges, even though heavy barrels are used.

Too frequently the barrel-maker is called in after inaccuracy occurs, and is asked to diagnose the case and point out the true cause of the difficulty. If he is inclined to be truthful, he can give an accurate account of the conditions surrounding the barrel's failure, together with a complete survey of the heat-treating conditions under which the steel had been handled. This should enable him at least to establish a starting point in the "circle of circumstances" in which the barrel's failure began.

This "circle of circumstances" prevails in the heat-treating department of the forge shop and, as the name indicates, is endless. It has its beginning, however, in the manner in which the barrel is forged, straightened and heat-treated. The problem of subjecting the barrel blank or forging to the proper heat and stress-relief treatments is one of major importance. This burdensome task must fall largely upon the department which heat-treats the barrels and other parts, both before and after the sequence of operations.

Forging and Heat-Treating a Barrel—It is highly desirable that we pause here to get a better understanding of the methods used in forging and heat-treating a rifle barrel, as seen in the forge shop of the Springfield Armory when at work on the Model 1906 barrel.



Courtesy Remington Arms Company

Fig. 6

The standard practise in all arms plants of forming a gun-barrel forging rolled from the hot bar of steel

A blank is first cut off a bar of W. D. 1350 steel. This blank, approximately 2 inches in diameter and nearly 10 inches in length, is heated in a furnace at forging heat. While hot it is passed through a rolling mill in which the two rolls carry a series of grooves or depressions cut in the upper and lower rolls, of which two are cylindrical and the balance tapered to conform to the contour of the finished barrel. This operation consists of passing the hot blank from one form to another until it is gradually lengthened out and emerges from the last depression of the rolls in the form of a rough gun-barrel forging, with sufficient material left on the outer surface for the turning and grinding operations. After being rough-straightened under a drop-hammer, the forgings are normalized at a temperature between 1600 and 1650 degrees F. in a furnace for a period of three quarters of an hour. They are then allowed to cool in free air.

Following the normalizing heat treatment, which places the structure of the metal in the best condition for the machining operations, it is heated between 1500 and 1550 degrees F. for one hour and quenched in oil, which gives the metal a hardness between 50 and 54, Rockwell "C" scale; removed from the oil, it is then tempered to the required machining hardness and tensile strength, at a temperature between 1060 and 1100 degrees F. by leaving it in the furnace for three hours or longer, in order that the proper hardness shall be even in the light and heavy sections.

To the inexperienced the forging or barrel blank appears exactly suitable to attach to the receiver when finished, but the metallurgist may detect some very unusual conditions in the structure of the

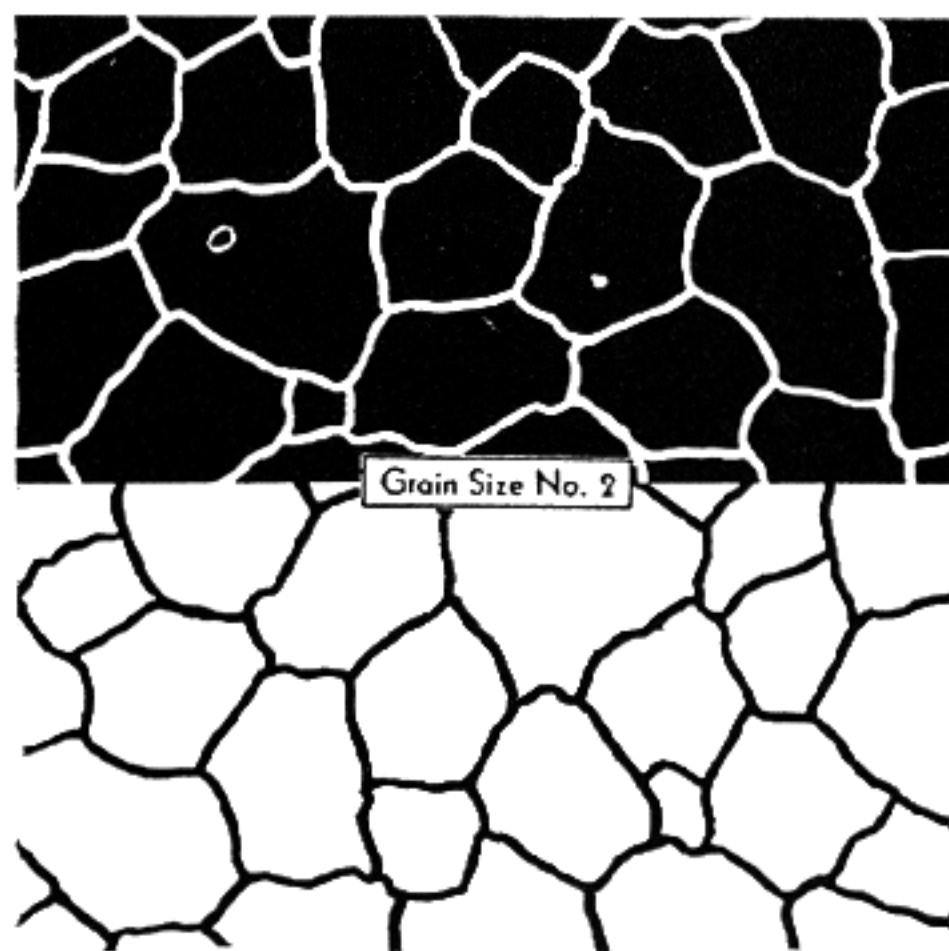


Fig. 7

Grain size Number 2

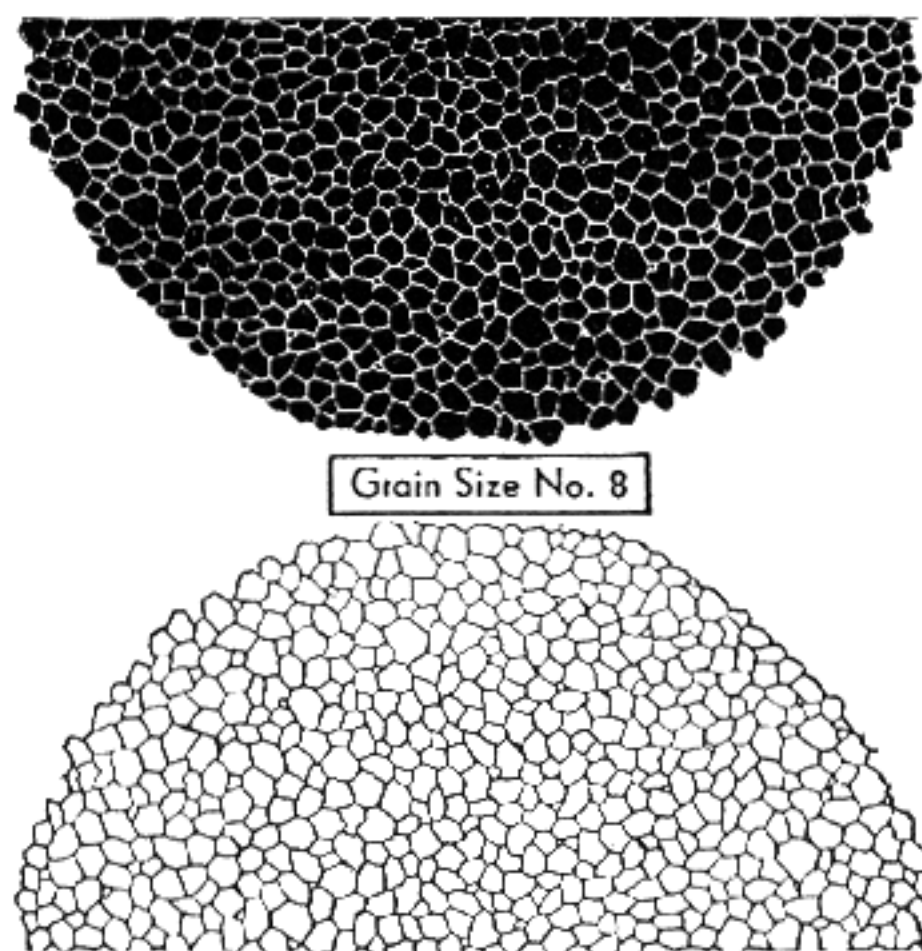


Fig. 8

Grain size Number 8

metal. He may find that the rolling operation was done at either too low or too high a temperature, causing the grain sizes to be much too large; and he may discover that the normalizing treatment did not correct this fault, for grain size number 2 appeared instead of size number 7 or 8. (Figures 7 and 8 illustrate this difference.) Experience has proved to the metallurgist that large grain sizes tend to absorb neighboring atoms into the structure. If a barrel were composed entirely of grains of the same size and arrangement, and of the finer sizes, all unstrained, then all the grains would possess equal vibrating tendencies and no changes of groups from such a barrel would occur. Therefore, the finest grain size and arrangement of the crystals should be in evidence, giving the metal toughness and strength in order that it may be able to yield at will during the passage of the bullet through the bore, and settle more quickly to a set position after each shot is fired, even though the heat of the powder gases and the friction of the bullet in its passage are the most illustrated factors controlling accuracy.

Stress-Relief Treatment—The mere effect of perspective observation is a powerful cause of illusion. It is better now to carry the romantic vision of the operations in the forge shop away with us, than to follow the barrels to the cold straightening operation. We cannot resist the temptation to suggest that barrel forgings should be straightened hot under a drop-hammer after coming off the rolls as nearly straight as possible, so that the straightening

operation in a cold state may be eliminated; for if straightened cold, stresses and strains of the worst kind are likely to develop, and these are difficult to remove even by a stress-relief treatment. Such stresses will remain in the finished barrel for a long time, unless it is artificially seasoned by its owner.



Fig. 10
The microstructure of overheated steel

Discouraging as it may seem, there are times when a shop has a run of bad barrels; they "crop up," and the defects are not discovered until the cold straightening of the forgings takes place. Those bent in the center are straightened in a special press in which a ram operated by air is used to remove the kink or bend, as the forging rests upon two V blocks. Should a number of such barrels require this undesired operation, it is natural to believe that they will continually change their center of groups when finished into completed guns. Strange as it may seem, these forgings are not now given a stress-relief treatment, though it would certainly seem desirable to do everything possible to remove the stresses and strains formed in the metal by this straightening operation, so that the steel would remain in nearly a certain set position regardless of the number of shots fired from the barrel.

A new gun, regardless of its kind or caliber, is often disappointing. All that we can reasonably expect is fair results, for the steel in all new barrels has a natural grain growth or tendency to grow larger and move in various directions, due in part to not being properly stress-relieved at the factory. Extensive experiments on this subject were made on the type-II Cummins injector bodies—length $5\frac{1}{8}$ inches, and made from T-1350 steel without a stress-relief treatment—to secure a fair estimate of

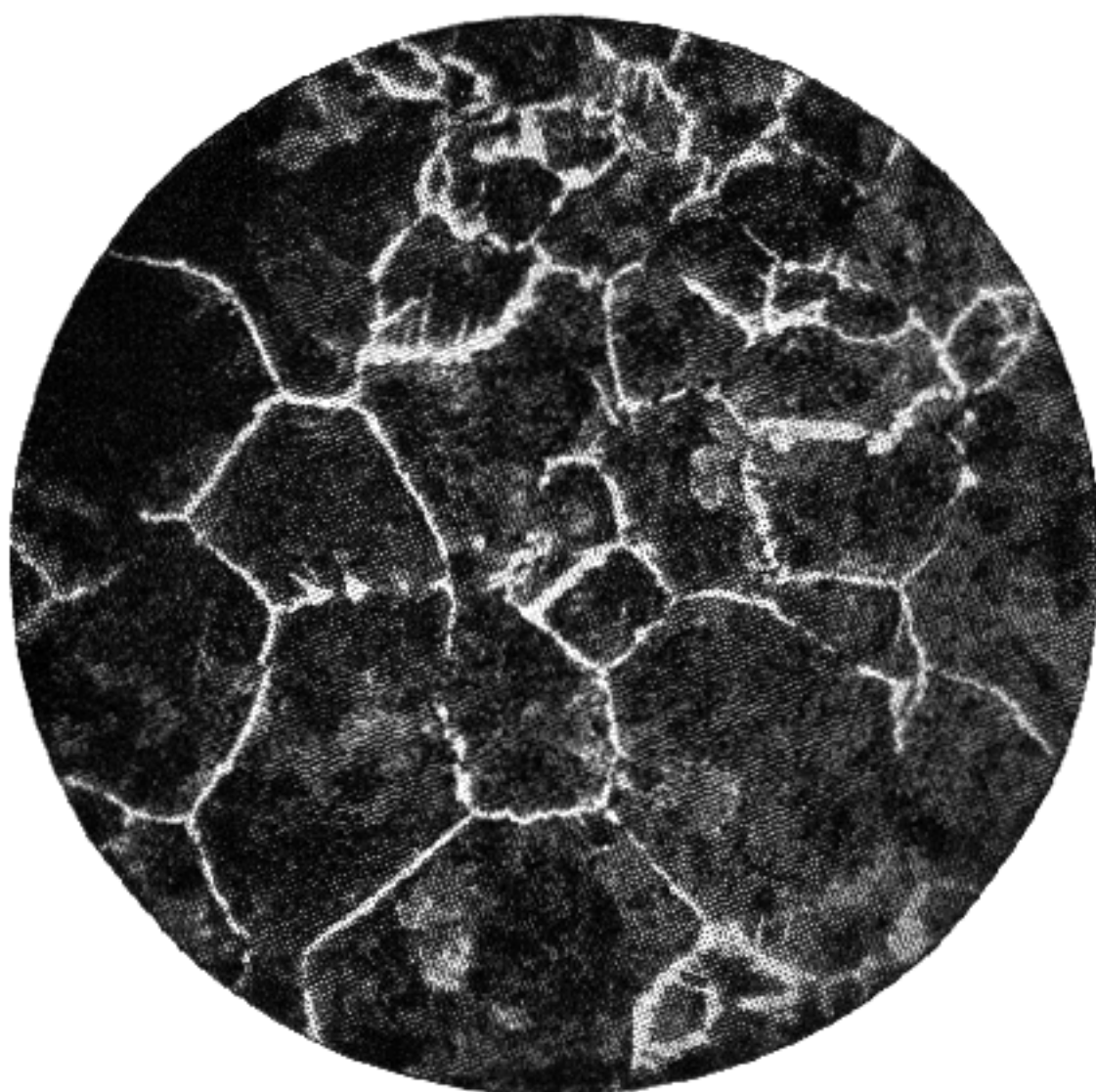


Fig. 9
Discovering the coarse microstructure in steel

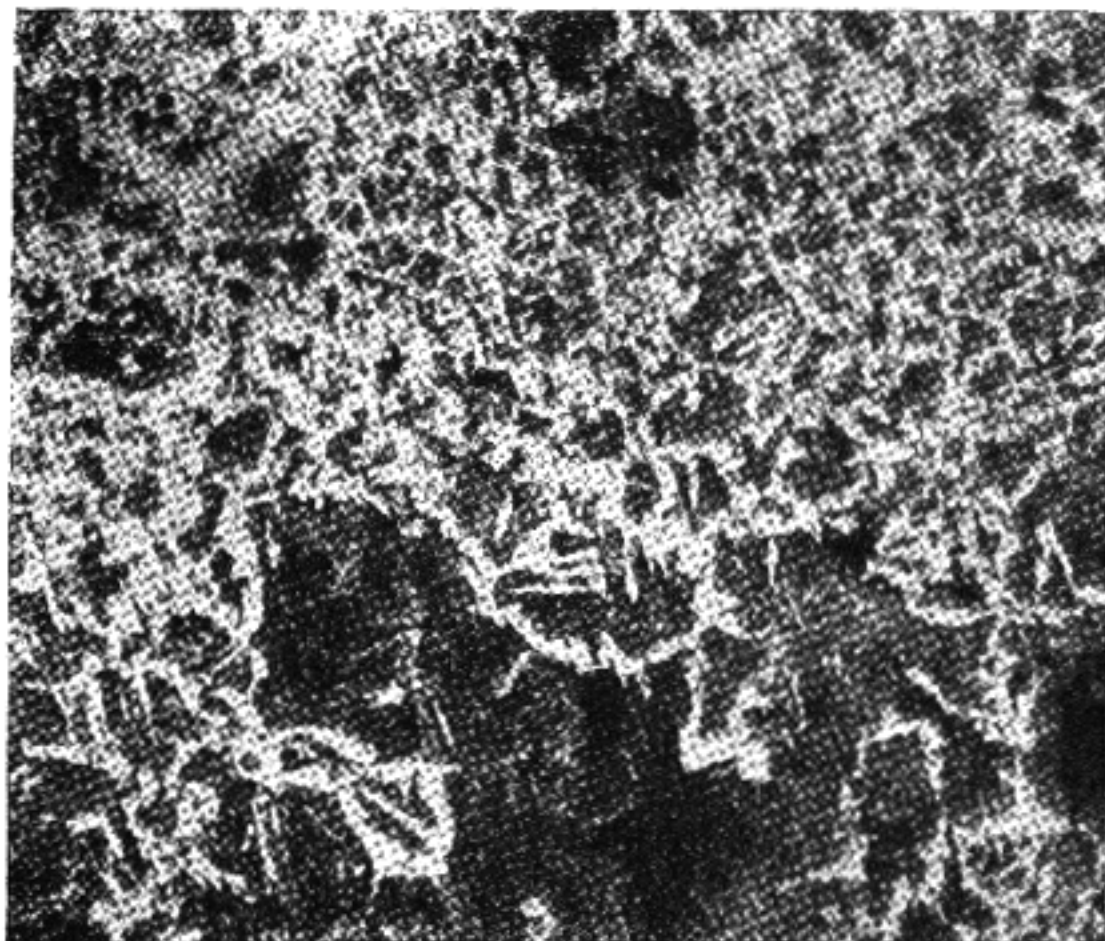


Fig. 11

The microstructure of steel showing incomplete heat treatment

the structural changes taking place in the metal.

The first course of these experiments required three weeks to find three near-perfect injector bodies out of 600 produced in that period of time, injectors in which the holes were without a blemish, and were straight, with gauges that were perfect according to a set standard. The holes in the three bodies measured 0.37520 inch, and were fitted with perfectly lapped plungers which measured 0.37500 inch; this allowed a tolerance of 0.00020 inch between body and plunger, and allowed them to drop through the hole in the body by their own weight at room temperature. The three bodies and plungers were placed at nine o'clock in the morning of December 5 in a holder which held both bodies and plungers in a vertical position in a room heated to 72 degrees F. during the day. At 4 P.M. of the same day, one of the bodies proved to have developed a kink which did not allow the plunger to slip freely through the bore without the aid of a $\frac{7}{8}$ -inch steel ball placed in the radius on top of the plunger. This body was marked number 1. On the morning of December 6, the second body, and also the third, now possessed bad kinks, which would not allow the plunger to slip through the bore without the aid of various-sized balls, some as large as $1\frac{1}{2}$ inches; whereas, those two bodies had been perfect in the afternoon of the 5th. It may be mentioned that all three bodies varied in hole straightness over a thirty-day period; and to our surprise, body number 1 came back to its original straightness, while the other two continued in a warped condition. And the warp proved, from various experiments made, to be always in a spiral direction; that is, the indications of the warp were influenced to move in a spiral direction, proving

that stresses and strains in steel are released in a spiral, and remain in that form even when time alone does the seasoning, whether in a gun barrel or in a highly finished hole in an injector body used on a diesel engine.

To obtain the proper results in an experiment of this nature, of course, the room temperature should be held to within two degrees above or below 70 degrees Fahrenheit during the whole twenty-four hours. Even though the experiments were conducted during the cold of early December, and a wide range of temperature existed, the fact is that they were carried out under about the exact conditions which a rifle would encounter in the hands of its owner. The tests also proved that there existed too wide a range of grain size of the crystals under the microscope; the grains were rubbing against each other in the entire length of the bodies, never allowing the atoms to come to rest. In order that the atoms may come to rest, the steel must be given a stress-relief treatment at a temperature between 200 and 400 degrees below the tempering treatment.

Other special tests which we carried out at the Springfield Armory proved that it required a pressure of 1100 pounds to the square inch to force a minimum bullet through a maximum barrel (tests upon Model 1906 barrels); whereas, it required a pressure of over one ton (2000 lbs.) to force a maximum bullet through a minimum barrel.

It is always a mistake to think that the barrel is a rigid body incapable of bending; it is very sensitive to stress movements—to the pressure of the explosion, the pressure of the bullet as it is driven along the surface of the bore, and the unequal outside pressure of the stock and the clamps that hold the stock to the barrel. To prove this, clamp your action and barrel in a milling-machine vise, or in a vise upon a solid bench, allowing the barrel to swing free in space, and then gently tap the muzzle with your fingernail. The muzzle vibrates like a tuning fork! You may not believe it, but the barrel will bend perceptibly under pressure which can be put on it by the fingernail. It is like any other metallic rod or tube. A gun barrel vibrates even when struck by the finger, but owing to its tapered sectional area, it does not have the same vibrations that are found in a straight metallic rod. When the seasoning treatment takes place (we shall come to that a little later), it is these vibrations that we are trying to control by a simple elementary treatment. The object is to allow the metal crystals, in their relations to each other, to be lubricated, so to speak, in order that they shall always return to their original positions.

From such a simple experiment it can readily be

seen that the shock of the explosion sets up all these vibrations much more forcibly than the fingernail. The whole barrel vibrates, most violently at the muzzle, less so at points near the breech, while the latter remains still, for it is the point where it is fixed—the receiver. The frequency of the essential vibrations depends on the design of the barrel and the metal allowed along its entire length of taper, for the fixed ratio of the vibrations is governed by the taper design. In all good barrels we find that the vibrations are evenly distributed along the entire taper, and the friction of the bullet does not exert such an influence.

Of course, the bullet, when shot in any high-velocity barrel, fits the bore tightly, makes a perfect seal between bore and bullet, and in doing so creates a high degree of friction during its passage. If there is any increase in the amount of force required to urge the bullet through the bore, the increased friction will naturally affect the metal, causing it to yield to a certain degree along the entire length of the bore before the bullet ever reaches the muzzle; for the vibrations travel much faster than the bullet. These vibrations, reaching the muzzle ahead of the projectile, naturally cause the target groups to vary in relation to the distance shot. In other words, the barrel's vibrations are a reflection of a controlling factor, and not a prevalent error.

If we follow a barrel after it has left the Pratt and Whitney gun-barrel drilling machine, we can readily see that unless it receives the proper stress-relief treatment all the strains in the metal will remain active and become greater as the rest of the operations are performed. It is important to bear in mind that the more the barrel is handled in the machining operations, the worse the strains will become. The removal of metal by the reamers, the engraving of the surface of the bore, the turning and grinding operations, all tend to release stresses and strains from the center of the bore to the outer diameter, causing kinks and bends to run in a spiral direction between bore and outer surface of taper; and all this tends to give a false impression between the fit of the bullet and the established tolerance in the bore. Whenever an extremely good barrel has been found—a barrel in which a 0.0002-inch tolerance has been established between the gauge and bore, and from breech to muzzle, without kink or bend, a hole in which a plug gauge five inches in length will slip through perfectly without binding along its passage—whenever such a barrel is found, you may be sure that it has been stress-relieved by the proper degree of heat in a furnace.

Seasoning a Gun Barrel—In a gun shot over a long period of time, the metal becomes seasoned

by the expansion caused by the maximum bullets shot through the bore. The ever-present stresses and strains in the molecular structure of the metal have come to rest, and an artificial stress-relief treatment at this stage is, of course, too late to be given any consideration. Experience has convinced us that rifles and shotguns, if kept in use, become seasoned by time alone. Like good whisky, they improve with age; a rifle barrel improves with shooting—if it has proper care at the hands of its owner. A gun barrel will not really settle down to perform good shooting until a number of boxes of ammunition have been shot through the bore; and in many cases, the stresses and strains which were first detected in the metal will then have come to rest. But an artificial method should, in many instances, be employed to season a new rifle barrel if it is to be used on the target range. If a new barrel does have a tendency to be continually changing its center of groups, a "seasoning" treatment should be employed.

Every one who is acquainted with firing a high-velocity gun slowly, that is, three or four shots per minute, knows that the barrel can then be handled without fear of burning one's hand; but if fired as many as twenty shots per minute, it will blister



Fig. 12

A cleaning tube with funnel is an aid in the seasoning treatment

one's fingers, and above that number the barrel becomes very hot. One hundred rounds of high-velocity ammunition can be fired without any more injury to the barrel than a slight discoloration of the finish. To heat a barrel for the "seasoning" treatment by the use of ammunition, therefore, would be rather expensive; and it would be almost impossible to secure the correct temperature in a caliber .22 barrel to season it by this method. A more logical method is to use an electric furnace or a gas range, in which it is possible to encircle the whole barrel and regulate the temperature between 325 and 375 degrees F. Of course, whatever means are employed to heat the barrel, the rifle must be stripped of all its parts, and only the barrel and action left intact.

The only rational way of treating a barrel is to heat it, and we shall assume that the barrel has been subjected to the required degree of heat, either by some artificial process, or just by firing a number of shots through the bore to secure a barrel so

hot that the hand cannot touch it without fear of badly burning the flesh. If the latter method is used, the bolt must be removed, then water poured through the bore with the aid of a rubber hose containing a cartridge in which the end is drilled, and a piece of tubing soldered therein, long enough to clear the end of the action, or with the aid of a cleaning tube and funnel. Start the water through the bore very slowly at first, continuing until steam no longer forms, then allow the water to flow more rapidly until the outer surface of the barrel is really cold. In some cases it will be found necessary to apply this treatment as many as ten times in order to secure the results desired; but as a rule, three or four such treatments will produce unexpected results.

There is little to be gained by employing this seasoning process upon defective gun barrels, those made from bad pieces of steel, or those which have been straightened often during the sequence of operations. Neither do we recommend a seasoning treatment for an old barrel, or for a shotgun or a revolver; for in such weapons the human element enters into the picture too strongly. A shotgun must be considered as a "scatter gun," and to pour cold water through the bore would only remove the powder residue; for the slightest amount of set, if it could ever be measured, could never be noticed in terms of accuracy. As for a target revolver, even though it were placed upon the finest machine rest,

and extensive firing trials were made and the results analyzed, there would be no results worth recording.

The habit of looking through rifle barrels has caused many sportsmen to find imaginary things, one of these being the straightness of the bore. The sportsman, by using his imagination, has never yet been able to discover a crooked or bent barrel, that is, a badly kinked one. Such barrels may outshoot the straightest barrel ever made. It is not, as many suppose, the crooked or kinked barrel which causes the most trouble: it is the one possessing unsettled strains in the metal; the unseen factors which are too great for the average person's comprehension, but often come to light after a few shots are fired by those possessing technical knowledge.

There are, of course, some unavoidable manufacturing conditions existing in all plants where firearms are made, and some defective gun barrels are bound to be found by those who are very alert—the best of target shooters. Were this condition to occur frequently, the manufacturer's final loss would be greater than his profit. But manufacturers are bound by necessity to inspect all guns made, and to make them capable of good shooting. If a new gun is only worth what can be shot with it, it is equally worth only the expense of energy to place it in the best of shooting condition, and a seasoning treatment will naturally earn that for any new target rifle.

Producing Finishes and Surfaces

LIVING with guns represents love for an art and a pleasure of a very high order. Every sportsman who purchases a firearm of any kind satisfies this desire by living, as we may say, in his own small world, for in mind he is often completely absorbed in antique arms of the past, or in gun design and progress of the present, thus developing a certain insight into an art which would require a lifetime for others who are lacking in this interest or even incapable of analyzing what he has gained in wealth—contentment of mind.

To a gun lover, one single hour among his guns at the end of the day is worth more than an entire day spent at golf, in business, a trade, or a profession. Looking for the secret of this curious interest and source of pleasure, we find that what this man really enjoys is the excitement produced by examining the finishes and surfaces of old and new guns, and by testing his imagination upon the methods used by men who made such works of art, yesterday and today.

It may be that the sportsman of gun lore is nothing more than the helpless victim of an irrepressible appetite, a person for whom intellectual gun intoxication begins as a pleasure and later becomes the compelling force necessary to make his whole life complete. Some may wonder why any rational person, finding himself sinking into such a regrettable condition in early life, did not receive some severe discipline, verging on the patriarchal or autocratic type, which would have compelled him to concentrate on the better things in life—automatically excluding guns. But, whether it be guns or fishing rods, those things which are capable of bringing him to the outdoors are the things which arouse such a young man's interest, quicken his enthusiasm, raise his energies above the dead level of mere animal existence—and help to make him a sane and intelligent man.

As no man can put new wine into old bottles, so no one can hope to put different beliefs into young men who are unable to enjoy life without firearms. That, at any rate, is what the study of the dyed-in-the-wool gun-minded enthusiast has taught us. If we have misinterpreted the recorded lives of sportsmen throughout the centuries, we have not done so with wilful intention.

Charm of a Beautiful Finish—Should finely designed and constructed sporting firearms be ranked among the world's art objects—things of beauty created by skilful craftsmen? Certainly they are objects of finished craftsmanship created with individuality and distinction. It should not be very difficult to give credit and honor to the gun-makers who so cunningly conceived and admirably completed the finishes on finely made guns, thus meeting the critical demands of those who select them.

Who can disregard the powerful personal element entering into the execution of the examples of beautiful gunmaking from the present day down to more than a century ago? Who can resist the attributes of elegance, the outstanding external finishes applied by hand work to steel and wood, which are revealed in such guns, and illustrative of the critical selection for those of our era? To the sportsman who may be a lover of choice guns, all such weapons speak with a strange, magical, and bewitching tongue. In all of them he recognizes the expression of genius, the creations of master gunsmiths, whether they be rifles or shotguns, or the accessories found in the leather cases which are so vital to the complete service of such weapons in the field. In such leather cases, whether old or new, the sportsman of appreciation sees the results of much forethought in designing proper cleaning equipment, and for the older arms the necessary loading tools; there, too, he sees the gun's form: the contour of the action, the sights, everything is there in finished outline, for the wood in the stock and forearm does carry rich pigments, beautiful streaks of brown and black, of twisted ripples seen only in gun-stock woods grown either in southern France or Italy, and finished by nature. Today, as yesterday, the growers of walnut trees in southern Europe cultivate their trees for gun stocks, obtaining the ripples or wavy form of "coon-tail effect" by wrapping chains around the trunks and allowing these to remain until the growth of the tree has embedded them to a certain depth, only to remove them and relocate them again between the old indentations to make the finishes complete when formed into a gun stock. After such trees are cut, seasoned and sawed out for stocks, the spiral-like streaks are to be found close together, and inter-

mingled with colors which can be finished only by nature's handiwork. The chains are the instrumental means of enhancing nature's finishes in order to please the senses of the critical lover of firearms.

We ought, nevertheless, if we desire to think accurately, to know that there are two separate senses in a sportsman, the first of which detects a thing finished, and the second detects it well finished, internally and externally. The first refers to the mere neatness and completeness of actual hand labor, as we speak of a well-finished gun, or the optics in a telescope; and the second is a sense which refers to the effect produced by the thing shown; thus we may call a high-priced British shotgun well-finished in all details, whether on the interior or exterior surfaces, because it produces the effect of reality on the mind of the observer.

The way we all really act with regard to the sensations produced by the appearance of finishes is this: A high polish on any of the essential working parts of a firearm, including the interior surface of the barrels, does not necessarily mean that all parts contain a good surface finish. Nor does it mean strength of surface similar to the much-abused expression, "mirror-like polish," a surface which one will judge very quickly by observation, for with the aid of the microscope one reviews all the marks of the workman's ingenious methods of securing a deceiving polished surface. Nor does it mean the usual lapped finish, that which we often see upon the interior surface of finely made shotgun barrels. A finished surface to any part of a firearm should mean that dull-appearing surface which will take a natural polish; for a surface which is not completely free of deep scratches and any tool's harmful effects to cause surface fractures will reflect light, and this in turn produces the effect of deceiv-

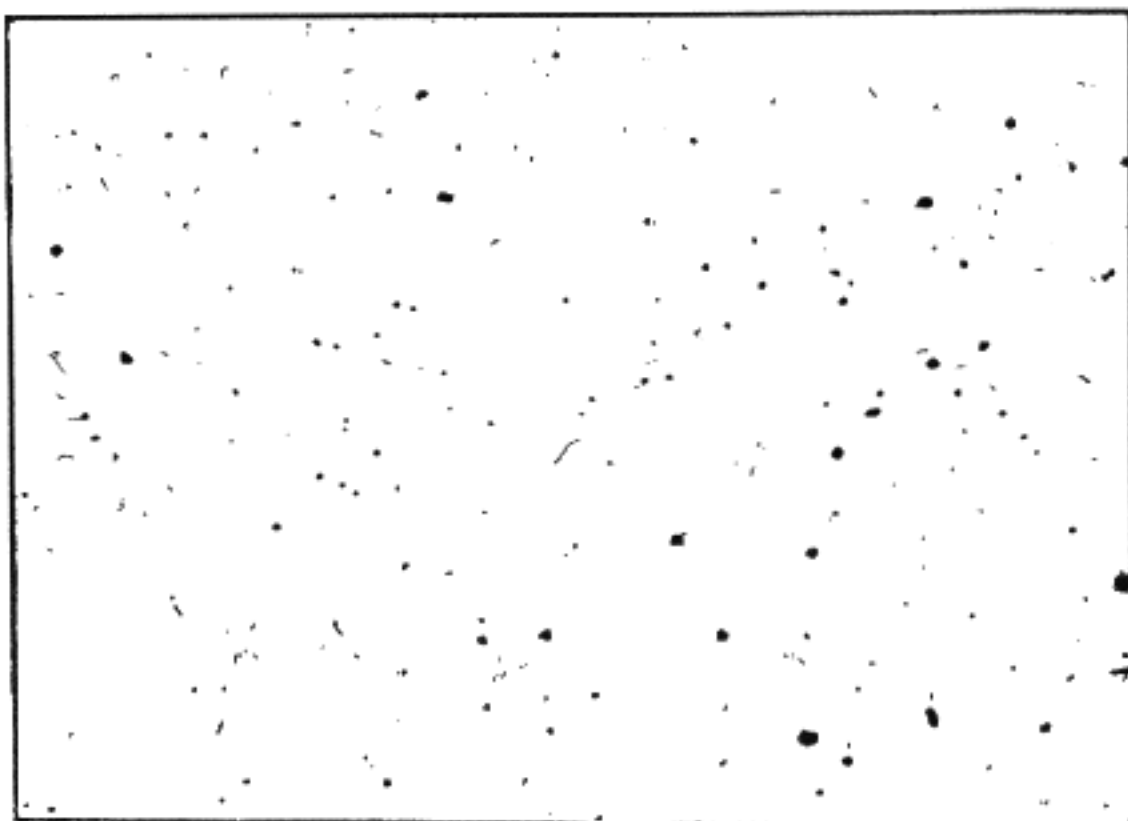


Fig. 13

A perfectly finished surface without a scratch in evidence: 100 X, unetched

ing reality upon the observer, for such a surface can never be made into a "mirror-like polish." When a surface is viewed under the microscope, it should appear flat without any exaggerated superficial traces of "hills or hollows" such as are made by abrasive materials. Figure 13 shows a perfectly finished surface as seen under the microscope, without a scratch or a fracture. The small specks which the eye discovers are nonmetallic inclusions, but so minute in size that the metal is considered the best and of airplane quality.

Discovery of the Spiral-Fluted Reamer—Metallurgists, with the aid of their microscopes, have a great advantage over the toolmaker with his small magnifying glass to detect the faults of reamers, particularly straight-fluted reamers used for the purpose of reaming gun barrels. A common vice



Fig. 14

The spiral fluted reamers of $\frac{3}{8}$ and $\frac{1}{2}$ inch diameters

of straight-fluted reamers is the false impression they leave on the surface of the hole they ream, but the worst vice of all is their tendency to fracture the surface of the metal they ream to a depth between 0.003 and 0.007 inch; when such parts are hardened, there will appear, in many cases, surface ruptures and seasoning cracks.

After this had been discovered, experimental developments were started on a spiral-fluted reamer to correct such faults (illustrated in Figure 14). Had it not been that the diesel-engine injector body required a highly burnished hole, a reamed hole in which all surface fractures had been completely eliminated to correct the vices of erosion and corrosion—a far better finish than that given to gun barrels—the special spiral cutting reamer probably would never have been brought to light.

This discovery required two years' study and experimenting on methods of securing a reamed hole which would be highly finished. After all other conditions had been attended to—the selection of the proper steel, heat treatments of the same, and stress-relief treatments—experiments were made on various types of cutting angles on reamers with a spiral cut in the flutes, using from one turn in 3 inches to one turn in 9 inches, and made with odd flutes. The odd flutes consisted of 3, 5, and 7 cuts along the circumference of the reamers, in order that no two flutes would be cutting from opposite sides and

hinder the efficient cutting of the metal in contact, having in mind to produce a chip from the cutting edges in a curled form similar to those produced from a well-ground lathe tool. Applying our thoughts to this purpose, we found at last that a spiral of one turn in $5\frac{1}{4}$ inches produced the effects desired, but to our surprise chips were removed in a curl-like form, and in lengths as great as 12 inches, from the diameter of a $\frac{3}{8}$ -inch hole in which only 0.002 inch stock was left for this reamer to remove. This meant that the cutting edges removed only 0.001 inch of metal from the circumference of the hole, proving also that whenever a 12-inch length of chip could be removed, the surface of the metal had not been fractured in the complete length of hole reamed. Whenever the interior surface of metal is left in such a state, it is possible to secure that "mirror-like polish" in any hole, especially when a scrape-reaming operation follows such spiral reamers; that is to say, by using spiral reamers for the roughing operations, the scrape reamers are capable of producing a perfect finish when viewed by the naked eye from each end of the hole.

There is hardly a reamer to be found today that is not a straight-fluted reamer, whether used for reaming a caliber .22 rifle barrel or a 16-inch cannon. The fundamentals of the cutting efficiency of the special spiral reamer will vary greatly in comparison to the work produced by the straight-fluted reamers, especially when we demand of the bore surface in gun barrels the best possible finish, and these requirements branch out to various industries, particularly in plants where airplane engines are made. To the minds of many, reamers are just reamers, without any practical thought as to their vices in a piece of steel; the reamer is only a tool to them, a tool which will ream a hole to a given size, without taking into consideration whether the parts reamed are subjected to fatigue, corrosion, or the stresses and strains in the metal which are released by a heat treatment, and which may rupture the surface reamed to a greater depth. Of course, straight-fluted reamers are used largely because of the ease with which they can be made in the average toolroom, and the cheapness with which the standard sizes can be purchased through tool catalogues. But whenever a part must withstand great fatigue strains, as in a gun barrel or an airplane-engine part, or where the parts may or may not be heat-treated later, regardless of the kind of steel used, a spiral-fluted reamer should be employed, in order that those parts reamed will not show any minute fractures surrounding the circumference of the hole. Today, there should exist some improvements in our antiquated methods of reaming, particularly in the reaming of gun barrels, of airplane-engine parts,

and even of common engine parts in a motor car. The following rules, therefore, should apply in general:

- (1) Avoid the use of straight-fluted reamers in all deep-hole reaming; namely, in small-arms gun barrels, heavy and light cannon, propeller and cam shafts, etc.
- (2) Avoid the use of straight-fluted reamers on parts subjected to fatigue stresses and strains.
- (3) Avoid the use of straight-fluted reamers on parts which may be subjected to erosion and corrosion.
- (4) Avoid the use of straight-fluted reamers on parts which are to be heat-treated.
- (5) Avoid the use of straight-fluted reamers in steel low in either Brinell or Rockwell hardness tests if perfect internal finishes are desired.

Since there are so many factors affecting the "fatigue limit" of complicated parts which contain a reamed hole, reamers must be selected which will reduce all serious failures which may be anticipated, especially in parts that have an important role to perform. The ability of steels to resist localized concentration of minute fractures, such as are usually found in the circumference of a reamed hole, may not be so great when the alloy steels are used, compared with steel found in the lower-numbered brackets; and whenever such steels are carbonized, the failures resulting are soon proven by the aid of the microscope. But, regardless of the steel selected for a given part, surface fractures usually appear in great numbers in certain concentrated areas of the metal, and usually increase in depth whenever a heat treatment is given to that particular part. Also, corrosive environments embed themselves in such fractured surfaces, and will appreciably shorten the life of any steel parts under fatigue stresses. The extent of the life of a rifle or machine-gun barrel depends upon the perfect finish within the bore, for powder gases have the ability to cut away the metal carbides between the crystals, thus leaving deep grooves in the structure of the metal, especially in the bullet seat, that location where the bullet enters the rifling. Contrary to the opinion long held by many metallurgists, we find that it is not possible to secure a near-perfect surface whenever the conventional straight-fluted reamers are used. A metallurgist has, of course, his own theory of what a reamer should accomplish in a piece of steel, but the choice and nature of the holes that are produced should not be matters of theory.

When a gun barrel fails—a barrel which has been reamed with the conventional type of reamer, and which has been subjected to the repeated strains and stresses of overloads of cartridges—the metal-

lurgist seldom looks for the minute fractures surrounding the circumference of the hole by cutting out his specimens from that locality, nor does he stop to think that the structure of the metal may have been damaged by the reamers during their passage through the bore. The usual explanation of such damage is that the steel was "crystallized" in the hardening operation. It is known by all metallurgists that metals are crystalline in nature; but failure would not occur so readily from the inside if some mechanical part had not contained hundreds of minute fractures, and hundreds to a depth greater than 0.007 inch. In the process of reaming steel, particularly parts which must be submitted to fatigue hardships, we are bound to eliminate all the internal minute fractures of the metal surrounding the diameter of the hole; and this applies not only to a gun barrel but to the largest propeller shaft used on an ocean liner. Clearly, the danger lies in the rubbing together of the crystals which are located around the ruptures, and which increase in depth by fatigue strains, until at last the fracture of the part occurs. It is those fractures which may cause a vital part of a gun to go "bad" so suddenly.

Whenever internal-surface fractures are found under the microscope, they are the result of the straight cutting edges of the reamer's flutes breaking off the chips rather than shaving them away from the surface they contact. Reamers of this type naturally fracture the structure of the metal between the crystals, producing an effect similar to that characteristic appearance of a freshly planed surface of a pine board run through a jointer which carried extremely dull blades. Therefore, whenever a reamed hole is only judged by the naked eye, it is not possible to observe the minute defects left by the conventional type of reamer, for specimens must be prepared and viewed under the microscope for surface defects; and it is only in such a manner that we might become familiar with the finishes produced, and the exact damage to the surface of the metal by the reamers employed. A reamed surface, when viewed under the microscope, should be free of all fractures, and specimens should be so prepared that the edges of the hole from the center can be readily explored; and when etched, all exact vices are very plainly detected, especially when viewed under different magnifications.

Of course, under various magnifications, all kinds of internal-surface imperfections can be found, which are difficult to eradicate without employing burnishing or scrape reamers, reamers which have a scrape cutting edge, and which are illustrated on pages 121 and 122, Volume II. Regardless of the type of first reamers employed for the roughing

operation, scrape reamers must be used to produce a very high surface finish, and an exact size, as in the case of a rifle barrel. In the manufacture of gun barrels, of course, three scrape reamers are used to produce a finish and a correct gauge size, but they are unable completely to eliminate the fractures caused by the straight-fluted reamers. Whenever much finer finishes are required, a spiral fluted reamer must be used with a sufficient oil supply so that the flutes may not labor under operation, and so that the curled chips may come away from the flutes with the utmost freedom, as a curled shaving comes away from the blade of a keen cutting edge of a carpenter's plane, whether under a heavy or a light cut.

Lapping—It should be remembered that surfaces which cause friction must be transferred from raw-machined and process-finished surfaces to limits terminating in a solid surface capable of reducing friction to a minimum, especially in a gun barrel and all the working parts of a firearm able to maintain an adequate and suitable oil film. This subject should be of paramount interest to those who make rifle and shotgun barrels, and yet it is one about which very little is known definitely, as we have already pointed out. It is a proved fact, that minimum friction to the passage of the bullet through the bore of a rifle barrel is obtainable only when the projectile makes its starting flight with complete freedom after the rifling is first engraved upon the bullet's bearing surface. The bullet then responds to an independent velocity without being retarded by the file-like appearance at the top of the lands (which can be discovered by the aid of the microscope), and which removes minute particles of metal at the bottom of the grooves engraved in the bullet. It is the pointed, sharp surfaces of the file-like minute scratches that peel off the metal and produce abrasion, so by removing these by a lapping operation, if found necessary, the life of the barrel may be multiplied a number of times.

Lapping to produce a fine finish to the interior of a fowling piece or a smooth-bore musket is probably one of the oldest arts in gunmaking. In other industries, today, it is used in the production of optical work of all kinds, and in the toolroom on precision tools and gauges.

Of course, it is entirely different from all other mechanical operations for producing a finish in that lapping is limited to the use of powdered abrasives, from various grades of emery powder, diamond dust, to that of finely powdered rouge. The abrasive materials are usually mixed with different types of carriers such as oil, grease, etc., and charged into the porous surfaces of hard woods, cast iron, brass,

lead, etc., together with the lubricant and used to lap various parts of guns, including the barrels. Today, in mass production of firearms, all parts are either turned, reamed or ground to size, and a lap is very seldom used on a rifle barrel.

For most commercial purposes it is too expensive a method to be of much value, except in the tool-room and in the small experimental shop of the gun-craftsman. Lapping is something that requires the greatest amount of personal skill and experience for the production of finishes. It is a very slow and precise operation in securing exact measurements, and the resultant finishes depend upon the experience and ability of the mechanic handling the laps and abrasives. Even the experienced mechanic generally leaves a finish of minute scratches over the entire surface of the work—scratches so fine that the naked eye cannot detect them. Yet they are easily measured or photographed, and a photomicrograph of the ordinary lapped finish at 50 magnifications indicates the surface to be a miniature surface of a skating rink in January. Yet it does not require the aid of the microscope to measure surface smoothness as we do it in the laboratory, for the ball of the finger can be used, or the fingernail, the edge of a coin, the use of a thin nonmetallic edge, the naked eye, and the edge of one's front teeth. Of course, the latter method cannot be used on any large parts, except by those who happen to have false teeth, and then they would have to be removed to perform the operation. This method is not advised in public.

American vs. British Finishes—We are all aware of the singular advance made within the last half century in the United States in the gunmaking industry. Yet, apart from all the modern improvements, the problem of the "finishing" of firearms has been sadly neglected, internally and externally. The finishing on American firearms when compared to that on all British makes is neither as substantial nor as lasting. It is evident, to begin with, that American guns have two forms of finishing—a useful finish and a useless finish. This distinction, which can more or less be detected, may be further defined as "substantial finish" and "apparent finish,"

or, more bluntly, "lasting" and "deceiving." So far as the finish is contrived for the purpose of deceiving, we have nothing to say against it, because it serves a purpose at the price paid. But there is a form of vanity which displays itself in an attempt to give the outward appearance of firearm durability to a finish that will not survive hard handling. Yet, when such a gun is purchased, there is much in this finish to be admired—until it begins to wear off by hard usage. The finish on most British guns, on the other hand, is completed for the purpose of lasting, and we find much to be said in its favor; it has certain qualities—smoothness and fineness to a certain degree, and a texture which would be worthy of admiration on any kind of firearms, for it has been placed on the exterior by acids, and then finished by a burnishing operation—quite unlike the finish upon the majority of American guns, which has been produced in a day by the fumes from chemical compounds.

Our best finishing process by chemical compound is by no means a coarse one, but it can deceive the inexperienced. For we may be able to smooth the surface, externally and internally; and, externally, soften the outlines round barrel and action, but if a good magnifying glass is used on our miracle of factory skill, the visible finish on the metal in all details will appear incomplete; the pores in the stock and forearm will appear partially unfilled; the oil finish, which requires from three to four weeks' time, is hurried—completed, as it shows, in a day. When it comes to a comparison of American with British guns, it seems as if the British gunmakers are capable of producing a much better finish than our gunmakers. The higher-priced the American gun becomes, the higher the finish and ornamentations, and the same is true of the interior of its mechanism. But it is not high enough to warrant a sportsman's paying the higher price when he can select a standard gun and have the ornamentation executed to suit his own taste and liking; that is, the engraving more in keeping with his idea of intelligent expression. Nevertheless, good American firearms do exist. They are all about us, and sportsmen are justified in making their own critical selection, for it is their money which they spend.

CHAPTER VI

Essential Results of High-Velocity Experiments

WE APPARENTLY must admit the inherited stupidity of nations in failing to arm themselves intelligently. That stupidity is evidenced by the creeping slowness with which medieval men improved their means of warfare when opportunities for improvement lay all around them waiting to be observed and embraced. Again, it is evidenced by our own failure to gain the most for the proper defense of our nation from the opportunities offered by men of science, particularly in employing them constantly in experimental development and research. Viewing the improvements made in military weapons year by year, it is true, one can see a progressive betterment—at a tremendous cost. But the ways of the past are too slow for the present age.

We have recently become seriously thoughtful of our responsibilities regarding defense preparations. We can now be properly optimistic as to the changing design of weapons necessary for our complete protection from the air. We have also become alert to the importance of complete efficiency of higher velocities in all calibers of guns.

Optimism, however, must have a solid basis if it is to be of any help to us in this emergency. One of the weakest points in our present preparedness campaign is due to the failure of our army and navy officers to foresee the possibilities of higher-velocity projectiles and to perfect the manner in which they can be perfectly controlled over long ranges. True optimism arises from courage coupled with knowledge through which difficulties and pitfalls are foreseen and guarded against. Our military and naval experts have large departments at their fingertips, so to speak, but these are not always used to their full capacity. It is important for us to understand fully the need of entrusting all such research and experiments to efficient employees rather than to army officers who are changed to other posts every four years.

The Gerlich Gun—Before proceeding to discuss high-velocity research and experiments, it is desirable for us to review our file marks in a research engineer's habitual manner. The story begins with the way in which a high-velocity gun was discovered by German army officers, and how, from this discov-

ery, arose the guns which are now employed on the Channel coast line of France to shell England.

To make the picture more complete, it will be necessary to review one of the most essential developments made on higher velocities over the conventional types of arms and ammunition. Gerlich, a German inventor who was the originator of the tapered rifled barrel and finned bullet, tried for many years to interest various European nations, including his own, in his high-velocity invention; but he failed in all his attempts. In 1932 the United States Army became interested in his idea and thought of purchasing his patent rights, provided it were possible to secure the velocities he had made claims for, which were supposed to be greater than 6500 f. s. (foot-seconds). Paying Gerlich's expenses to this country, the U. S. Army conducted firing trials with his original guns and ammunition, which he brought with him from Germany; but it was found to be possible to secure a velocity of only 4500 f. s. For a period of four years the army worked upon his patent at a cost of many thousands of dollars, and then discontinued all experimental work because it was impossible to secure a greater velocity than that of his original guns and ammunition. Both the Dupont and the Hercules powder companies were called in on this problem, and they manufactured many different grades of experimental powders, but failed to bring the velocities up to the inventor's claims.

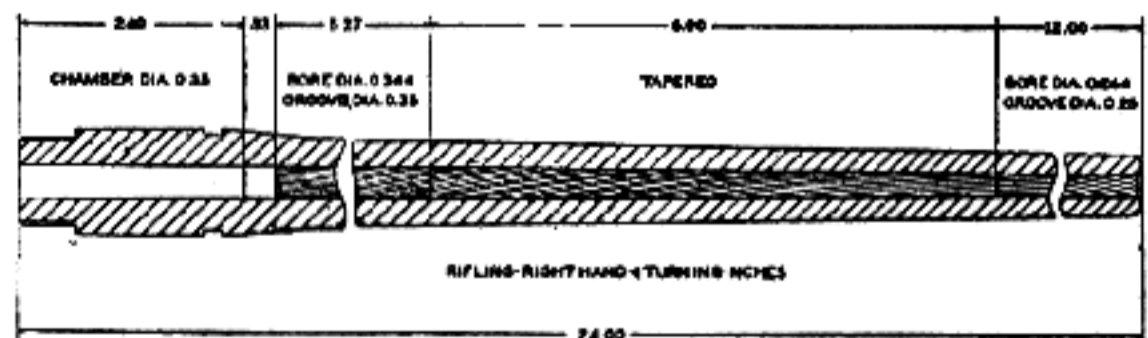


Fig. 15

The Gerlich high-velocity tapered rifled gun barrel

Even though his gun had failed to produce the velocities that he had claimed, Gerlich's ultra-high-velocity gun had many promising features. The interior of his barrel was made in three tapered sections; that is, they were tapered rifled sections, consisting of a short tapered section at the rear, an

intermediate taper, and a straight cylindrical section of about 12 inches back from the muzzle, as illustrated in Figure 15. The rear taper in front of the chamber is enlarged to a caliber .35, and ends at the straight cylindrical diameter as a caliber .25, the two tapers and straight bore being rifled their entire length. The cost of all the experimental barrel work at the Springfield Armory was nearly \$40,000, which proved that the cost of manufacturing such barrels for military purposes would be prohibitive.

After the Springfield Armory completed the Gerlich tapered barrels, they were shipped to the Frankford Arsenal, which made the experimental bullets and conducted all firing trials and ballistic tests. The bullets fired in this rifle had two flanges which might be described as fins. These fins, in the beginning flight of the bullet, engaged the first taper in the groove diameter of the rifling, making a perfect gas seal. (This bullet is illustrated in Figure 16.) When the projectile leaves the mouth of the cartridge case, the fins gradually fold into the recess cut below the cylindrical diameter, and by the time it reaches the caliber diameter, it is delivered at the muzzle of the barrel as a solid bullet, and with a much higher velocity than can be secured with the

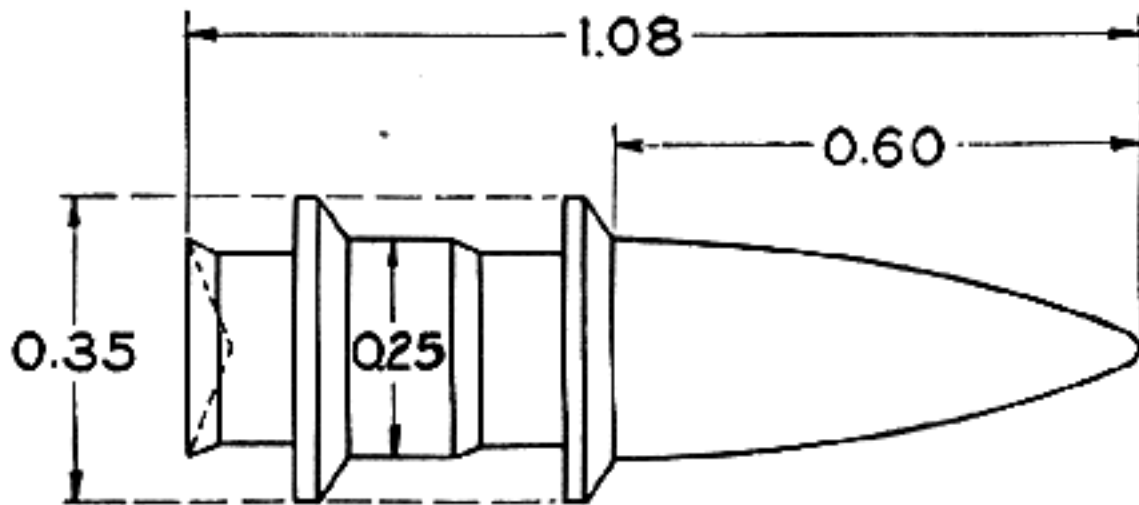


Fig. 16
The Gerlich two-diameter bullet, caliber, .35—.25, weight 100 grains

conventional type of bullet. The firing of Gerlich's own cartridges, even loaded with German powders, developed velocities far below that which he himself had anticipated, and all further experiments were given up.

A High-Velocity Discovery—Life carries us much more toward experiments than toward perfection, so that on January 2, 1937, I accepted a position at the Springfield Armory, and was assigned to the further development of a high-velocity gun and its ammunition. But I was to attack the problem from a different angle than that specified in Gerlich's patents, and was to secure, if possible, the velocities which Gerlich anticipated.

Our experiments in the beginning were not encouraging, for we used the same bullet as Gerlich—a two-fin bullet—but reduced the caliber to a .30-.22; that is, we used the standard caliber .30 Model 1906 cartridge case, and reduced our caliber to a .22 in the bore, using a bullet whose weight was over 60 grains. Success along these lines eluded us until we had reduced our bullet to 45 grains and used but one fin, with a fiber base over the rear of

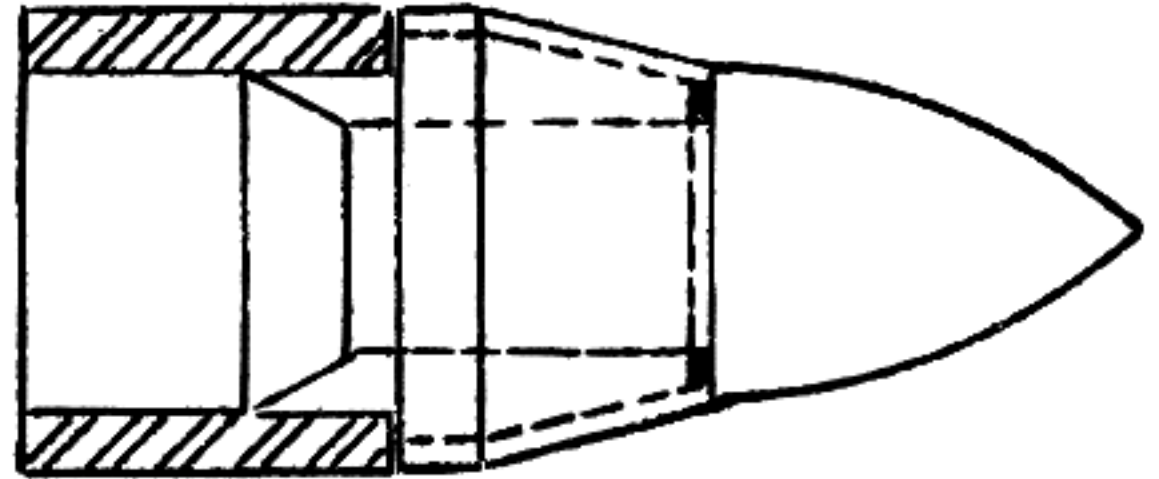


Fig. 17
The two-diameter bullet with but one fin, and with fiber base attached, caliber .30—.22, weight 45 grains

the bullet to hold it centrally in the mouth of the case and keep it centered in its passage through the gas-expansion chamber—the auxiliary chamber or tapered cone. (Figure 17 shows this bullet with the fiber base attached.) The complete details of all experiments leading to the high-velocity results will be given later in this chapter.

Our experiments then produced results more quickly than we had ever expected. After centering our pressure gun on the screens, a velocity of 5122 f. s. was recorded on the Aberdeen chronograph with a pressure slightly above normal, using a powder which was made for the Gerlich experiments. Many more shots were then fired, but, although the bullets penetrated both screens perfectly, and the needles on the chronograph issued sparks from both, there was only one shot that recorded a velocity, namely, 7100 f. s. From all the rest of the shots fired, no indications of the recording marks could be found, proving that the velocities were too high for the instrument to handle, or that the bullets had made such large holes in the screens that the wires were short-circuited, so that the proper contacts could not be made back to the instrument.

Though we had secured these high velocities, the appropriations ran out on this order, and without the necessary funds to go any farther, I was assigned to some of the more serious problems on the Garand automatic rifle, especially in regard to the receiver, which was causing difficulties for those who were trying to place it in production. Having become very much disgusted and discouraged with

the methods used in securing production of the receivers for these weapons, I then severed my connection with the Armory in May, 1937.

It is undeniable that it is very difficult to get either the Army or the Navy Department at Washington to take much interest in new ideas, particularly in such a problem as higher velocities for all types of weapons after the failure made with Gerlich's patents. The remarkable results that I had secured in a period of six weeks were apparently wasted. Therefore, knowing military traditions from experience, I did not attempt to present the problem any further in this country, but was most fortunate in having the British Government become interested in my idea, and left for England in July, 1937.

Failure in England—The discouraging element of the situation was the fact that we did not complete our firing trials here, but went to England with two barrels with pressure gauges attached, and with a supply of bullets and cartridges. When we had been assigned to the Woolwich Arsenal, and our ballistic firing trials had been started, it was found necessary to ream the expansion chamber to a much greater length. This chamber had purposely been left short, for as the firing trials progressed it was to be reamed to the length which would give velocity up to that secured in our original barrel. But after five shots were fired, the surface became nitrated, or hardened, and the reamers brought along for this purpose would not cut the surface of the metal. Under such circumstances, I then returned home; not discouraged, but with hope that some day I could prove that my original ideas on high velocities were not to be just another foolish experiment. My faith was not shaken, though it had come up against some pitiless natural forces.

It requires considerable money to bring such an idea to the front, and this burden ought not to be shouldered by the inventor, especially when such weapons are efficient only in military and naval operations, and could never be used successfully as either target or hunting arms. As for the outcome of this endeavor, speaking generally, I should say that it was considerable, but incomplete; the results attained, though far short of success, were more than worth the trouble and pains of a trip to England. If we did not get all the velocity we had counted upon, we did get very much that had never entered into our calculations, notably the respect and generous treatment of the British army officers, who were broad-minded enough to say that the best of inventions are imperfect in the beginning.

The two negative words that best characterize all our inventions from this point of view are, in

the beginning, *imperfection* and *uncertainty*. Looking at the situation in such a light, but with unabated faith in the ideas upon which I had spent so much energy, I turned to other phases of research and experiment, and allowed the high-velocity problem to rest until I should be more able to prove my claims.

An Accusation—Down to this point I can speak with the authority of experience, and may mention that in July, 1940, while in Washington, I visited the War Department—without any thoughts of our high-velocity experiments in mind, but merely to meet friends and discuss various angles of ballistic problems. As I was sitting in one of the offices, an officer entered (no names shall be mentioned in this case) and accused me of spending a good deal of time in Poland before the German invasion of that country, and of having sold my high-velocity ideas there for a large sum of money. It is evident that there are two opposite ways of avoiding error; one is to know all about the point at issue, and the other is to know absolutely nothing. In this case I knew absolutely nothing, and simply offered my accuser a watertight alibi. Even then, I could see that there was considerable doubt in his mind. Not until I had completely satisfied him that I was never in Poland did he tell me what had caused his accusation.

According to reports reaching the War Department through our Berlin attaché, an army officer attached to the U. S. ambassador's office, there was a high-velocity gun among the captured war material reaching Berlin after the invasion of Poland. This gun, so it seems, had been putting the German tanks out of commission, the projectiles penetrating their heavy armor. After the gun had reached Berlin, and in the presence of many of the German army officers, the American attaché had had an opportunity to examine the barrel and ammunition, and had come to the conclusion that I had sold my idea to the Polish government; and he had sent an official report back here to that effect.

He also reported that the Germans went to work at once and made a 6-inch rifle by following out the same pattern as found in the Polish high-velocity, and in their tests found that it was possible to secure a range three times greater than with the conventional design of the same caliber, or a range of forty miles. As they had secured such phenomenal velocities in their experimental tests, they started the manufacture of the weapons at once, and these are the guns which are now used to shell England from the coast of France.

I am fully aware that, at first sight, this may seem a secret trust which should not be reviewed,

but it furnishes the key to a complicated situation in which I happened later to be the first to discover the methods of securing these high velocities. So I am recording the results as told to me, which is the only effective means of pushing our claims to the front, and of proving the inherited stupidity of our own War Department. Our War Department, no doubt, looks upon all inventors as people they must humor and push aside as soon as possible. Any deep subject pertaining to improvements puts a strain upon its officers' minds, and they are unable to act upon it according to its merits. A just criticism may be anticipated in this case, especially when some British army officer observes the damage done by the shells fired from those long-range weapons, and remembers the claims which we had formulated. The general broad claims, of which they have a copy, were these:

Subject: An invention to increase the velocities of small arms and artillery projectiles over the present standards, especially in the design of barrels and their ammunition, such weapons being the ones used for the purpose of military and naval defense.

- (1) The material reduction in weight of many minor and major caliber guns and their projectiles, securing greater efficiency of performance over long ranges.
- (2) A material increase in small-arms bullet velocities over the present standards; namely, that of increasing their velocities between 50 and 100 per cent; and in artillery and naval guns, there should be a material increase in velocities greater than 20 per cent.
- (3) The reduction in weight of many major-caliber anti-aircraft guns; for example, the 3-inch anti-aircraft gun could be reduced to a 2-inch caliber, and with a higher velocity given to the projectile, an object can be reached much sooner.
- (4) Greater life can be secured to the bore and rifling in all classes of weapons; for when a higher velocity is given to a projectile, the surface of the metal absorbs a high percentage of the carbon from the powder gases, thus hardening the bore and rifling to such a degree that longer life can be given to all major-caliber guns without showing any harmful effects to the surfaces of the metal as found in all conventional types of barrels.
- (5) The ability to secure high muzzle velocities and high remaining velocities over long ranges while the projectiles are in flight.
- (6) The most favorable condition attending this invention is that there are not any expensive manufacturing methods required to make either the barrels or the projectiles, nor is there any necessity of using special materials which are hard to secure from other countries in time of war.

In general—to illustrate: By reducing a one (1) pound projectile (7000 grains avoird.) to six (6) ounces (2625 grains), and the bore of the barrel to one inch from 1.437 inch, the muzzle velocity is increased materially—for instance, to 4000 f. s.—by this reduction in caliber. When this reduction in weight takes place in the projectile, it is capable of producing the same striking energy as a one-pound shell against an object in foot-pounds. Clearly, these figures will prove our statement: When a one-pound shell is fired at a muzzle velocity of 2400 f. s.,

it produces a striking energy of 89,552 foot-pounds; but, on the other hand, when the six-ounce projectile is given the greater velocity of 4000 f. s., there is produced a striking energy of 89,730 foot-pounds, which is practically the same striking energy as that which had been secured with the heavier shell. To accomplish this, normal pressures are easily maintained in the barrel chamber. This interesting reduction in the weight of the projectile, with normal pressures maintained in the chamber, decreases the time of flight to the target, which is of particular value in the case of moving targets, including airplanes, tanks, etc. This reduction in weight of the projectiles and guns proves a vital factor, also, not only in efficiency in actual use, but in the transportation of ammunition to the points of operation.

Under the most unfavorable circumstances, we have secured high velocities in military small arms, using the service Springfield action, to which a special-caliber .22 barrel was connected; velocities between 5122 f. s. and 7100 f. s. were thus obtained. Discovering the means of securing these high velocities in small arms led us many steps further in thought, causing us to assume that the same principles could be applied to the larger calibers, holding the same relations to the mechanical reductions as the gun originally tested.

Scientific Aspects of High Velocity—Let us now turn our attention to the scientific aspects of high-velocity experiments. Interest in such ballistic experiments keeps us constantly seeking for new kinds of original thought in scientific matters—and at the same time constantly exposing ourselves to new troubles of which we might otherwise have remained ignorant. Great men like Newton never allowed their minds to remain dormant. It was Newton who discovered the "Law of Inertia" that "To every action there is an equal and opposite reaction"; and that the existence of a force implies of necessity some resistance against which the force is applied. When a force is applied to a bullet at rest, the resistance offered by the bullet is due to the inertia of its mass. By the same token, if we attempt to alter the existing weight of any bullet or projectile, a resistance is immediately experienced from existing standards. This co-existence of action and reaction, and the resistance which a projectile offers by reason of increasing or decreasing its mass, is the resistance due also to inertia, without taking into consideration the resistance of friction, which we shall touch upon later.

It is known that certain laws of nature—those in particular which govern mechanics and gases—are basic. In the basic formulas the following equations hold:

$$\begin{aligned} \text{Pressure} \times \text{Area} &= \text{Force} \\ \text{Force} &= \text{Mass} \times \text{Acceleration} \\ \text{Velocity} &= \text{Time} \times \text{Acceleration} \end{aligned}$$

Since our maximum pressure is limited, due to our present strength of materials, it appears that

the only method open to us for obtaining greater velocities in projectiles than that already obtained from established bore diameters, is to increase the area over which the pressure acts in order to give greater momentum to the bullet or projectile upon its axis, and to reduce both the mass of the projectile and the caliber of the gun.

Let us now imagine, for example, a caliber .30 M-1 bullet that has a diameter of 0.3085 inch and weighs 173 grains, upon which a pressure of 52,000 pounds per square inch is exerted, giving an initial velocity of approximately 2650 feet per second. We find that should we reduce the weight of the bullet to 86 grains, causing it to move with the same powder charge, we would normally expect twice the rate of speed, and the momentum of the bullet about its axis would help to give us, as we may suppose, a velocity of 5300 feet per second. This is a perfectly legitimate way to look at the situation, and should it fail, we may think that had we used a barrel twice as long, to permit a greater acceleration of the bullet for twice the distance along the bore, it would have succeeded. But when we come to consider the laws of bullets in flight, we find that bodies in motion have some laws of their own. To deal with them an entirely new idea of force is required.

Here we strike the root of the whole theory of mechanics. It is the foundation of the system which the tremendous genius of Newton conceived in order to explain the motion of the sun, moon, and stars. Forces were treated by him as proportional to the motions, and the motions were proportional to the forces. With this idea he solved a part of the riddle of the universe. Great discoveries are made only by the ability to see things clearly.

But mass, which is the bullet or projectile, is nothing more than a quantity of matter. Knock a brick against your head, and you will then know what mass means. It is not the weight of the brick which gives you the jolt, but the mass. Try to throw a heavy stone from a shovel, and you will understand what mass is. Try to push a Ford car to get it started when the battery is run down, and you will soon realize what mass means. Weight is the earth's attraction on mass, and it is proportional to the mass at the same place.

Therefore, when powder gases act for a certain time on a projectile which is free to move, however small the powder charge may be, or however small the bullet may be, that projectile will move. The powder gases, of course, always tend to produce projectile motion. If motion is impossible at the beginning, then pressure is developed which can be measured by the aid of a pressure gauge, and observed. After the projectile becomes free in flight, its flight can also be measured by the aid of the

chronograph, figured, and observed; and when we have these two sets of figures, i. e., pressure and velocity, they can be compared. Then we begin to reason: "A force like this powder gas, acting on a bullet composed of a mass whose weight is 173 grains, should produce, if the mass is reduced $\frac{1}{3}$ of its weight, $\frac{1}{3}$ more velocity." True, it works that way in certain calibers, especially where there is a great variation in the weight of the bullets; for instance, in the .300 magnum, where it is possible to select bullets between 110 and 225 grains.

But how many other factors must we consider in this hypothetical quest for higher velocities, particularly those above the established laws in ballistics acting upon projectiles—factors, for example, which give rise to a change in motion? The term used for the change of motion is "acceleration" or speeding up. In all cases it is the force of the powder gases acting upon the base of the mass which produces acceleration. If that force then continues to act on the projectile, the projectile will keep moving faster and faster. When the powder gases stop acting, the motion which the projectile has acquired, continues, but the acceleration stops. That is, the projectile, theoretically, at least, goes on moving in a straight line uniformly at the pace it had when the pressure of the powder gases stopped.

What then will happen to such bullets when exposed to the pressure of the powder gases and yet held tight? They will, of course, remain fixed until the pressure wrenches them free. Then, the longer the powder gases act, and the pressure keeps putting more and more force and motion behind the bullet without undue friction to contend with, the faster will the velocity become. The bullet keeps all the motion it had, and it keeps adding to this motion. So if, in one second, a motion of one foot (for the purpose of illustration) is imparted, then in another second a motion of one foot per second more will be added, making altogether a motion of two feet per second; in another second of forced action by the powder gases, the motion will have increased or "accelerated" by another foot, and in theory, if all mechanical effects are correctly designed, will continue to increase in the case of a high-velocity bullet.

But here the other factors begin to enter into the problem, and one of these is the loss of velocity due to friction in the double length of barrel which has been suggested; or for that matter, there would be no difference in this regard if a standard length of barrel were used, one measuring 24 inches. In all cases, the powder gases act. The lighter the bullet, the more velocity it has. If the bullet is large, it will require greater gas pressure to make it move to

a higher velocity; if the bullet is small, it moves more quickly in the beginning of its flight, but loses its effective striking energy near the termination of its flight.

Very little is known about the flow of powder gases at a high pressure. There are no experimental data, so far as we are aware, to assure us that heated powder gases at a pressure of 52,000 pounds per square inch will be able to produce a force capable of imparting more motion to a bullet than 7100 f. s., the highest velocity which we were able to secure a record of in 1937 in our experiments with high velocity.

Friction—The analogy between friction and velocities is so close that we are always tempted to forget friction at the expense of velocity. The right mode of procedure, in projectile and barrel design, in order to secure the higher velocities, is to take certain negative factors first, and not to accept positive factors as a compensation for the element of friction. Friction is the resistance obstructing the motion of a projectile when forced into the bore and the rifling of a gun barrel. Under these circumstances, the surfaces in contact have a certain tendency to adhere. The surface of the bore is not perfectly smooth, as we have already pointed out in Chapter V, and in consequence a considerable amount of force is required to overcome the mutual resistance of the two surfaces, i. e., projectile bearing surface and bore surface. If the velocity is increased, the resistance to projectile motion is increased also; on the other hand, if we give a high finish to the surface of the bore, and decrease the bearing surface to a bullet no greater than $\frac{1}{8}$ inch, friction is diminished, though it can never be entirely eliminated. By decreasing the bearing surface of any high-velocity bullet to $\frac{1}{8}$ inch; that is, moving the bearing surface to the rear of the bullet—accomplished by turning the original bearing surface down to the bore diameter up to the $\frac{1}{8}$ -inch new bearing surface—a 25 per cent increase in velocity can be secured.

The results of my experiments in high velocities would indicate that the friction factor at low velocities is small, as in the case of a caliber .22 lead bullet; it increases rapidly at first, then more gradually as the velocity increases, until at a certain velocity a maximum friction factor is reached. This depends upon the surfaces of the bore and groove diameters, the bullet in contact, and the intensity of the pressure required to force it through the barrel. An increase in the intensity of the pressure (the number of foot-pounds on a square inch) changes the amount of the maximum factors, and reduces the velocity appreciably. The more yield-

ing the bullet material in the maximum diameter of the bore, the higher will be the velocity—in the case of lead bullets; but this is not so in a minimum barrel with a hard bullet jacket material to be contended with in its passage through the bore.

The existence of rifling the entire length of the interior of a gun barrel implies that when force is applied to the projectile by the powder gases, the projectile meets with resistance and retardation. But by eliminating the rifling back of the muzzle—that is, only allowing between 4 and 6 inches of rifling to remain near the muzzle, and eliminating it along the route where first the projectile encounters retardation—friction is reduced appreciably, which naturally increases the projectile's velocity. Since our maximum pressure in a cartridge chamber is limited to our present strength of materials, the most logical method open to obtain greater velocities than those which have been previously obtained in the conventional type of gun-barrel, is to have a bullet or a projectile bore-free when leaving the mouth of the cartridge case. It is even true that greater momentum to the projectile can be secured before entering the rifling remaining at the muzzle; and in its advance to this remaining rifling, it meets no opposite reaction to retard its initial velocity.

My experiments proved that a pressure of 2000 pounds to the square inch could be placed against a steel plug, in which the tolerance of 0.0002 inch was used between plug and barrel bore, and a leakage of only 2 c. c. of light oil per minute was secured. In conducting this test, a tube was reamed to 0.3752 inch diameter, and the bore was fitted with a lapped steel plug which measured 0.3750 inch, of a length the same as the bearing surface on a caliber .375 bullet. This experiment proved that a projectile of the same caliber could be "accelerated" to a greater velocity than one shot in a barrel which contained rifling; and if a bullet of a smaller caliber were shot in a similar barrel, its flight would be nearly that of the velocity of powder gases.

We have already established the fact that it requires a pressure of 2000 pounds to the square inch to force a maximum caliber .30 bullet into the rifled section of a minimum barrel, and a pressure of nearly 1000 pounds per square inch to force it the rest of the distance through the rifling. Therefore, the greater the velocity becomes, the greater becomes the force required to keep the projectile moving along its course in preparation for the friction encountered in the bore, at the bottom of the grooves, and on the edges of the rifling. Powder gases, of course, produce projectile motion, but if projectile motion meets with any

obstacles at the beginning of its flight, velocity is reduced accordingly at the expense of friction; and this, of course, generates a high degree of heat in barrels, whether on a rifle, a machine gun, or an automatic military rifle, and their efficient operation is impeded.

A bullet or projectile, when it leaves the mouth of the cartridge case, should be a free body, to act and move until reaching an established point where rifling is to be engraved—the muzzle. The law of inertia is partly established in ballistics. Therefore, in a barrel free of rifling at the rear, and with faster-burning powder confined in the cartridge case, the projectile would be a free body to move along its path, for the powder gases would be putting more and more velocity and motion behind the mass; and without friction to encounter, the projectile would keep on going faster until it reached the rifled portion at the muzzle, which would be engraved only to a depth that would impart a satisfactory spinning motion. We might call such a semi-smooth-bore gun barrel a “gas-expansion chamber.” In a barrel of this design, the faster-burning powders could be used instead of the slower-burning powders, and these would be instantaneously converted into a gas to move the projectile. The faster-burning the powder employed, the greater the force and motion behind the projectile, resulting in a much higher rate of speed than that obtainable from the slower-burning powders. In all cases, the ballistic factors would become more efficient; thus, the lighter the mass, the greater the velocity; and even with the larger mass, a greater velocity could be obtained over all conventional types of weapons now in use. All weights of projectiles would move more quickly in their flight from the mouth of the cartridge case, and along their route through the gas-expansion chamber, without loss of powder energy, and by the time they entered the rifling at an established point back from the muzzle, a much greater velocity would be recorded on the chronograph.

We would find that when a projectile is fired in a barrel which is bore-free for a certain distance, friction is reduced at least 30 per cent at the rear portion of the barrel, especially where the greatest amount of heat is generated; therefore, a greater number of shots could be fired from automatic rifles and machine guns, and the life of their barrels would be increased appreciably. Yet for a certain type of mind a gun barrel free of rifling at the rear, and with rifling only at the muzzle, cannot be imagined as practical; it is just another wild, fantastic idea. Willie, a neighbor living close to our plantation, still thinks the world is flat and does not turn upon its axis. “If the world should

ever turn,” he argues, “all the stones would fall off, and if we could not hang on to a tree, we would fall off, too.” So we shall find many who will continue to argue that a gun barrel must be rifled its entire length. They belong to the age that thinks like Willie and his uncle Buckey, who backs Willie up in all his opinions.

We have been told all our lives that a rifle could never be expected to give real accuracy unless the rifling extended its entire length. It is possible, however, that we all have been misled by a standard practise without investigating its merits. In my high-velocity tests I found that a bullet readily took the rifling even though the bore was made smooth 6 inches ahead of the cartridge chamber. It was also found that the bullet entered the rifling after passing through the smooth section without the least signs of any stripping action, and emerged from the muzzle with the perfect engraving of the rifling upon its bearing surface. So under the clarifying light of analysis half the difficulties of high-velocity experiments vanish like mist before the morning sun. But all experiments must have a beginning, and the most simple were used to make us respect this analysis when they were completed.

The High-Velocity Experiments—An unnecessary difficulty has been experienced in the failure to understand properly the fin reduction on the bullets shown in Figures 16 and 17. The fins are drawn down and folded so neatly in the recess cut out of the cylindrical diameter, that they will not be broken or partly destroyed during their passage through the bore, especially if the bullet has been made of brass or bronze and turned from the solid bar. These two materials are, to a certain extent, satisfactory for the construction of bullets for experimental firing trials; they are the materials all bullet experimenters have selected as far back as I can remember. Brass and bronze have been used for more than half a century in the construction of experimental bullets, due in part to their softness and easy working qualities on a lathe. But why should high-velocity experimenters favor these two materials when they know that accuracy cannot be obtained—that there is nothing to keep such a bullet stable in flight over long ranges? Of course, accuracy can be achieved by the employment of electrolytic copper. The closer the material comes to having the specific gravity of pure silver, the more stable our bullet becomes in flight; therefore, a copper-nickel alloy is the more appropriate material to use.

On the other hand, the methods of making bullets from materials most suited for ultra-high velocity

experiments are as varied and infinite in number as the materials themselves. In these experiments it became our duty to select the materials which would give the best results, and then these were to be given our further consideration after certain velocities were reached; for the deeper our experiments went, the harder became our problem of holding the fins in the recess after a velocity of 4000 f. s. was reached, and the more valuable became the copper-nickel alloy not only in securing stability in the bullet but in keeping the fins intact when folded down in the recess.

Regardless of the materials employed, the true explanation lies in the fact that the proper method of securing a high velocity does not lie in the design of a bullet containing either one or two fins. The proper solution lies in a mechanical reduction of a material moulded upon the bearing surface of the bullet. Thus Figure 17 illustrates the fiber base, upon which the powder gases will act effectively within a given time, and burn it as fast as the mechanical reduction takes place through the tapered cone or expansion chamber, which can be seen in Figure 19. By this mechanical reduction, and the complete ignition of the plastic material, the bullet is delivered into the reduced bore diameter. Fins placed upon bullets offer great resistance to velocity. In our firing trials, we soon discovered that even the fiber base had certain detrimental effects; later we used bases made from a compound of celluloid and resin, and more stable results were secured.

The useful knowledge gained through this discovery led to the possible application of a plastic material moulded to the bearing surface of the bullet, thus eliminating the fins entirely. Along with this discovery we were able to analyze the possibility of such a practical material in its scope and popularity in industry. It can easily be moulded to the bearing surface of any projectile in special dies, by using either of two thermoplastic materials—cellulose nitrate and cellulose acetate.

Cellulose nitrate is made by the action of a mixture of sulfuric and nitric acids on cellulose, which is thereby converted into nitrocellulose. Nitrated cellulose containing 14 per cent of nitrogen is highly explosive, but for use in moulding it to the outer surface of a projectile the nitrogen content could be controlled at around 12 per cent. By incorporating a slight amount of camphor it could be made a valuable material. The camphor would act as a solid solvent dissolving the nitrocellulose fibers and converting them into a solid solution.

Cellulose acetate, like nitrocellulose, is produced in rods and tubes, but its greatest interest here would be to mould it to the outer surface of a

projectile by working it in hot moulds with no risk of fire. It is also adapted for the process of injection moulding, in which the moulding material is heated until plastic and then forced under high pressure through a small aperture into a cold mould which would fill completely and could be ejected immediately.

Up to the present point we have been dealing with materials, not with experiments. Experiments under all combinations of mechanical conditions in a chapter of this kind would be impractical, for we have over 10,000 words of experimental data, and since such data would probably be misleading, only the mechanical aspects of the experiments will be given.

We will now fix our attention on Figure 18, which illustrates the first experimental type of barrel made. In this type of two-sectional barrel, it was reasoned that since the pressure of the powder gases acts equally in all directions, and since the rear portion of the caliber .30 barrel of

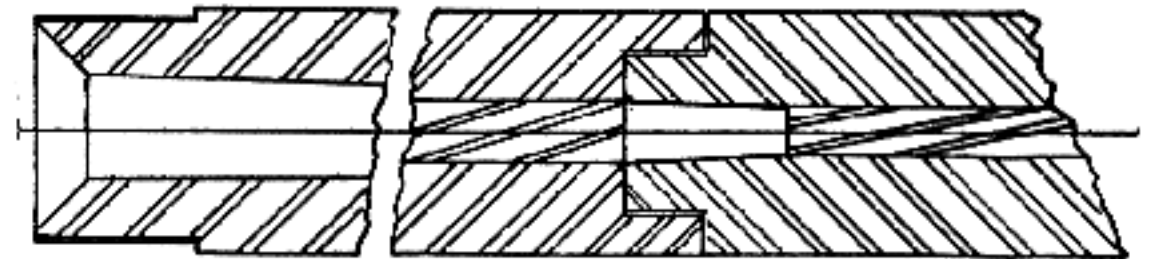


Fig. 18

The experimental two-sectional barrel. Here, a caliber .30 barrel has been attached to a caliber .22 barrel

a length of 12 inches is screwed to a caliber .22 barrel, the caliber .30 barrel would act as a gas-expansion chamber, which would give a greater opportunity for the gases to expand and in which a faster-burning powder could be used, while at the same time it would create less frictional resistance, especially at the first few inches of the bullet's movements.

The joining end of the caliber .22 barrel had a smooth cone, reamed to a length of $1\frac{1}{4}$ inches. The 12-inch length of caliber .30 barrel was fitted to a Springfield Model 1903 receiver, and the chamber reamed to take a caliber .30 Model 1906 cartridge case. When this experimental gun had been completed, it was loaded with the two-fin type of bullets weighing between 60 and 65 grains, and these were fired at a large piece of paper 50 feet from the muzzle. The shots upon the paper proved that the bullets were very unstable, for many passed sideways through the paper. Bullets were then fired into cotton waste; many were found intact; others had parts of their fins missing, which were believed to have been torn off by the recovery medium. Then a pressure gauge was mounted on

the same gun, and fired for pressure and velocity. Though we loaded our cartridge cases with standard military powder, filling the case even to the base of the bullet, only a pressure of 21,000 pounds per square inch was recorded.

Broadly enunciated, the conclusion that we came to regarding this experimental design was that the caliber .30 barrel was too long, causing the bullet to tip in various directions along its course; upon entering the cone in the caliber .22 barrel, it folded down its fins in a sort of resizing operation, and was not capable of taking a direct course in the rifled portion of the barrel. It was even impossible to find a suitable powder; some of the fast-burning powders were used, together with the improved military powders of both Dupont and Hercules manufacture, but they were unsatisfactory, and so were those used for the Gerlich experiments. So the result of this experiment confirmed our conclusion, there and then, that such an auxiliary chamber could be eliminated, and that other means should be sought to reduce the fins on the bullet before it ever entered the rifling.

From this starting point furnished by our own researches we proceeded to collate the knowledge we had gathered, and began trying to push it further; for knowledge once gained casts a faint light beyond its own immediate boundaries. There is no experiment so limited as not to illuminate something beyond itself. With this thought in mind, steps were taken to make three special barrels, each having six lands which measured 0.046 inch wide, and with rifling one turn in 10 inches, one in 12 inches, and the other in 14 inches. The barrel blanks in question were selected from forgings already drilled for the caliber .22 M2 rifle. The steel used in such forgings was W. D. 1350, which was heat-treated and had a tensile strength of 130,000 per square inch.

After the barrel blanks had been rifled, the exterior diameter was just cleaned up on a lathe and the barrels allowed to remain their full length of 24 $\frac{3}{4}$ inches. After completing this operation they were chambered for the cartridge case, and all three fitted to receivers. A pressure gauge was fitted to the barrel having the rifling which had one turn in 14 inches, while the barrel having the 12-inch rifling was used for our accuracy trials, as well as the one with the 10-inch rifling. In each of these barrels, a taper was reamed ahead of the chamber for a distance of 2 $\frac{1}{2}$ inches, which we then termed the "reduction cone" or "expansion chamber."

Out of the experience gained in the two-sectional gun there grew something that stirred the imagination more than a mere experiment; and this ob-

servation at our very fingertips, so to speak, provided material for speculation upon the barrels we had now completed. We reasoned thus: That a finned bullet could be reduced in diameter by a long tapered cone, in the same manner as metal is formed in a tapered die, provided the taper is long enough to fold the metal without breaking it; the long tapered cone would do just that, if our metal had the proper ductility in the beginning to form it properly. We also disregarded the established rule of having a bullet enter the rifling after leaving the mouth of the cartridge case, thus setting forth to investigate some difficulties of a nature quite different from all those connected with the established rules of barrel design; for the bullets which had been fired from the two-sectional barrel proved, when recovered, that they did take the rifling without stripping. Now, having reamed a much longer taper in our new barrels, we would not be resizing our fins into the recess so suddenly as we did in the abrupt taper in the two-sectional barrel, but in a gradual degree by the length of taper established; allowing, at the same time, the tapered cone to act as an expansion chamber for the powder gases. Figure 19 illustrates this taper, in which the resizing operation takes place, aided by the force of the powder gases.

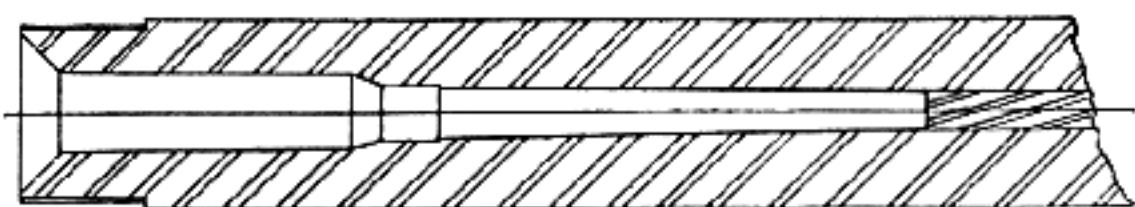


Fig. 19

The tapered cone or gas-expansion chamber constructed ahead of the cartridge chamber

Enough had been shown in the illustration to indicate that such a design had some possibilities. When our first experimental firing trials took place, the pressure gauge with the barrel possessing the 14-inch twist was used, and by loading our cartridges with Hercules No. 3 powder, and using the two-finned bullet of over 60 grains, we were able to secure velocities between 3650 and 3800 f. s., the pressures ranging between 46,800 and 56,800 foot-pounds to the square inch. Not very encouraging, but very gratifying for our firing trials with the short taper, which was increased in length after the one-fin bullet was adopted.

All who are engaged in small-arms research are painfully aware of the time consumed in the preparation of bullets and barrels, in the elimination of possible errors in design, in the testing trials, etc., and the disappointments which follow. How much ingenuity and thought are involved in bringing a

gun and its ammunition to perfection! How much more than mere expression of the idea on paper! Persons working on small arms and small-arms ammunition often experience much impatience and overexcitement, in pursuits with a very narrow range of certain possibilities, whose importance, to outsiders, appear to be trivial and contemptible. The outsider does not see the possible results coming from these carefully undertaken preparatory measures. And it was at this stage of our tests that we investigated the pressures required to fold down the fins into the recess, for here, we imagined, was what was defeating our efforts to secure a higher velocity.

The results of our investigation were very surprising. From previous tests we knew that it required between 1000 and 2000 pounds to the square inch to force a caliber .30 bullet through a barrel; therefore, we set out to investigate the pressure it required to force a finned bullet through the tapered cone we had reamed in our experimental barrels. To accomplish this, the breech end of a caliber .22 barrel was cut off to a length of $5\frac{1}{2}$ inches, and by using the same reamers as used for the tapers in the barrels, a taper was reamed to a length of $4\frac{3}{4}$ inches, leaving $\frac{3}{4}$ inch of rifling remaining on the bottom end. By using a tensile testing machine, our turned bullets were pressed through this section of barrel, all with high recording pressures, until we discovered that the section of barrel had been bulged near the bottom, and the proper results were not secured. Then a steel die was made of the same length, but out of a 2-inch piece of steel, and hardened, which would require a great pressure even to crack it with the largest-diameter bullet. On one of the two-finned bullets we found that it required a pressure of 65 tons to force it through the die; that is, through the tapered section before entering the cylindrical diameter. Of course, many were found which required much less pressure to force them through the die, but all required a pressure far too high, at that, to force an ordinary bullet through a rifle barrel. A little reflection convinced us that we had been using bullets which offered too great a resistance to the powder gases, and that we would have to design a turned bullet which would pass through the die with no greater pressure than 500 pounds to the square inch, in order to secure more satisfactory results.

Obviously what was demanded was a bullet with only one fin; for those with two fins, even though they were made light in the web thickness of the fins, required too great a pressure to force them through the die, and the die must be used as a gauge to set the tools in the turning operation,

regardless of whether a one- or a two-fin bullet was used. The turning operation on even the one-fin bullet was not so easy as one may think, for though it might be possible to go straight under the fin with a turning tool, and though stops could be set to secure the proper measurements, the delicacy of the turning tools required, and the smallness of the diameters to be worked upon, were bound to cause variation in sizes. Overcoming all such difficulties after a considerable period of preparation, we made a number of the one-fin bullets by setting the proper stops on the bench lathe so that all were turned to give the same pressure when forced through the die. Figure 17 illustrates this bullet, the fin acting as no more than a gas check. The sectional view of the object over the base of the bullet is the fiber base, which was turned from a solid rod and forced over the base of the bullet in order that it might be held centrally in the cartridge case—also as a means of holding it centrally in its passage through the expansion chamber or tapered cone.

Having completed a number of the one-fin bullets on a bench lathe, and also turned the fiber and celluloid bases and fitted one of these over the rear portion of each bullet, we next made pressure tests by forcing the assembled bullet through the die, centering a punch only on the base of the bullet, and found that these bases contracted and gradually slipped off the rear of the bullet as it passed through the die, so that no false pressures were recorded. Firing trials were then conducted for pressures and velocities, and surprising velocities between 5122 and 7100 f. s. were recorded; but not until we had reamed the expansion chamber to a length of 5 inches, which proved to us that a certain length of expansion chamber must be established, varying with the caliber of the guns.

Having completed our high-velocity experimental tests in such a satisfactory manner, we felt that perhaps we had reached a very valuable conclusion. Many ideas came to mind, urging us on toward further progress, particularly in testing the effects of these velocities from scientific angles—even velocities reaching beyond 7000 f. s. The direction which all these experiments took, leads us to believe that a much higher velocity in small arms can easily be attained. Success must ever depend mainly upon the amount of refinement necessary in the direction which we have already explored. Ballistics has long been an all-absorbing study to many, for our senses stand between the law of motion and the reasoning mind. We can observe the motion and the force required to impart that motion, but are not satisfied with mere observation: the facts must be accounted for—fitted into

their proper places in the line of cause and effect, and applied to the practical development of weapon and ammunition.

Curious Bullet Effects—Let us now cast a momentary glance over the targets we left behind. We found that we had acquired some valuable information from the results of bullet penetration through heavy wrapping paper stretched over a wooden frame; furthermore, we had gained a much clearer insight into the mechanics of bullet penetration through other substances. Our first findings were the peculiar perforations surrounding the bullet holes through paper, the even spacing of "air holes," and the discoloration surrounding the apertures the high-velocity bullets made. Of course, we have seen a similar condition produced by the .22 Swift bullet through targets; but in our case the perforations were burnt through as though hot sparks had issued from the outer surface of the bullet. One might surmise that the bullet was throwing off small particles of its fins, which were causing these burnt-like holes, but this theory was soon rejected. We assumed that the small perforations were caused by the rapid spinning of the bullet around its axis, which in turn was forcing the air molecules apart, and thus causing them to act as solid minute substances in a broken state, capable of penetrating the paper for a radius of about $\frac{3}{4}$ inch from the bullet's center of perforation. And the discoloration around the bullet hole might have been caused by gases expelled by the heat of the bullet due to the friction of the air, similar to that of a meteor as it hits the solid atmosphere. The bullet also tore the paper surrounding the aperture it had made, instead of showing the clean penetration which a bullet of a lower velocity makes. This was caused, perhaps, by the anvil of air being forced ahead of its point, and the evenly torn surface around the aperture had been completed by the vacuum following the bullet.

The emission of gases from these high-velocity bullets, which are very hot during their passage through the atmosphere, is, of course, the result of friction. Should we establish a standard velocity of 6000 f. s., this friction might heat the outer surface of the bullet to nearly 1500 degrees Fahrenheit; in other words, above a red heat. The greater portion of the heat is doubtless carried away by the vacuum created, but what it has gained, it keeps, and remains at a high temperature over a long range. If a bullet thus heated to a high degree, and traveling at a high speed, hits an object, it will perhaps explode, as a meteor does when it hits the atmosphere surrounding the earth. The

short period of time occupied by such a bullet in passing through space allows only a thin superficial layer of the outer metal to be heated, and only a small quantity of the heat is able to penetrate to the interior; therefore, the outer layer of heat tempers the core, and coming in contact with a steel surface, the mass generates such a high degree of heat instantaneously, that the surface of steel plate is fused and melted to a considerable depth, as if it had been up against the flame of an electric arc. At present there is little prospect of this theory being proven incorrect.

In mechanics, the product of the mass of a moving body into the square of its velocity, expresses what is called the "mechanical effect." If, for example, an anti-aircraft gun, pointed vertically, shoots a shell upward with twice the velocity imparted to a second shell, the former will rise four times the height attained by the latter. If directed against an airplane, it will also do four times the execution. Hence, the importance of imparting a high velocity to all classes of projectiles in war.

Having thus cleared our way to a definite conception of the mechanical effect of a moving projectile, we are prepared to look back to the last battles of the First World War, and to note the attempts which have since been made to lengthen the flight of all projectiles. With such an object in view, means must also be invented to control such projectiles over long ranges, especially in the case of large cannon; not, however, in the case of anti-aircraft weapons, for that would be like using a high-velocity rifle to shoot a hawk on the wing. We must remember, moreover, that each war has its good and bad points in the weapons employed, as well as the weaknesses of those weapons, and that by the time a new war starts, most weapons are obsolete; therefore, in our hurry, we only make slight improvements on those which are obsolete.

The advantages of a light bullet, a high velocity, and a flat trajectory, are the objects to be sought. The value of these, however, must not be overestimated. Though we believe in a high velocity and a long range, we must never sacrifice projectile striking energy at these long ranges, for it is one of the most essential features: after reaching our objective, we must also annihilate it. The great discoveries in which a high velocity shall play a part can only be accomplished by surveying the problem clearly.

In trying to annihilate enemy aircraft over large cities, our ground troops must be protected by defensive armor like that used by soldiers four centuries ago.

CHAPTER VII

Gunpowder and Its Influence

EVER since the two volumes of *The Modern Gunsmith* were published, from one direction or another have come various requests for the formulas for making black gunpowder, smokeless powder, gun-cotton, T. N. T. (trinitrotoluene), fulminate of mercury, and even nitroglycerine. We seem to have some difficulty in understanding the motives of these requests. Naturally, we can understand that there are hundreds of experimenters seeking a propellant of much higher velocity; but surely not, likewise, a sudden opportunity for Saint Peter to make a check on their past actions.

My answers were always rather discouraging, but since we have read so much about high explosives in the dispatches from the front, we might as well go into the subject at greater length in a non-technical manner so that all may understand it.

Obviously, a low explosive like gunpowder burns by a process of rapid combustion. It is a flashlike fire. A high explosive does not burn. It detonates. It is converted into a stable gas, which proceeds by a detonation that varies from 15,000 to 25,000 feet a second. It takes about one ten-thousandth of a second for a typical 1000-pound air bomb to detonate. In other words, the high explosive is suddenly converted into a gas at very high temperature and pressure. The effect is that of a sudden and terrific blow.

To arrive at a better understanding of the inventor's affection for a higher explosive, we are going to reply at length to many of our correspondents, and we select nitroglycerine from among the high explosives to enlarge upon its impossibilities as a propellant.

Nitroglycerine as a Propellant—Many inexperienced shooters are as convinced that nitroglycerine can be used for a propellant as they are that the sun can be harnessed to store heat energy "for commercial purposes," as one man wrote us. We answer such experimenters that this explosive has great convertible power, of course, but it has no value whatsoever as a propellant. If exploded in the chamber of a rifle barrel, it would completely demolish the receiver, and possibly the chamber end of the barrel, before the bullet would ever move from the mouth of the cartridge case. There is,

first of all, no logical means of confining nitroglycerine in a cartridge case even in a weakened state; and there is, secondly, the space between bullet and load, and across this space is found an anvil of air. The gases collide, they oscillate, and suddenly recoil. When this action takes place, we may expect a change in the metals, which would mean the complete loss of the gun mechanism.

There is a great amount of misinterpretation in regard to the limit of propellant force behind all classes of projectiles. Inventors are constantly seeking information to formulate more powerful projectile agents as a means of obtaining increased velocities, but a careful study of the mechanical arrangements of our modern firearms and cartridge cases will prove, not only that our present propellant agents are ideally adapted to our modern weapons, but that their energy and capabilities far exceed the tensile strength of the metals confining the gases generated. The experimenter of an inventive turn of mind should be convinced that what is needed is not a stronger propellant, but newly designed weapons, cartridge cases, and projectiles which would improve and encourage the "mechanical effect" and thus obtain greater velocity from the powders now on the market. I do not mean to say that a better propellant cannot be made than those now in use. But our present powders are by no means deficient in potential energy; what we need is to convert their complementary force and give them greater expanding energy on the opposite side of the pressure curve.

Select any of our modern rifle powders from the long list, and you are certain to secure a volume of gas that would normally occupy a space three or four hundred times that of the rifle chamber. As the grains of the powder are rapidly decomposed, and are still in a perceptive mood, they are gradually expanding as they follow the bullet a certain distance up the barrel. On the other hand, nitroglycerine, when detonated, releases a volume of gas one thousand times greater than that now used, and it is set off instantaneously. In order to appreciate the difference of effect, such an experiment would have to be made in free air. Yet it would be found that the free air would be pressing with enormous weight and mechanical force, equally on all sur-

faces surrounding the detonation. In such a sudden detonation, say of nitroglycerine, the gas must lift the whole weight of air pressure, which is similar to the weight used in a pile driver. Such a large block of metal cannot be lifted without the help of a powerful engine. For example, then, if we should detonate a small quantity of nitroglycerine yielding a cubic yard of gas, it would lift the pressure on one square yard of air, or about 50,000 foot-pounds, which is equivalent to the pressure developed in a service Springfield rifle chamber. This sudden volume of gas would be equivalent to a blow by the force of the atmosphere against the weight; or, a more apt illustration: The air would become the greater mass, and would act as an anvil; therefore, it would become a forced blow by the air against the weight.

For the sake of comparison, let us consider the action of improved military gunpowder under the same conditions. It would yield only one-third the volume of gas that nitroglycerine would yield, and would raise the same weight only one-third as high; it would be doing only one-third the amount of mechanical work, but it would be a much better propellant force. The gas generated from gunpowder requires one hundred times longer to get into action—to release all the gas confined in the powder grains—than does the gas of nitroglycerine; and under such circumstances, it is easier to lift the weight than the air.

For the sake of discussion, we will now consider the pressure of air against any broad surface; for instance, a block of wood which will measure one cubic foot. Naturally, such a block is equal on all sides. When it remains still, all the air molecules have freedom of movement around it; when we move it slowly forward, we encounter a slight resistance. If we push the block rapidly forward, the resistance of the atmosphere increases, for we have not given the air molecules time to change their position, and they have retarded the block. If we were to increase the motion to the highest speed ever attained by a racing car—say, six miles per minute—there would be encountered still more molecules offering resistance, and considerable friction. Increase that velocity ten times, which is sixty miles per minute, nearly four times the velocity of sound, and the block of wood would disappear in dust. Multiply again the velocity ten times, and not even a plate of steel $\frac{5}{8}$ inch in thickness could withstand such resistance, for we have now reached a greater velocity than that of the earth as it passes through space; but the comparatively dense air at the earth's surface would present an almost impregnable barrier against the hardest piece of metal, and it would be burnt up by friction when hitting such a barrier.

So, in the case of the detonated nitroglycerine, when the weight of the metal in the pile driver strikes the atmosphere with such a velocity, it has the same effect as that of hitting a solid anvil, and the metal block may be fractured by the sudden blow.

Black Gunpowder—We shall again fix our attention on the gunpowder which urges a bullet in flight. This is composed of combustible matter which, if burnt in the open air, would yield a certain amount of heat. It will not yield this amount if it performs the work of urging a bullet from a rifle barrel. The heat in the latter case will fall short of the heat produced in the open air, by an amount equivalent to the weight of the bullet; but the original amount is again restored by the bullet on its collision with any object. This is not difficult of comprehension, especially if the bullet is instantly recovered after hitting a hard obstacle, as many shooters have painfully discovered. In this perfect way are heat and mechanical motion connected.

Most high-school boys have tried to make black gunpowder at some time or other with varying degrees of success. My own experiments usually led to a large puff of smoke, a bad smell, and no harm to anyone, until I thought of confining the mixture in a heavy piece of pipe with one end welded shut. Over it I rammed a lot of newspaper and a heavy lead slug made out of a piece of water pipe. This contraption was then aimed at the rear of an out-house ten yards away—one of those places which had a crescent moon cut out on the north and south sides for ventilation. After the smoke had cleared away, and I had recovered from the explosion, I ran to examine the effects of the bombardment. The lead slug had gone sideways, so it seemed, for it had made a hole in one of the boards which I could have put my head through, and had torn off a large board on the edge of the door on the opposite side, together with the button which kept the door closed. It was very fortunate that no one was in the place at the time, as this possibility had never occurred to me. But it was not long before the damage was discovered, and I was accused of destroying property with a pickax. This I acknowledged, and took the licking I so richly deserved. The experimenter will usually owe his safety to his invariable lack of complete success, but if he compounds his black gunpowder correctly, as I had mine, it is capable of doing a lot of harm, especially in the hands of a high-school boy with no common sense and a lot of sporting instinct.

One thing is quite certain: If charcoal, saltpeter and sulfur are ground very fine and mixed together, and if this mixture is not successful as an explosive

when confined, we have at least done our best, for we have produced a glorious blaze and a horrid smell. But to make the compound really successful, the mixture is wetted and pressed into cakes and dried, and when dry, broken up into small pieces and ground to the size of grain desired. The precise proportions of the materials seem to vary a great deal with various makers, but generally speaking there is about 75 per cent of saltpeter (potassium nitrate), 15 per cent of willow charcoal, and 10 per cent of sulfur.

Black powder, like all explosives, is simply a mixture of certain elements which are capable of burning very suddenly when ignited. When the furnace fire has been started, we let in plenty of air to encourage the process called combustion, or the generation of light and heat by the chemical reaction of oxidation.

What really takes place in the furnace is that the carbon confined in the coal enters into combination with the oxygen from the air, and the two together form the compound called "carbonic acid gas." There is nothing lost or destroyed in this process; the carbon and oxygen have simply been changed into the new substance, and if we were to weigh the gas produced we should find that it agreed precisely with the weight of the carbon and oxygen consumed. Naturally, a fire is required to heat our home, but the chief feature of this process is not the forming of gas, for that simply goes off into the free air through the chimney; the important thing is the heat which is released. The heat is hidden, locked up, "latent" in the coal; we cannot feel it nor can we perceive it in any manner, but it appears as soon as we allow the carbon to combine with the oxygen.

To most minds, however, the energy of heat presents itself as a thing totally distinct from ordinary energy. When we apply the match to the fuel, all we do is to set up the conditions under which carbon and oxygen are able to follow their natural instincts. By the friction of wood a savage can raise it to the temperature of ignition; by properly striking a piece of steel we can cause it to glow, and thus generate heat.

A coal fire burns slowly, for the simple reason that ignition is only at the surface of the lumps; it is only there that carbon and oxygen are in contact. But if we grind up the coal, as Dr. Diesel did, into a fine powder, and then blow a cloud of it into a cylinder of compressed air, so that every minute particle is surrounded with air, a spark will cause an explosion. And if the cylinder were made of glass it would be shattered into minute particles.

To cause an explosion, even in a small mass, we require fuel, just as we do to make a fire; but the mass must be intimately mixed with oxygen, so that

it can burn completely in practically a single impulse. In black powder we obtain these ideal conditions. There is the carbon in a definite form, and the sulfur which likewise burns readily, and in the potassium nitrate (saltpeter) the requisite oxygen.

At all events, it is plain that we do not need to speculate upon the furnishing of air for the oxygen, for the powder thus compounded possesses it, confined in the potassium nitrate. Surely, we now can understand why it is so important that all the elements be ground very fine, for only by this means can every particle of the ingredients be put into close relations with each other, so that they are ready to furnish the necessary amount of oxygen when ignited. Then, every particle is pushed against its neighbor and forms a gas with extreme rapidity, so that the bullet is propelled so fast from the muzzle of the barrel that the eye cannot detect its presence as it speeds toward the target. It is well to remember that all substances whose names begin with "nitr-" contain nitrogen: while the termination "ate" signifies the presence of oxygen. Thus we need the oxygen, not only in the primer mixture, but also in the powder, to cause the explosion. We make no direct use of the nitrogen, yet it has to be present, for without it the oxygen would be too slow in forming the essential gases.

Nitrogen is one of the strangest substances on this earth. Alone, it is extremely lazy, but it has the faculty of hurrying any other group of elements which are specifically radical. Whenever it is possible to have nitrogen gas enter into combination with other elements, it is well to look out for some extraordinary activity of an explosive sort.

Let us now turn our attention to the spark that we may apply to a quantity of gunpowder. This spark passes among the particles in which we have set up an ideal condition for the combining of carbon and oxygen. The result may be anticipated. The nitrogen acts upon the oxygen which has been stored in the nitrate, and a sudden burning is the result. Here, then, our gunpowder is suddenly changed into a volume of hot gas; that is to say, one cubic inch of gunpowder has been suddenly changed into 2500 times its volume, and we now have what we term an explosion. If this takes place in an enclosed space, so that the gas cannot expand as it wants to, the result is a pressure of so many tons to the square inch exerted in all directions. And if this enclosed space is the chamber of a gun, that energy or working power is available to force the projectile from the barrel, measured in so many feet per second. And if the bullet is shot upward at any desired angle, it consumes the actual energy which the gases were capable of producing, together with the stored-up potential energy. When it

reaches its utmost height, all of its actual energy is consumed, its potential energy being then at its maximum.

Black powder, of course, is very seldom used now for sporting purposes, but it still has some special uses in warfare. Because of the great amount of smoke, such powders are not used for military operations today; all powders are of the smokeless type, and known as the improved military rifle powders. The reason why black powder makes a dense smoke, is that the burning which takes place is very incomplete; therefore, more than half a century ago, attention was fixed on the producing of powders that would burn more completely.

Smokeless Powders—One of our best-known smokeless gunpowders is a double-base powder, the basis of which is nitroglycerine. This was one of the first to be successfully used in military small arms, and its main ingredient is glycerine.

Glycerine consists of carbon, a lot of hydrogen, and some oxygen. These are not merely mixed together, but are in chemical combination, just as oxygen and hydrogen are combined in water. Both carbon and hydrogen will combine with oxygen and give off heat in the process, but in glycerine they are already dexterously united. Glycerine itself has no value as an explosive, but if we bring nitric acid and sulfuric acid into contact with it, an affinity takes place, and two new combinations are formed, one being water and the other a compound containing carbon and hydrogen, a considerable amount of oxygen, but most important of all, nitrogen, that restless element to be feared.

The term "force" has been for some time creeping upon us. We now apply it to nitroglycerine, a particularly dangerous explosive (as we have already pointed out), for nitrogen seems to be so uncomfortable in this mixture that at the least provocation it will tear apart the whole combination, liberating a mass of free atoms of carbon, hydrogen and oxygen, all seeking molecular attraction, which may be called chemical affinity, and all set for a glorious detonation.

So untamed is nitroglycerine that it was almost useless until Nobel tamed it by mixing it with an earth called Kieselguhr, which reduces its sensitiveness sufficiently to make it a safe explosive to use. To this mixture Nobel gave the name of dynamite.

It becomes interesting at this point to compare the action of nitroglycerine with that of black powder again. The latter is only a mixture: the former a chemical compound. The smallest particle of the typical black powder contains millions of molecules and a still larger number of atoms; but when nitrogen breaks up nitroglycerine, just before the actual

detonation takes place we have but a mixture of single atoms; therefore, the burning is quicker and more thorough, and a moving force collides with the atmosphere.

Gun-Cotton—Another well-known explosive is gun-cotton. In the early stages of its discovery, many attempts were made to use it as a substitute for rifle powder, as it possessed the advantage over all other powders of burning without any perceptible residue and also without any smoke. It seems very strange, but is perfectly true, that nitrogen can turn glycerine into dynamite, and can also turn cotton into gun-cotton. Cotton consists mainly of cellulose, a compound of carbon, hydrogen and oxygen, which has no tendency whatsoever to change into anything else, least of all to explode in its natural state. But that state of things naturally changes when we employ nitrogen to hasten the action of the other elements.

In actual manufacturing practise, cotton, pure and clean, is dipped into a mixture of sulfuric and nitric acids whereby the cellulose is changed into nitrocellulose, just as a similar process changes glycerine into nitroglycerine. Naturally, the whole process of manufacture is far more complicated than that of simply dipping the cotton into the acid tanks, but this is the fundamental process. The greatest problem is to eliminate the superfluous acid before reducing the mass to a pulp and pressing it into blocks. It is probably the safest of explosives, since it can be kept wet, in which condition the danger of an accidental detonation is practically nil, provided reasonable care is taken. Even when dry, one need not fear it. If ignited, it burns but does not explode—unless confined. The burning, that is to say, is not rapid like that of black powder.

When confined and exploded by a primer—by which is meant a cap inserted in the base of a cartridge case where a small quantity of a very hot explosive is confined, such, for example, as fulminate of mercury mixture—the result is a swift formation of gases which leaves little to be desired in a modern load for small-arms cartridges.

Powders made either from nitrocellulose or from nitroglycerine, of which gun-cotton is the basis, will produce four times greater explosive effects than black powder; for the density of smokeless powder is less than that of black powder, and therefore the weight for the same volume is less. Nobel also discovered, in 1866, that if the proportion of nitrocellulose was approximately equal to that of nitroglycerine, and the materials were incorporated by rolling the pressed blocks between hot rollers, he thus obtained a suitable rifle powder. This is now called a double-base powder because it contains

both nitrocellulose and nitroglycerine. The single-base or nitrocellulose powders were bulk powders and were originally designed to load on the bulk-for-bulk basis with black powder.

By combining various substances or elements, various characteristics can be secured in the propellant. The propellant must not be too sudden in its action. It must have a steady, expanding force. Its purpose is to drive the bullet; therefore its action must be slightly delayed but continuous while the bullet is still in the barrel.

The primer or detonator, which is located in the base of the cartridge case, must be indeed sensitive when hit by the striker or firing pin; yet it must be absolutely safe, so that it can be handled by all classes of people with very little risk of exploding. I have seen heavy trucks flatten out loaded ammunition as thin as cardboard, and have never known of one primer exploding under such hard treatment. But a sudden blow by the striker makes a vast

difference. Of course, primer mixtures vary, but fulminate of mercury is often employed for this purpose, together with meal black powder, potassium chloride, antimony sulfide, etc.; but in all combinations of which they are made, nitrogen figures largely in the mixture.

Uniform Loading—One thing may be mentioned in relation to powders and primer charges which is of the greatest importance to those who use a lot of ammunition. The manufacture of ammunition demands not only the best of chemicals but also the utmost *uniformity* in the loading operations, so that when a sportsman inserts a cartridge in a gun chamber he can rely upon its throwing each bullet nearly to the center of its predecessor. A target shooter seeks to throw bullet after bullet within the center of the ten ring, which would clearly be quite impossible if one powder charge were heavier or lighter than the other.

Gauging the Wind in Shooting and in Rifle Testing

WE HAVE been firmly convinced for a number of years that all shooters, together with the technicians testing arms and ammunition for accuracy, tend to overestimate the strength of the wind upon bullets in flight. We believe we can show to a reasonable degree of satisfaction that any shooter or technician who estimates the velocity of the wind while at the firing point is almost certain to make a bad guess, especially if the wind is strong.

To begin with the negative (as naturally the first in order to clear the ground for the other): I have no belief in any perfect or ideally accurate gun or ammunition when fired against any weight of wind force; and as our philosophy of the subject is founded exclusively on firing-trial observations for a number of years from the proof house (a laboratory where guns and ammunitions are tested), and from the firing points of the rifle range, we are largely limited to firing-trial experience from these positions rather than on the range, where weapons are shot from the shoulder, and where we have to depend directly or indirectly upon personal observation. Also, we have no confidence in the duration of such accuracy as a gun and ammunition may actually possess under such circumstances. We have too often experienced that, in changing winds, the accuracy of the gun and its ammunition may be destroyed by causes over which we have no control. The two negative words best to characterize our accuracy in both rifle and its ammunition from this point of view are therefore the *imperfection* of the mechanical features of the gun and the known *uncertainty* of the wind pressure against all weights of bullets in flight. This law applies to all small arms and their ammunition without exception. There are very great differences in the degrees of accuracy when the human element and wind pressures are considered as factors, for under these circumstances the best of guns and ammunition are imperfect and the targets uncertain. The best results are those obtained with guns and ammunition upon a still, cloudless day, with the temperature at 72 degrees F.

On the other hand, the positive side of my belief in the accuracy of small arms and the human factors controlling all shooting results is as de-

decided, and as firmly rooted in reality, as the negative. I know from my own experience, and from the experience of many others testing arms and ammunition, that the accuracy of these arms is of the very best, and that we can all accept it as the best in our day and age; for the accuracy of the best grades of arms and ammunition is much closer, when tested from the proof house, than when the weapons are fired from the shoulder. Therefore, the owners of firearms have a chance to accomplish the best possible results under all shooting conditions; but first, a study of the wind conditions under which bullets make their flight to the target must be made.

It may help us to understand the question more thoroughly if we consider that there are two distinct ways in which the strength of the wind may be specified. It may be expressed in terms of pressure, or it may be expressed in terms of velocity. Both pressure and velocity are quantities which can be measured directly with instruments. But, lacking the proper instruments, the shooter is obliged to describe the wind solely with the aid of visual and sensory observations. The prevailing tendency among shooters, under these circumstances, appears to be to estimate the wind in terms of velocity. That is a mistake which we shall now attempt to demonstrate.

To gauge the speed of the wind correctly, we must be able to determine the distance which the air travels in a given time. Obviously this can be done without instruments (other than a watch) only when the drift of smoke between two fixed reference points separated by a known distance can be observed. These aids are not usually available on the range. It hardly seems necessary to indicate further the absurdity of attempting to estimate the velocity of the wind when the motion of the air is not visible.

Doubt has often been expressed as to whether it is of any use to concern ourselves about wind pressure at all in shooting. The less we think about it—the less we consciously aim to take it into consideration—the more probable it is, according to my own experience, that we shall never attain the honors that go with successful shooting. Those who wish to win all honors possible must face the

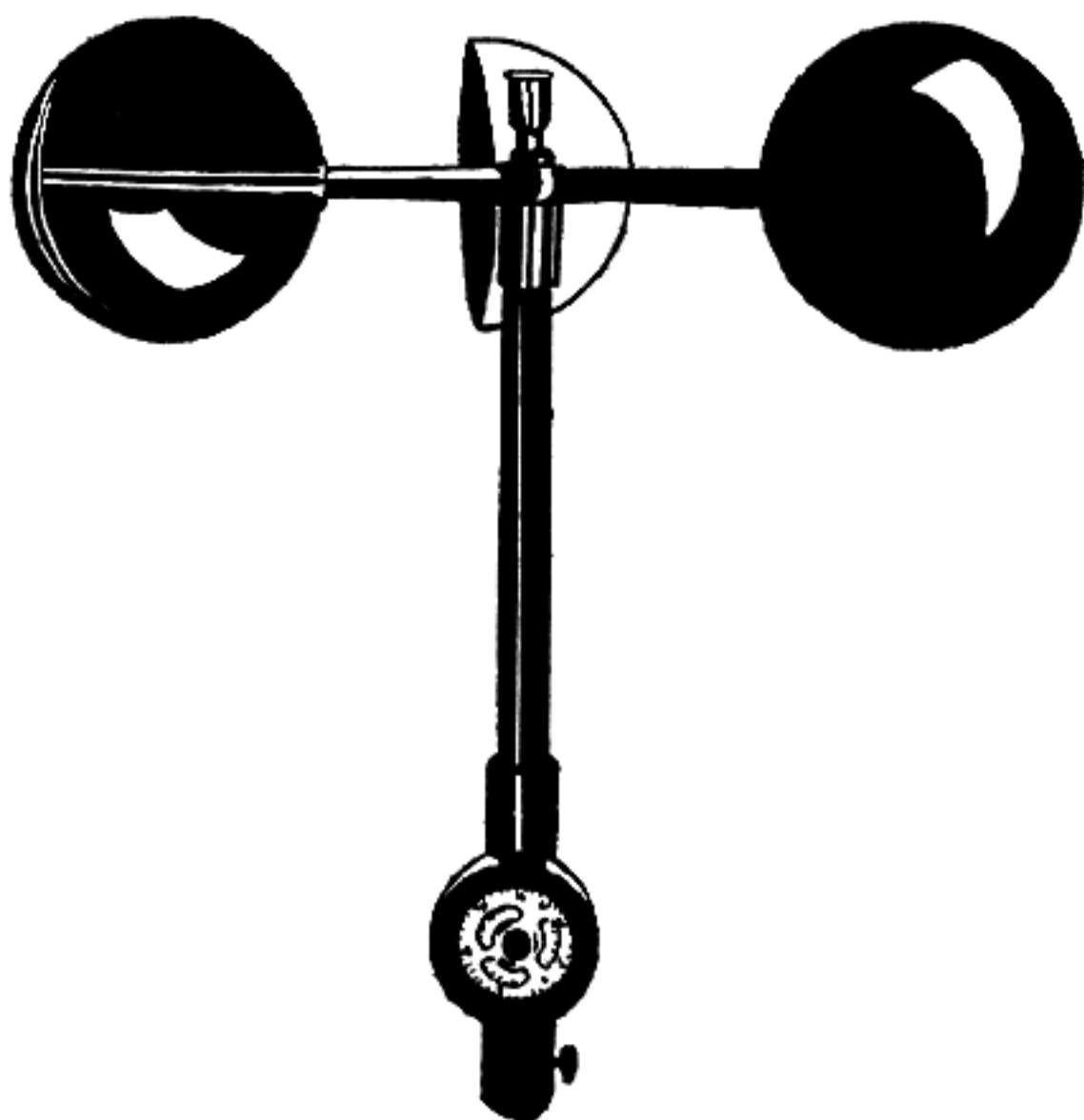


Fig. 20

All marksmen should have an anemometer in view to tell the force of the wind

fact that the pressure of the wind produces definitely observable effects upon bullets in flight. The behavior of a flag serves as a direct measure of the wind pressure, as does the degree of ruffling of the surface of a lake. Therefore, the logical way in which to describe the wind while on the range is in terms of pressure or force.

Because of the practical impossibility of observing visually the motion of the air, it is probable that most shooters formulate their velocity estimates from the perceivable effects of the wind pressure upon the grass and weeds between themselves and the target. Now, it would be perfectly legitimate to use these effects as a measure of the relative velocity if the absolute velocity were proportional in simple linear fashion to the pressure. Actually, however, the pressure is proportional to the square of the velocity, and on that account it is wrong to assume that the velocity has doubled because the "weight" of the wind has increased twofold. Certainly, this is the outstanding if not the sole reason why so many shooters tend to overestimate the velocity of strong winds blowing over any rifle range. Most of us have discovered how this can occur.

In like manner a shooter gauges the "weight" of a certain breeze by its effects on a specific weight of bullet. He later learns that an anemometer (shown in Figure 20) recorded the velocity of the breeze as 14 miles per hour coming from the direction of "3 o'clock," as shown by the wind gauge

(illustrated in Figure 21). The pressure brought to bear upon a bullet by a 14-mile breeze, whether coming from 3 o'clock, 6 o'clock, 9 o'clock or 12 o'clock, is approximately 0.75 pound per square foot. In like manner he is deceived by a breeze which, judging by its effects, has twice the weight of the 14-mile breeze against the weight of the bullet, so that he assumes it must be blowing 28 miles per hour. But the velocity of a breeze which exerts a pressure of 1.5 pounds per square foot is only about 20 miles per hour. The whole velocity, it must be said, has been overestimated by 40 per cent. For example: a wind which has three times the weight of a 14-mile breeze has a velocity of only 20 miles per hour. The relation between wind velocity and wind pressure is the effect of a slow, continuous change in the drift of the bullet in the opposite direction from that which the pointer of the wind gauge shows, except when it is blowing from the direction of either 6 or 12 o'clock.

The impossibility of realizing the ideal in shooting over long ranges will be seen at once, which proves clearly that in the interest of accuracy it is necessary to estimate the wind, whether upon the range or at the proof house, in terms of "force,"

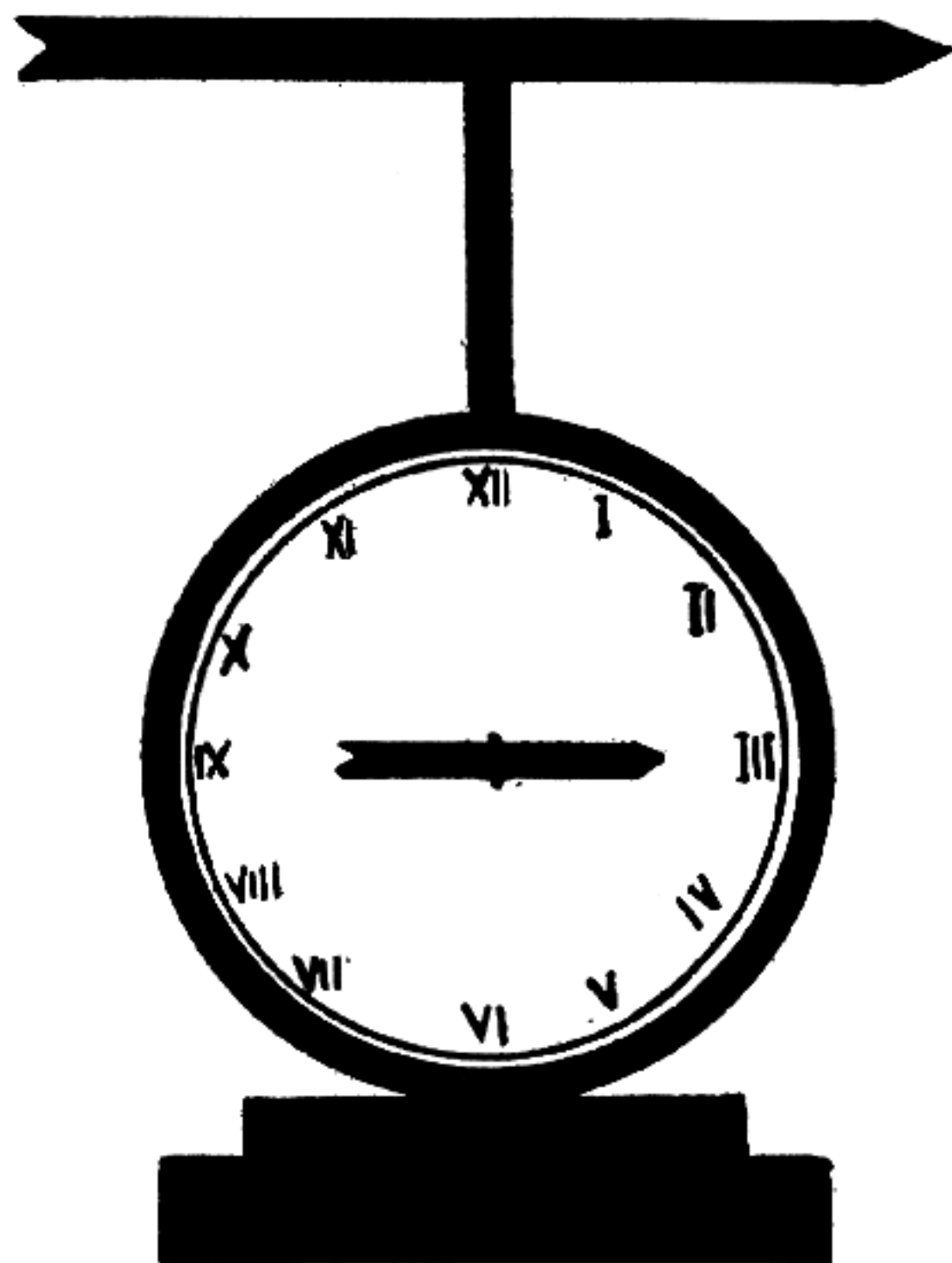


Fig. 21

A wind gauge also should be in view on any target range so that the changing direction of the wind may be observed

that is to say, in terms of the pressure brought to bear upon the weight of the bullet and the distance it is shot. The most usual practise, and the most favorable, although it is not adhered to, is to record the velocity of the wind, and later on convert this into wind force against the bullet over the distance it is shot. Too many target shooters, I believe, merely guess at the velocity of the wind, and never refer to any written record. Since this method amounts to putting the cart before the horse, and since it is never followed by the experts, the wisest plan for all beginners in target shooting is to really study wind pressures and their effects on all kinds of shooting. All the laws of nature can then be easily repealed, and the shooter can free himself of guess work and get down to reality.

The beginner in target shooting who has the sense of reality in nature is not surprised by wind phenomena, though he may at first disregard them and then seek some practical means of overcoming their evil effects. For him, as well as for other riflemen during the past century or more, it has been a natural force to contend with in rifle shooting. Men specified the strength of the wind through such descriptive terms as "calm day," "air gently moving," "breeze," "wind," "heavy wind," qualified by such adjectives as "light," "moderate," "fresh," "strong" and "heavy." Riflemen could not define these expressions concretely in terms of velocity, pressure, force, or the weight exerted against a bullet in flight. The evil done by the action of the wind on weeds and grass tops in front of the shooter, has caused him to move so many clicks on the windage screw of either aperture or telescopic sights, or to hold high, low, to the right or left of the ten ring's center on the target; yet this is as nothing in comparison with the good that can be accomplished by understanding the facts as presented by the proper instruments made for such purposes.

A correct estimate of the force of the wind cannot be made at the firing point by observing what the ground elements do, for a measurement of its velocity has little meaning unless it be translated

into accurate terms of pressure. Even the exposure of the anemometer must be taken into account if it is desired to convert wind velocities recorded by the anemometer into windage clicks.

It should now be clear that the determination of wind velocity equivalents into that of windage clicks, if indeed it is possible to say at all what limits can be rigidly assigned, is by no means a simple problem, for the reason that there is no unique relationship between wind velocity as recorded by anemometers and estimates to be made on windage clicks. But the rifleman without an anemometer is concerned only with availability of reliable methods of estimating the strength of the wind in terms of either velocity or force, that which deflects the bullet in its flight toward the target. As we have already pointed out, the logical way is to estimate it in terms of force, not velocity.

However, an enterprising rifleman with a scientific turn of mind could, if he were willing to take the trouble and shoulder the expense, make a series of measurements from an accurately made machine rest equipped with micrometer adjustments, and thereby devise a scale of measurements in thousandths of an inch, which would enable a shooter to use so many thousandths to counteract the force of the wind against various weights of the more popular bullets, shot at various distances and at various velocities. In view of the growing popularity of target shooting here in this country, and the greater tendency in this direction that will come after many of our young men are discharged from the army, such a scale of measurements would be invaluable, because the sight instruments controlling windage and elevation now on the market are far from accurate. In all instances, more precise determinations could be made if the machine rest were used as the gauge, not to consider the "drift" of the bullet, but to observe that factor together with the trajectory. In fact, any attempt to draw up specifications of a spinning bullet against the force of wind would merit the attention of all target shooters.

CHAPTER IX

The Cost of Firearms

IN THE city of Teheran lived Baba Khalet, the Wise One, to whom came many Persians, traveling from far and near for counsel, which he gave freely to all, seeking nothing for himself in return.

There came to him a young sportsman, foolish in the spending of his money. "Tell me, O Wise One, what shall I do to receive the most for what I spend?"

Baba Khalet answered, "A thing that is bought or sold has no value, unless it contains that which cannot be bought or sold. Look for skilful workmanship, that which has great value!"

"But, how shall I know that, if it is a gun which I buy?" asked the young sportsman.

Spoke the Wise One, "My son, workmanship can be easily proven. Glance at the products displayed in the market places, look at the guns, therein will you find the honor and the integrity of him who makes it, or the lack of these qualities. Consider well his name before you buy."

What weary American sportsman, gun-buying tired, does not feel something of the truth of those words? It is difficult even for a man who is not a sportsman, but is one who just likes guns, and likes to walk into an ordinary sporting-goods store occasionally without paying particular attention to the extraordinary number of guns displayed in the showcases. He wonders who buys them, how any real value can be set upon them, for at times, to him, they are just guns—all alike from a distance.

But most of us, I suppose, purchase them as presents for ourselves. We buy some four or five such guns during our lifetime, out of such showcases, and we are not really gifted with the true sporting instinct. But if we were true sportsmen, on rare occasions we would take particular pains to see that our indulgence shall not be wasted on cheap guns, for this time we intend to purchase a gun worth buying. Many good guns, of course, can be found in showcases, but the very best are usually purchased on special orders from the best gun-makers here and in England.

In our early days of gun enthusiasm the matter was comparatively simple. We were then influenced by simple people, who held communal ideas about personal property. Your guns, old and newly pur-

chased, were at their disposal, to be borrowed at any season of the year. Or others would reason in this fashion: "Sportsmen of just ordinary intelligence seldom like a good gun, and those with intelligence are dissatisfied with all good guns, for they were never cleaned when they were returned, and for that reason sportsmen purchase only cheap guns." And it is very likely that many of the guns in such showcases are just cheap guns to be purchased for just that purpose, even though there are good guns among the cheapest, with a good American name stamped on the action or the barrel. And these are influencing factors in the purchaser's mind.

Gun-Appreciation Sense—In the first place, guns can never be counted among the necessities of life, nor among its more common luxuries. The man with false sporting ideas gushing through his mind, in some manner becomes rich, and is able to command luxuries. He then feels it his duty, along with his other falsely developed appetites and tastes, to attempt to buy guns. He may understand motor cars, and have three or four of the best make, together with good clothes and a fine home, miles out of town, but his esthetic sense has not had the proper training in sportsmanship. Fine guns do not find a place in his beautifully built gun cabinet. He does not understand them. Perhaps, he is not to be blamed for this, because there is nothing in the wealth-winning process of this modern age to develop a love for such an art, or the power to judge it.

To purchase guns one must have money, and after buying them, one must be able to appreciate them in order that they may become a constant source of pleasure; and to like the best guns, one must also have an educated instinct for the outdoors. There are a great many people who have money and are quite willing to spend it for guns, could they be certain that they would receive their money's worth. They know that there is great satisfaction to be found in owning good guns, and in winning good scores on targets or bringing home full bag limits. Having no confidence in their own judgment, however, they hesitate to buy, lingering for a long time before a well-stocked showcase. They weigh and dispute the merits of rival models,

calibers, shotgun gauges, "the speed of bullets," "the accuracy of shotgun loads." They repeat the lies others have told about a gun's killing power, and after laboriously deliberating, they usually select—just a gun, irrespective of gauge or caliber or maker, the kind of gun we would be ashamed to have in our possession if we had money at our command.

It is not until a later day that they begin to doubt, and to wonder why they ever purchased such a gun, or why it so enchanted them at the time. The psychologist would, perhaps, diagnose this doubting as the first step toward the acquisition of a gun-appreciation sense.

Encouraging the Gun-Maker—This seems to bring us, finally, to the point where we are about to purchase either a rifle or a shotgun. The possibility of realizing the ideal will be seen at once as we examine two admirable weapons, one, a second-hand shotgun made thirty years ago; and the other a rifle, made but recently by a maker whose name is respected the world over. Both guns are priced at the same figure. Either, we feel, would be a treasured addition to our gun cabinet. The temptation at such a moment is to toss a coin. But there are, as a matter of fact, many reasons why we should purchase the modern gun, and all worthy reasons. If we decide to purchase the shotgun we shall not be conferring a benefit upon its maker. We shall not be encouraging the dealer to purchase various models of that particular gunmaker's work. We shall not be bettering the conditions of a gunmaker's life, for a few days, weeks, or merely hours. But we may, by purchasing the modern rifle, encourage him to continue his work of producing better guns.

Individual gunmakers, that is, the best of them, here and in England, are not business men. Unlike the manufacturers of other commodities, they have but few opportunities to dispose of their products or increase their fortunes. The private gunmakers, unlike our large American arms companies, have no combination of interests to reach the great purchasing public. Many would suggest advertising. Yes, we know that the world was not very old in culture when it began to advertise. Today, a "horsy" sportsman, laying aside his newspaper or magazine, might remark, "I rode through page after page of advertising without saddle or bridle. Now what can I believe?" But private gunmakers cannot advertise extensively, for there is not so great a profit in their creations as in other lines of business, even though many have been termed "robbers" by self-styled sportsmen. I remember being called a robber by one who was worth two million dollars,

after I had worked all day upon his Westley Richards best make of shotgun and charged him the exorbitant fee of seven dollars. Expressions of that nature have been coined only by men of that caliber, and are so easily said.

Advertising—And so we are advised to advertise? Advertising leads to competition, and competition to pressure. Whether a gun is as accurate as an arrow shot from Nimrod's bow, or as bad as an old Civil War musket we once experimented with, nowadays it must be "pushed," or it will remain unknown. If sportsmen, the world over, could make known exactly what they want in firearms, and, having done that, would have the patience to devote time to a search for gunmakers who would fill their needs, the so-called "push" would not be required.

The sporting world is too lazy to determine its own wants, and the advertisements of rifles, shotguns, revolvers, cameras, fishing rods and tackle, binoculars, etc., all of which can now be purchased on the installment plan, are a perpetual reminder, insistent and powerful, and indispensable under modern business technique. So we turn to the pages of our favorite magazine or newspaper, and we see the ability of the showman to arrange words and pictures to catch the eye of the experienced and inexperienced alike. But practical observation of good firearms by the interested buyer is the best method of being impressed, especially by their performance in the hands of others.

Tailored and Untailored Guns—Sportsmen are willing to admit that good guns can be made by our best private gunmakers, and that our large arms companies are capable of turning out admirable firearms successfully under the direction of experienced men. In England, if they have not been destroyed by German bombs, sporting firearms are privately made by individual gunmakers whose firms have been in business for several generations. Here in the United States there are only a few small gunmaking establishments, with a small number of shops whose owners barely make a living, while the great mass of guns manufactured come from the large plants and are standard models, untailored, so to speak. The British sportsman is more fortunate for the reason that his guns are tailored to fit him. He feels at liberty to deal with one particular firm of gunmakers, whom he appreciates, admiring their models, their designs of actions and barrels, and their performance in the field, whether rifle or shotgun, and their name, as well as their workmanship, is in his mind superior to others in many respects.

London and Birmingham are the centers of the

British gun trade. In London are found the greatest number of rival gunmakers. There are many good establishments, and to do justice to all, it would be necessary to name all of them. If, for instance, we were to say that Purdey is considered to make better guns than Westley Richards, or Churchill, that would be doing these firms an injustice, for all three firms turn out excellent guns. It is not the duty of an author or a magazine writer to say: "In my opinion, ———— makes the best gun." The opinions of any author, in such a case, would be ineffective when there are a dozen good firms making excellent products. It is the sportsman who must form such an opinion for himself. He is the one who must make the choice between a heavy and a light gun; between doubles and over-and-under; long barrels against short; large gauge against small; choke barrels against open bores; single against double triggers; engraving against no engraving. Questions and decisions to make, choices of models which have had the support of sportsmen for more than a century! What wonder that opinions are both pro and contra, here and in England?

Cost of the Best Gun—The chief differences of opinion have come from sportsmen using the best guns—the famous best guns. It is only in the establishments of the British makers of famous guns that standards have been set, to be used as a means of judging or rating the guns made in other countries, including the United States. The best gun in England costs between \$750.00 and \$850.00, which is the price by which to judge the value of other guns.

We must admit that \$850.00 is a high figure to set for the best gun, but that is the price, the value at the top, if we consider the sportsman's buying ability as one would a person's credit rating. As the financial standing descends, so do the prices of guns, until we reach the lowest value for weapons; for example, we learn that it is possible to purchase a gun for \$3.59 through a mail-order catalogue. That would represent the lowest financial credit rating. It is not enough for one to become acquainted with gun prices only; a gun's value is determined when the maker's name, the finish, the workmanship, the accuracy and performance are disclosed. Their values must be proved. It is obvious, however, that a perfect comparison cannot be made, due to the fact that the prices of guns vary so greatly, being naturally adjusted to suit the tastes of sportsmen whose finances will not warrant the expenditure for the better-grade guns, which come under the heading of luxuries.

We, as sportsmen, would not hesitate, provided we had a good income, to purchase the best guns,

but unfortunately the majority of us are only able to purchase certain kinds of guns at catalogue prices, and in turn to consider the value of the pleasure they may bring to us. We get the best we can afford, and, strange as it may seem, are often satisfied with the value received.

That money is worth only what we can purchase with it, is perhaps a truism, but it is a truism which a majority of sportsmen ignore, because they rarely find themselves with a large enough bank balance to purchase the best guns. They know, of course, that variations in the price of firearms do exist. But money does not cause a sportsman to change his viewpoint on the worth of guns, for they are not a medium of exchange. They have no more value than the paper on which money is printed. It is the estimate which the sportsmen places on guns which is of value, and this is based on the amount of pleasure derived from shooting them and being outdoors.

The price of guns is not regulated by the price of the ammunition which they shoot, but by the amount which the owner can afford to spend upon his pleasure. Therefore, among sportsmen, guns have a certain value which to others is nonexistent—an intrinsic value that comes with the feeling of possession.

There is one class of people, we have found, to whom money in itself is of value, and they are the sportsmen who have never earned it. But to the vast majority of sportsmen, money is the medium of exchange between hard labor and their needs. They labor and in return for their labor they have food to eat, a home, and a fire for warmth. We do not purchase guns with dollars, but with hours spent at a desk, behind a plow, in front of a machine, or in an office. We should not, when we purchase a gun, think of the gun's worth or cost in terms of so many dollars, but in terms of so many hours. And so, in the same way, when we open a catalogue, we should translate guns and dollars into labor. You will often hear sportsmen say of an expensive gun just purchased, "And in five minutes a month's salary went south," which is simply one way of translating pleasure into energy spent at labor.

The dollar is the interpreter, the medium, between our guns and our work, and we cannot form any true conception of the value of any gun in a catalogue until we have seen it pictured in reality, until we have seen dollars in terms of our ability to earn them, particularly in terms of labor. If dollars are worth only the guns which can be bought with them, they are equally worth only the expense of the energy used in the earning of them. And perhaps the cost of all kinds of firearms is just this—that you receive in value all that you spend.

Semi-Automatic Military Weapons

PARADOXICAL as it may seem, the most complex of all firearms, the human body, continues to offer the simplest analogy for the clarification of the story of semi-automatic weapons and their simplicity. Yet, with the simplest analysis, the paradox is clarified and the analogy is justified.

“What is a semi-automatic military weapon?” An impulsive instrument. So is the human body.

“How many types of semi-automatic guns are there?” Technically speaking, only two; first, the gas-operated gun; secondly, the recoil-operated or blow-back type of action. But automatic and semi-automatic may assume a wide variety of physical and mechanical forms and considerable variations of behavior. So may the human body, if we consider stature, race, color and creed.

“What makes a semi-automatic gun work?” Essentially, the assembly of various mechanical units, individually contributing to the accomplishment of a common cause, the conversion of chemical energy to gas, and gas to work. Thus, in the automatic system, when the trigger is pulled back the gun is “permitted” to work continuously, but in the semi-automatic system the trigger must be “pulled” for each shot fired. So the human body functions efficiently when diet is balanced, blood stream is kept free of impurities, and habits are reasonably controlled. So this progressive analogy continues, in the light of its soundness, to reveal the plausibility of its continued reference, in thought if not in words.

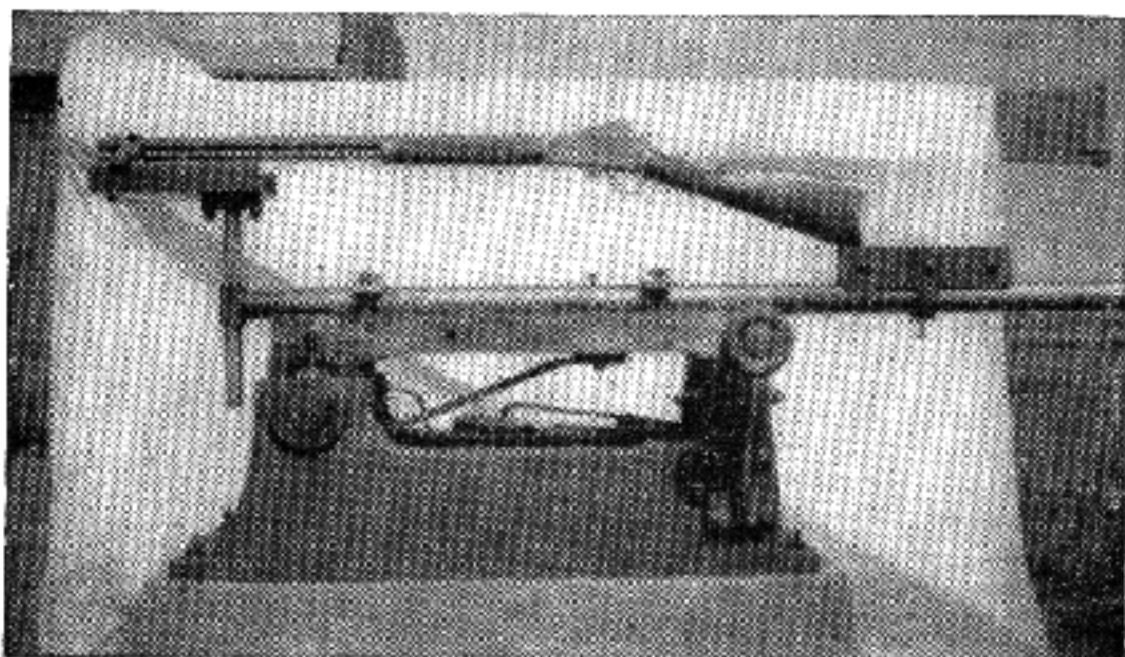


Fig. 22

The machine rest which was made by Otto A. Wagner, Ensign, Kansas. A very fine example of a home-made machine rest

Everyone interested in the subject of a fast rate of fire, and in semi-automatic and automatic small arms, is generally familiar with the fact that hardly a single six-months period went by after the First World War without some one deploring the psychological effects of our service bolt-action rifle (U. S. Springfield, Model 1903, Caliber .30) which had deprived soldiers of the fast rate of fire while in battle. However, regardless of such remarks, the service Springfield has been a very efficient military weapon for over thirty-seven years, and the wave of interest in automatic and semi-automatic rifles other than the Garand, which has swept over the newspapers and magazines these past four years, seems to indicate that the Garand Semi-Automatic Service Rifle has stood the test of just and unjust criticism, and will be the standard military weapon of the U. S. Army. It will be technically known as the “U. S. Rifle, Caliber .30, M-1,” or in more popular terms as the “Garand Semi-Automatic Rifle,” when placed in the hands of our newly drafted army in the year 1942.

Of course, many semi-automatic or self-loading weapons have been invented during this last quarter of a century, but we shall only touch here at length on three types; namely, the Garand, the Johnson, and the Thompson sub-machine gun, of which the latter has stood the test of time, and is popularly known as the “Tommy” gun when in the hands of our law-enforcement officers throughout the nation.

The Garand Semi-Automatic Rifle— We naturally criticize the old gray mare because “she ain’t what she used to be,” and, as the years roll by, a military weapon must be made much more effective and efficient than it used to be, if it is to escape criticism. So we find evidence that any semi-automatic weapon which is still in the stages of a tooling-up process in order to secure production in arming our new army must be classified as “subject to laboratory supervision,” and an object of “unfinished experiments” when in the hands of our infantry.

One of the serious problems that confronted the early makers of military weapons was that of securing accurately controlled machinery. Our arsenals have been compelled to install the latest types of

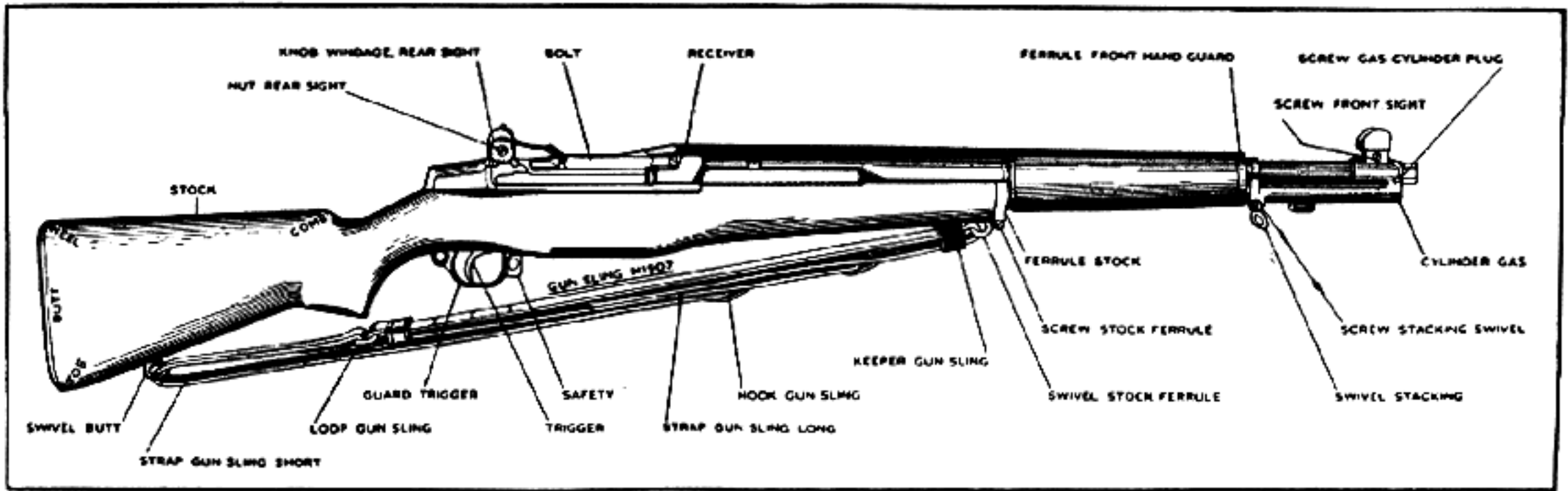


Fig. 23
Main exterior parts of the Garand Semi-Automatic Rifle

production machinery, for nowhere else has the use of automatic machinery reached the development it has attained today at the Springfield Armory to turn out the new Garand Semi-Automatic Rifle. To go back a little more than half a century, out of 800 men employed in the production of military weapons in Birmingham, England, 110 were found to be at work with hand files. A comparison with

the Springfield Armory showed that of the 1600 men employed only 11 were filers. But it must be noted that nearly a century ago a large part of the work on arms in the Springfield Armory was done by men with files or on a grindstone.

Year by year, machinery has been adapted to new uses at the armory, until today on the new model of the Garand rifle hand work is practically

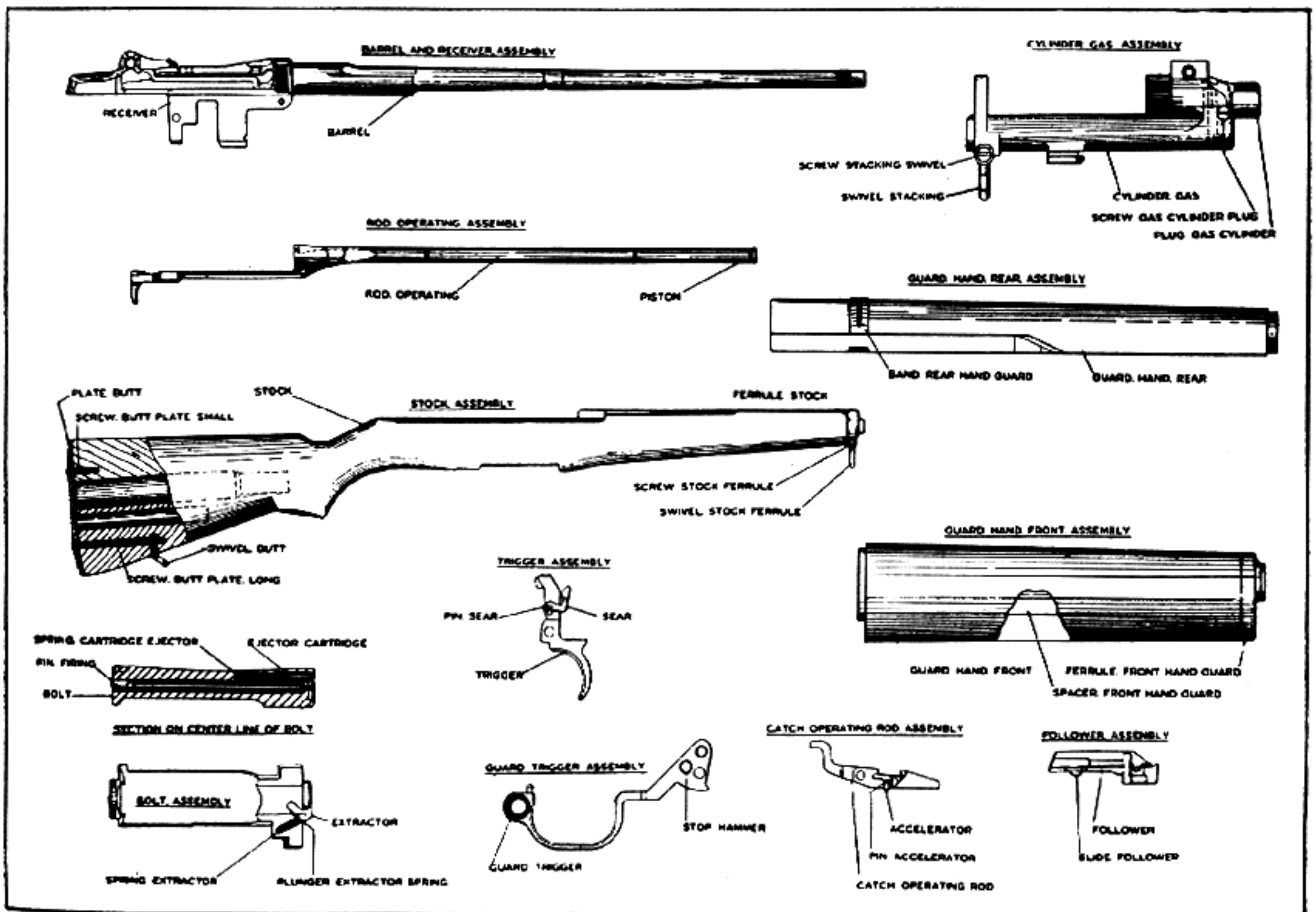


Fig. 24
Main interior parts of the Garand Semi-Automatic Rifle

unknown, except those parts which are buffed on circular buffing wheels; namely, the receiver, bolt and extractor. So entirely are steel and wood reduced to their final sizes by the positive and regulated action of drills, reamers, rifling heads, broaches, and milling cutters of various forms and sizes, that in this thoroughly organized arsenal the operations on this weapon, from the minute that the forgings encounter a machine, are exactly numbered as well as classified.

These operations are termed "cuts," and the amount of work required on this particular weapon is indicated by the number of cuts or operations needed to complete it. The Garand receiver alone requires between 120 and 130 operations on a great number of special machines to bring it to its final stages of completion. Each succeeding operation is the well-judged result of carefully planned experiments in the early stages of its production, in order that precise manufacturing tolerances could be established to assure production of the component parts, directed to the end of economizing labor in perfecting contour and size. With the new, efficient automatic machinery now installed, the final process leaves all parts of this new military weapon so perfectly finished that a file is seldom needed.

Thus, in executing a large order to equip two million men in the field with rifles, one device after another has been adopted to reduce the number of operations or "cuts." Although the arsenal receives a certain appropriation to manufacture so many rifles, it is required to render an account of its expenditures to the War Department at Washington, and the armory ultimately gains the advantage of any reduction in the cost of production. It should be remembered that the manufacture of weapons of this type involves the fabrication of a multitude of distinct parts, each of which has its individual character and cost to be considered. This new semi-automatic arm has seventy-two component parts, including springs, pins and screws. The constant changes which took place before this weapon was placed in production are indicated by the fact that all parts are now interchangeable with the corresponding parts.

An essential element in the system of producing these weapons is the use of gauges to test the accuracy of the work as it progresses. The mechanical definition of the gauge is "any instrument used to measure." It may be a pattern from which the gun stock has taken its shape; a plug to fit a hole and determine the exact size of the established dimension; an electro-limit gauge, which is a precision instrument to measure a diameter of a cylindrical part to the millionth part of an inch; or an instrument to determine the alignment of sights; a thread

gauge, micrometer gauges, plug gauges, all gauges to detect the slightest variations from the true established sizes.

For each component part of the new Garand rifle a set of gauges is provided, not omitting the smallest screw. The amount expended by the Springfield Armory in perfecting its system of gauging all the parts of this weapon is a great fortune in itself. Of each gauge or set there are two, a maximum and a minimum, the rule being that a part shall neither be less than the minimum nor tight in the maximum. Not only is there a double set of gauges for each component part, but each of the hundreds of finished cuts required to complete a certain part has extra sets of gauges held in reserve, together with the master gauges to check all gauges used on the operations.

The preservation of the gauges is a most important duty of the chief gauge inspector, who is held responsible for both master and working gauges. These standards are kept carefully locked up in a vault as large as a good-sized room, with compartments built from the floor to the ceiling to hold them. Each machine operator is furnished with a working set of gauges, and another set is divided among the inspectors, who are held responsible for the work produced by the machine operators. The gauges used for the inspection of the cartridge chamber are renewed each week, to avoid the infinitesimal change in size resulting from the slight wear to which they are subjected.

The superior quality and marked uniformity of the new Garand Semi-Automatic Rifle will be due in part to the thorough system of inspection to which it is subjected. The inspection at Springfield is now more thorough than at any previous time in the armory's history, for an examination of any one of these rifles will show upon each of its seventy-two parts that, aside from the hundreds of special operations performed upon these pieces, an inspector has made careful observations and tested the part thoroughly by gauge.

As an example of the thoroughness of inspection, we shall select the barrel, which goes through a great number of consecutive operations in which various machines are used—gun-barrel drilling machine, reaming machine, rifling machine, chambering machine, threading machine, turning and grinding machine, etc. The first inspection is made after the barrel is drilled, preparatory to the reaming operation; another after the barrel is reamed; again after it is rifled; again after it is chambered; and finally after it has been chambered, threaded, ground to size or completely finished. The gauges used in the final inspection are of the finest construction and scientifically accurate to the one-

millionth part of an inch. A deflection of 0.0001 inch in the sighting of one of these weapons can be easily detected. Without such accuracy the wonderful records of the Model 1903 Springfield at Camp Perry would be impossible.

The most exact inspection is, of course, given to the barrel, receiver, bolt, gas cylinder, etc. The inspection of the other parts of the gun is thorough, though less difficult. After the parts are assembled into the gun proper, each piece is carefully tested to see that its corresponding parts are well adjusted and interchangeable without difficulty, and finally the work of all the inspectors is passed upon, the last inspector examining every part of the assembled gun to see that the official stamp of approval has been impressed upon it.

The stock and forearm of the gun, made of black walnut, is first sawed into rude outlines of the shape it is finally to assume, before being submitted to the operations of turning, grooving, etc. The wood is carefully examined to see that it is straight-grained, well seasoned, and free from sap and worm holes. A practised nose will detect the smell of unseasoned wood as surely as a trained bird dog discovers a scent when he stands at point before the quarry.

Changes in Caliber—The caliber of military arms during the American Revolution was seventy-five hundredths of an inch (0.750), and it has been reduced by successive stages until it is now three-tenths of an inch (0.300). Down to 1866 the caliber of the Springfield musket was fifty-eight hundredths inch (0.580). In 1866 it was changed to fifty hundredths or one-half inch (0.500), again in 1873 to forty-five hundredths inch (0.450), and again between 1894 and 1898 to the present caliber of three-tenths inch. The length of the barrel, originally forty inches, has been reduced to twenty-four inches. The bullet meantime has gone through various mutations until it has arrived at its present form with a boat-tail base.

At the Frankford Arsenal in the year 1922 we had an appropriation of \$22,000.00 to manufacture a satisfactory cartridge, without the caliber being specified at the time, and \$16,000.00 to experiment upon a suitable automatic or semi-automatic shoulder arm to take such a cartridge. Out of the latter appropriation, three Model 8 Remington autoloading rifles were purchased; namely, caliber .25, caliber .30, and caliber .35. After many tests with these guns and their ammunition, it was decided to experiment upon a new cartridge in between the caliber .25 and .30 Remington. From the ballistic point of view, and with much figuring among army engineers, a caliber .276 was decided upon, due to

the fact that a cartridge of this caliber would develop the best possible accuracy ballistically, in theory, at least. It was also figured out that the use of this smaller cartridge would facilitate the design of a reliable and durable self-loading weapon within the prescribed weight limit, while the lighter weight of the cartridges would reduce the soldier's load.

The work accomplished at the Frankford Arsenal in the testing of the Remington self-loading arms, however, was all imaginative, with no opportunity to develop a semi-automatic rifle; the rest of the funds were transferred to the Springfield Armory, and there the experimental work on rifles to take the caliber .276 cartridge was begun by Mr. John D. Pedersen, and the Garand was designed and developed by Mr. John C. Garand. Both Mr. Pedersen and Mr. Garand carried on their experimental work at the Springfield Armory, allowing the experimental department at the Frankford Arsenal to develop the caliber .276 cartridge, which, by the way, was not completed until after 1925.

The Pedersen Rifle—The Pedersen Semi-Automatic Rifle had some very favorable characteristics; namely, that it was a recoil-operated action, in which the barrel recoils a short distance, together with the bolt, until the full angle of the camming action takes place, and the bolt-block moves to the rear, which is similar to the Luger automatic pistol action; whereas, the Garand rifle is of the gas-operated type, which is operated by a lever underneath the barrel by the escaping gases from the muzzle. Studying the difference in design, the army board of engineers considered it the better of the two, and it was adopted, and recommended to be designed to take the caliber .30-06 ammunition, due in part to the fact that this size of cartridge had shown better ballistic qualities than the caliber .276 cartridge in extensive firing trials. Even though the Pedersen gun was discarded by our War Department, it found a ready sale to a foreign government at a very high price, and is now seeing service, as I understand.

The merit of an inventor lies in his style of designing; his true originality lies in his thought of his design and in his manner of bringing his invention to perfection—that manner of expression which distinguishes the thing he may invent, whether it be a gun or a garden rake, which is different from that of another brain. So, Pedersen's invention was his own idea, and he had a right to sell it to the highest bidder; but now it is Mr. Garand who moves into the picture, for it will be his rifle with which our troops are to be equipped, and it must be given

the honors, for his gun had the admiration of the army engineers who accepted the design.

How the Garand Rifle Works—The Garand Semi-Automatic Rifle varies somewhat from the conventional type of gas-operated weapon in that there is no small hole drilled in the barrel for taking off powder gases to operate the mechanism. Instead, the muzzle of the barrel is provided with a sleeve, and while the bullet is passing through this sleeve and just as the base clears the muzzle, a small measured amount of gas is diverted through a port at the muzzle into a cylinder where it impinges upon the piston of the operating rod, driving it to the rear. The location of the port at the muzzle rather than at some point near the breech permits the use of gas at a lower pressure, thereby decreasing the fatiguing stresses on the operating mechanism of the weapon.

An opportunity to study the Garand Semi-Automatic Rifle came to me while at the Springfield Armory, and I found its working parts of particular interest, especially the bolt operating rod which extends underneath the barrel from the muzzle to the bolt. There a recess is provided in the rod which engages a lug on the bolt just to the rear of the front end of the bolt. This recess and the lug on the bolt have cam angular surfaces so arranged that as the operating rod moves to the rear, the bolt is first rotated in the same manner as the bolt in the Service Springfield rifle, until the locking lugs clear the locking recess in the receiver. After this rotating movement is completed, the bolt is carried to the rear by the operating rod. During this movement the operating-rod springs are compressed, the fired case extracted and ejected free of the action, and the firing mechanism placed in a set position.

After the bolt has reached its extreme back position it is immediately carried forward to the firing position by the operating rod acting under the tension of the operating-rod springs. During this forward movement of the bolt the top cartridge is removed from the clip—which holds eight cartridges—and is carried forward into the chamber. When the last cartridge in the clip has been fired, the clip is automatically ejected and the bolt remains in the open position. As another clip is inserted in the magazine, the bolt moves forward, feeding the top cartridge from the clip into the chamber. The striker or firing pin is so arranged in the bolt that it cannot protrude through the firing-pin hole until the bolt makes its forward movement and rotates upon the cams in its locked position. An easily operated safety feature is built into the front of the trigger guard, which disengages the striker from the sear when in the *safe* position.

The rear sight is mounted on the bridge of the receiver; that is, the housing for the sight's mechanical operation is an integral part of the receiver, located at the rear of the clip opening, and is of the aperture type, the diameter of which is 0.070 inch. The front sight is of the blade type protected by guards similar to that on the British Enfield.

The rear sight is raised and lowered by means of a knob located on the left-hand side of the aperture housing. Elevation graduations are engraved on the knob's outer surface in one-hundred-yard indentations up to 1200 yards. Between the hundred-yard impressions there are indentations in which finer adjustments are made, each click being equal to 25 yards of elevation. Windage adjustments are made by means of a knob on the right-hand side of the sight housing directly opposite the elevation knob.

Before leaving this subject of the aperture rear sight on the Garand Semi-Automatic Rifle, we may affirm that it would certainly be better for many of the newly drafted men, especially those who have never had much experience in the shooting of small arms, if they were to become more generally alive to the value of this type of sight. In their youth they were forced, we may suppose, to begin their shooting career with open sights, for then aperture sights were a novelty; but now, having the opportunity to test their skill with such a sight, many will be attempting to alter the size of its aperture. Many of the more experienced men will be unable to perform well with the present size of aperture, and if it is slightly enlarged will make better scores on all ranges. We cannot deny, if we are honest with ourselves, that we must enlarge the size of the aperture in order to accomplish better shooting results, whether on the range or on the battlefield. And yet we can recall with enjoyment some record scores made when testing and sighting many big-game rifles at one thousand yards with the same size of aperture as that now found on this semi-automatic rifle.

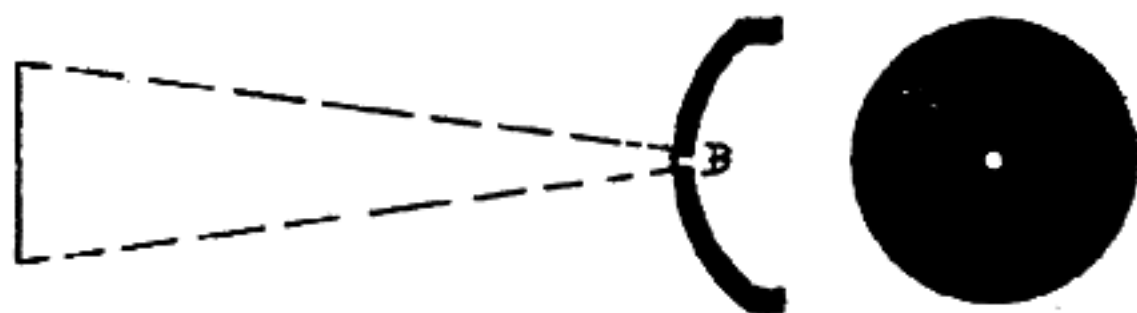


Fig. 25

An aperture is nothing more than a hole in a disc
B = The direction in which sighting is directed

Looking through a hole 0.007 inch in diameter, drilled through a disc, we see little if anything. But remove the lens from a camera, attach the disc in place of the lenses, and it will be possible to take a picture which may be a photographic masterpiece.

Before the time of Aristotle, the miniature hole in a disc was known as an optical device. Discovery of lenses and their adaptation to the telescope forced it out of men's minds until it was completely forgotten. Then, a century ago, when rifles were able to shoot some accurate scores, it was again brought to the front, and attached to many muzzle-loading arms. And today many expert marksmen, yearning to do some unusual shooting over long ranges, turn again to aperture sights. Actually, this sight on the Garand rifle is but a disc with a small hole drilled in the center! Discs are made by the sight companies as small as $\frac{1}{32}$ inch and up to nearly $\frac{1}{4}$ inch in order to suit the sighting caprices of various marksmen. It is certain that one's eyesight can rarely accommodate itself to any and every size of hole in a disc. One's choice must be allowed to fall upon many aperture sizes until the proper-sized opening is found. Therefore, there must be an opportunity for selection of diameters for various individuals, some graduated to the decimal of an inch, others to a larger fraction of an inch.

The fascination of sighting a rifle through a pin-hole for the first time is not only the advantage of simplicity; most marksmen prefer it to the average cheaply made telescope sight. It provides, for example, a notable softness of a target's outlines which contributes considerably to the eye's natural adaptability to avoid unnatural strains. It also permits a highly desirable control over the angle of view, and it has an unlimited depth of focus; that is, it can focus on any object ahead of the front sight, regardless of its distance. It presents the entire target or object in its correct perspective, without the blurring of nearby or distant objects, particularly if the disc has been located in the correct position for the eye.

Sensations caused by light striking the retina through the cornea give us the sense of vision. The outer surface of the cornea possesses a high degree of polish and smoothness; it recedes like a convex mirror, giving a clearly defined, but diminished and

correct, image of any target or object in front of it. The transparent membrane on the anterior part of the outer coat of the eyeball is nearly perfect for the purpose of transmitting light, for it allows every detail of the iris's radiant surface to be seen. But, when examined through a magnifying glass, it reveals something of its fibrous structure by irregularly reflecting the different elements of white light, so that the path of its beams renders those particles visible, just as will light passing through water or fog suspended in the atmosphere. This is a most important point to be considered in aiming through an aperture such as that on the Garand Semi-Automatic Rifle.

The Thompson Sub-Machine Gun—About the time when we were experimenting with the caliber .50 machine-gun ammunition, General John T. Thompson perfected his sub-machine gun in a small experimental shop in Cleveland, Ohio. After completing some experimental models, General Thompson had the Colt Patent Firearms Company, Hartford, Connecticut, manufacture a number of the caliber .45 models, which fired the caliber .45, Model 1911, automatic pistol cartridge. Although he had experimented on an automatic weapon to take the .30-06 cartridge, this was not so successful, and was discarded. However, he continued to improve on the caliber .45 sub-machine gun, which was then sold to various police departments over the entire country, as well as to our Army and Navy Departments.

The first guns manufactured, weighed but seven pounds. They had no buttstock attachment, and no sights. The later models included sights, two-hand grips, buttstock, and weighed eight and one-half pounds.

The Thompson sub-machine gun action is the simplest in any semi-automatic or automatic action now manufactured. A person understanding guns can be taught in thirty minutes to dismantle and reassemble it. There are no screws, inaccessible pins, or other parts requiring a tool. Complete disman-



Courtesy Auto-Ordnance Corporation

Fig. 26

The model 28 A C Thompson Sub-Machine Gun

ting of all removable parts except grips can be accomplished without the aid of any tool. The original model, which was purely experimental, had only eleven parts. The present model contains thirty-eight individual parts, including all screws, pins and springs.

The operating principle of the Thompson Sub-Machine Gun is purely a blow-back system, and the work is performed by a low-pressure cartridge. The pressure-friction necessary to hold the breech closed until the bullet has left the barrel is produced by means of a small wedge, and the rate of fire is 750 shots per minute.

The loading of the Thompson gun is exceedingly rapid, with either clip magazine or drum. The twenty-shot clip magazine can be charged in a very short time; the fifty-shot drum requires about five minutes. The latest model, with the buttstock attached and the fifty-shot magazine in place, weighs 15 pounds 6 ounces.

The Johnson Semi-Automatic Rifle—The Johnson Semi-Automatic Rifle is a recent development on the recoil-operating system, in which the barrel recoils to the rear for a distance of $\frac{3}{8}$ inch and the bolt is locked to it until the camming slot is reached; in this backward movement the bolt is rotating until the barrel stop is reached. When the barrel reaches the stop in the forward part of the receiver, the bolt is permitted to continue to the rear free of the barrel, carrying the fired case with it. In this movement, the fired case contacts the ejector, expels it free of the action, and continues back to cock the hammer by compressing the striker-action spring; at the same time it compresses the bolt-action spring in the buttstock, until it is finally stopped by a buffer plate. Completing this cycle, the bolt-action spring returns the bolt, and in its forward travel pushes ahead the topmost cartridge from the clip magazine. While all this mechanical movement is taking place, the barrel-return spring, which is housed in a perforated tube ahead of the receiver, brings the barrel forward to its normal position, and the cam rotates the bolt into its locked position with the cartridge in the chamber.

Practical in its appearance, this gun also employs the most sound fundamental principles in design. It has short recoil, in which the barrel and bolt move approximately $\frac{3}{8}$ inch to the rear before unlocking, so that the breech pressure is reduced to residual limits before the unlocking of the bolt occurs. The locking and unlocking functions are purely mechanical in operation, regardless of the pressure developed by the cartridge, but being reduced to low limits, free operation is in evidence. Before the complete cycle of this operation takes place, the bullet has emerged from the muzzle. When the bullet emerges, the barrel, locked to the bolt, starts to make its rearward movement, which is a traveled distance of $\frac{3}{16}$ inch, and then the bolt begins to unlock. After reaching the approximate length of travel, the bolt is completely unlocked, and the cycle of movement takes place, firing at the possible rate of 600 shots per minute, though the normal rate from a clip-magazine would be but one shot per second, or sixty shots per minute.

The bolt is $\frac{7}{8}$ inch in diameter and 5 inches long. In place of the conventional two lugs, as on the Springfield Model 1903 rifle, it has eight locking lugs. These are evenly spaced around the head of the bolt. On the opposite side of the bolt is the slot for the ejector. The extractor is flush with the bolt's diameter, and rotates with it, there being no clip to hold it in place; the knob-like operating handle locks the extractor in place, instead of a clip being employed as on the Springfield bolt. The cams and camming action are made on very abrupt angles of about 40 degrees. The rear end of the bolt is linked to a strut $8\frac{1}{2}$ inches long, which transmits the pressure of the action spring, which is located in the buttstock, similar to most autoloading designs.

A novel feature of the Johnson Semi-Automatic Rifle is its firing mechanism, which consists of a pressure contact of the sear against the bottom of the hammer, without recess or notches, and requires merely the straight sliding action of two flat surfaces to secure the hammer release. Flat-surface friction and trigger-spring tension are the only pull resistants, resulting in a really safe trigger release,

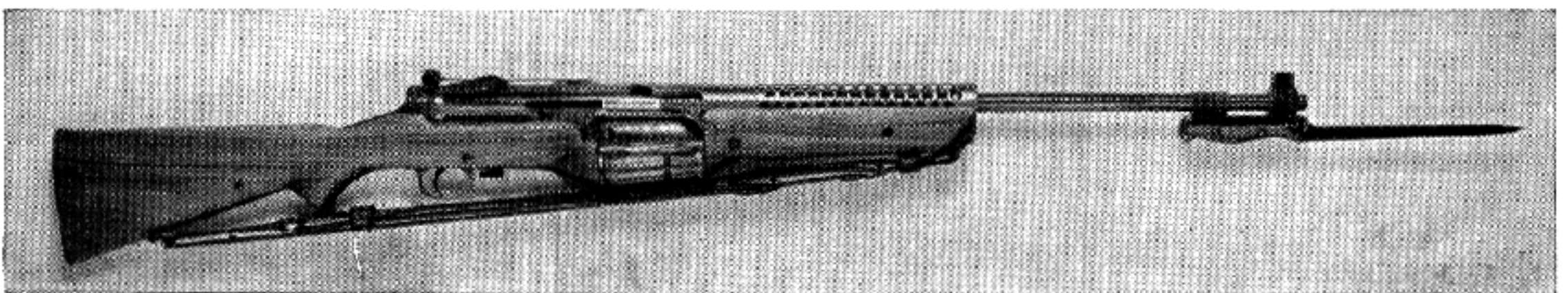


Fig. 27

The Johnson Semi-Automatic Rifle

and a most reliable design. Just forward of the trigger guard is a right-hand safety, with a grooved thumb lever that can be turned from side to side and engages a notch in the sear limb.

Either of the two systems used in the Garand and Johnson semi-automatic guns is quite practical. One is gas-operated, while the other is recoil-operated, the bolts merely gliding to the rear after being disengaged. At this point, and without either rifle having seen hard military service, one can hardly theorize as to which weapon would be the more efficient. At first glance it becomes apparent that the Garand bolt movement, in feeding the cartridge into the chamber, does not have to travel over much wasted space, so that it has much better feeding principles than the Johnson gun. On the other hand, the front-locking lugs on the Johnson bolt should give more accurate semi-automatic operation under fire, because the locking lugs on both sides of the bolt head absorb the recoil of the explosion, so that this is not taken up by any of the weaker parts of the mechanism, whereas, in the Garand the locking lug on the left-hand side of the bolt embeds itself in a complicated cam cut in the receiver, which is liable to give considerable trouble after being fired a number of times, due in part to the wear which will take place at that point.

Far more important than the principle of either semi-automatic system is the problem of what methods to employ in order to produce a large number of guns in the shortest possible time. We must find weapons which can be placed on an efficient, simple manufacturing basis. Knowing the difficult methods employed to produce the Garand rifle at the Springfield Armory, I may refer to one case in particular, though many others could be recalled. While on the tooling-up operations of the Garand receiver, I suggested having the magazine slots broached in a straight line instead of their being on a radius of 50 inches, for they were only clearance slots for the ears on the clip. The machine used for this operation, together with the tool provided, produced a very high percentage of scrap, and the receiver is the most expensive part of the whole gun. My suggestions fell by the wayside. After a lapse of three years, business carried me to Detroit to discuss some metallurgical problems with the Ex-Cello Manufacturing Company, and as the superintendent and I were passing through the tool-room, he pointed out a very large broach in the process of the grinding operation, and mentioned the fact that his firm had an order from the Springfield Armory for three such tools to broach the magazine opening as well as the clip slots. My memory naturally harked back to the day when I had made such a suggestion, and my critical sense was then in

a position to inform my emotional sense that it really took the military rulers at the armory nearly three years to wake up to the need of a simple manufacturing change in order to eliminate a high percentage of scrap from an impossible production operation. And I am still wondering why so much newspaper criticism, continued over a period of years, did not seem to have any effect. It is eighteen years since we had our first appropriation to experiment upon a satisfactory semi-automatic weapon, and today very few of these weapons are in the hands of our troops.

To manufacture a rifle with efficiency, the parts of the weapon must not be of a complicated form which requires complicated cutting tools, jigs and fixtures, machinery, and complicated set-ups on standard production machines. Complicated machining operations slow up production. From the standpoint of simple manufacturing operations, the Johnson gun seems to have more parts which are comparatively easy to manufacture on a production basis than the Garand. As a matter of fact, either gun, if complicated to manufacture, is not the answer needed in our ever-changing methods of warfare.

Far be it from me to believe that a semi-automatic rifle will be permanently applicable to modern warfare. Even if we accepted all the weapons that have been patented, they would only serve their purpose for a time. A just analysis of either weapon would merely lead to a war of words. In our primitive state, and only armed with our bolt-action Springfield rifle, harmony was a simple matter. But in the present state of feverish preparedness activity, each person in a position of authority is bent upon carrying out his ideas, whether right or wrong, and cannot see why he should subject his will and thought to others in a less authoritative position. Of course, our troops should be armed with a good light semi-automatic weapon, one which is superior to any weapon carried by those who may make war upon us; but we do not take into consideration the fact that some of our best semi-automatic weapons patented in the last fifteen years have been purchased by nations who are both willing and ready to make war upon us. Those who dream of efficient weapons above those of other nations dream of inefficient preparedness for such a time. And only time and a war will tell which nation has the most efficient semi-automatic shoulder weapon.

Our weapons of today will appear in 2040 as romantic and full of wonder as do the American Revolution guns to those who admire the past. Two centuries hence our present weapons will be museum exhibits only, guns to be examined curiously, affec-

tionately, odd relics of 1940, glass cases to be passed. Then a third century, following, will recognize in us a painful stage of innocence from which it has managed to emerge, pointing with pity at the millions we expended for simple shoulder weapons of war.

Such is time's spiteful revenge, difficult to accept, that we who now consider ourselves at the top, will appear in a succeeding age as models of simplicity and ignorance. Yet in the same way that we now look back longingly from our artificial existence to the direct outdoor life of the western pioneer, so will the soldier and the small-arms designer of another period look back on us.

Perhaps it is to no great purpose that we should

spend so much regret over the destruction of plain old military arms, but whatever new weapons may be designed in the future, the result will be identical. The Springfield, which seemed to us so wonderful as a military weapon, so accurate, and so inexpensive to manufacture when it was developed by our War Department back in 1903 at the Springfield Armory, a weapon which satisfied the needs of the Army, the Navy and Marine Corps, will be merely a relic for which some old soldier, sailor, marine or gunsmith will have a sentimental attachment. Yes, what will be the fate, too, in another half-century, of the Garand, the Johnson, the Springfield—and of us!

A Broader View of Craftsmanship

THERE IS something very fine and satisfying about good tools. The man whose hobby is working with gun stocks is proud of them. He should be, for he buys nothing but the best, taking care to keep them in perfect working condition at all times. His chisels, saws, planes, and bits are oiled as carefully as was his grandfather's shotgun. He has a genuine affection for the grain and texture of fine woods for gun stocks, and will run the palm of his hand caressingly over a well-polished and finished piece of walnut furniture.

No connoisseur ever looked at a Boss or Purdy shotgun with more delight than he feels in examining a fine old Kentucky flintlock rifle, the stock made from bird's-eye maple by some home gunsmith who two centuries ago searched perhaps for two years before he found the right piece of wood.

I know of no better way to improve the shining hours of winter's after-dinner leisure than to work in the sanctum of one's own shop, preferably a building away from the house, with a wood-burning stove and the family dog stretched at full length among the shavings, yawning contentedly now and then. A shop is a family man's refuge and, by an unwritten connubial law, it is—or should be—respected as inviolable.

It is interesting to know that gunsmithing as a hobby has become immensely popular among Americans since the close of the Second World War, which is supposed to have caused many important changes in our recreational habits. Undoubtedly an impressive number of leisure hours are now being happily spent in the home workshop, whether in the basement, garage, outbuilding, or attic. As the California ranch-type of home becomes more common more of these workshops will be found at ground level, thus making them more accessible and in many cases relieving the home from the assorted racket of circular saws, band saws, drill presses, wood planers, grinders, polishers, sanders and what have you.

Small power-driven tools have always fascinated that tool-using animal, man. Instinctively he welcomes electrically driven tools that not only save him long hours of monotonous hand labor but also make possible the accomplishment of more and

finer tasks in a fraction of the time his ancestors required. As these power tools become more varied in type and more precise in their results, hundreds of "how-to-do-it" books come into the market, stimulating the sales of these tools to a growing percentage of home craftsmen from coast to coast. Lumber sales to the home mechanic have also increased, for more and more men whose hands are not all thumbs are repairing their own homes and in many instances building them from blueprints supplied by the lumber companies.

The home workshop provides the impulse for many congenial hobbies such as gunsmithing, cabinet making, gem and mineral cutting, telescope making, miniature locomotive making, and many others. There are at least two million such workshops in this country today, and the sales of craftsmen's tools, both hand and power-driven, have astonished even the companies that manufacture them. It is very easy indeed to invest \$1,000 or more in a small basement or backyard workshop. True, the investment frequently bears little relationship to the tangible returns but it does serve to attach thousands of men to some absorbing and congenial activity, keeping their minds pleasantly occupied through many long hours that would otherwise be valueless to them.

The activities in the home workshop should have a purpose. It is my own impression that to many men any kind of a workshop means only sweat, headaches, chips, dirt, noise, bruises, grime, and grease—but to an enthusiast who knows what he is doing and how to do it these activities, however exacting, are a relaxation. And, if we are to believe the doctors, both his health and efficiency depend upon a man's ability to relax. This is where the hobby comes in.

Relaxation takes different forms, according to individual proclivities. One man I know finds an outlet for his nervous energy in repairing various kinds of antique gun locks and studying the mechanical characteristics of all kinds of British and early American gun actions which he buys here and abroad. To be sure, he bores his friends by talking guns on the slightest provocation and he is particularly happy to dilate at length upon his latest adventure in the world of gun locks. Yet this man is

an outstanding physician, and no doubt owes much of his happiness in life and his success in his profession to this special form of relaxation.

Another man known to me has a private book bindery where, with two of his friends, evening after evening is spent in the delightful task of restoring old and rare editions. One end of a large room is filled with his printing and binding equipment, while all around are stacks of books waiting for his attention. He once showed me a beautiful volume which he had just restored, lovingly fingering the soft leather as he read to me some favorite passages. Here, in the hours of his recreation, was a personality quite unsuspected by those who knew this man only in his office.

We are inclined to think of efficiency as expressed chiefly along industrial and mechanical lines, not realizing that many seek—and find—deep personal satisfaction in mechanical creations as elaborate as miniature locomotives, ocean liners, and even battle-ships. One may be an amateur telescope maker, another finds happiness in exploring the night sky for distant comets, a third may be upon the trail of some new chemical having unsuspected medical or industrial possibilities. But for all of these men attention was focused more upon the value of life than upon the crude practical value of their activities.

The trend of the times is definitely towards amateur science. One of my friends, wishing to know more about the atom and its behavior, constructed working models with nothing more than scrap materials. In a workshop cluttered up with small batteries, wooden models with magnets attached here and there; wires, strings, breakfast food, hair combs, sticks nailed to this and that, he was able to make his atoms perform to the astonishment of anyone who wanted a demonstration. What seems most remarkable is that he does not have more than ten dollars invested in equipment which yields results as satisfying to him as those which cost millions of dollars in the great physical laboratories of our universities.

Essentially, the contribution of this book to the art and technique of gunsmithing is one that cannot be analyzed. It does not lead to thorough knowledge, any more than knowledge of a foreign country can come solely from a guide book or a hasty review of its industries. But it does give the attentive reader the principal facts about guns and it will show him how, with patience, ingenuity, and a disciplined imagination, he may become a skilled craftsman-gunmaker.

Modern methods of gunmaking are very different from those in use a hundred and fifty years ago.

In former times the component parts of gun locks were made by hand with the aid of files, and even these simple tools were made by a blacksmith. Each hole in the lock-plate was drilled separately by crudely made drills, and each part separately fitted into place, so that the lock was gradually built up as one would build a house. Each component part, of course, only fitted its own lock and the parts were not interchangeable.

Time has altered all of this. Today, by means of expensive automatic machines, the separate parts of guns are turned out by high-speed form tools moving independently of the will of the operator, whose only duty is to stand by and see that the parts are produced. The machine is a servant that never tires and never talks back, demanding only that its cutting tools be kept sharp and true to form. The operator is needed only for supervision, pressing buttons, pushing levers, watching control mechanisms: he does not even have to change defective or dull tools—that is another man's job. From time to time he measures the product with elaborate instruments known as gages to see that it conforms to a master unit or to a blueprint.

When all parts have been thus manufactured you have a large number of boxes, each with a thousand or more gun parts in it, each part exactly like every other in the same box. You take a bolt or a spring from one box at random; to this you add, item by item, screws, springs, actions, strikers, extractors, sights, barrels, triggers, trigger guards, barrels, and so on until you have a complete array of everything needed at that stage. All that is then left to do is to assemble the parts as one would the pieces of a jigsaw puzzle. Everything fits; there is not even any filing or burring to do.

Such perfect interchangeability demands a precision to within the thousandth part of an inch, which means automatic machinery of perfect design and often of very high cost. But the resulting uniformity of product leads to a surprising economy in manufacture. You can now purchase for thirty cents a better gun part than could have been secured for ten dollars a century and a half ago. The savings may be spent for other equipment, or for ammunition.

Guns made in this manner are, of course, products of industry, not craftsmanship. They make no pretense to be artistic; they are simply—and superbly—useful. The machine tool, which can do so many things at the cost of so little labor, may be necessary to the craftsman but it is also a warning—a warning never to confuse speed with skill or utility with beauty.

Turning to comparatively ancient times, we

may find, in the John Woodman Higgins Armory, Worcester, Massachusetts, an exhibit showing a "screw-bolt" fixed upon a suit of armor of the 15th century. How many who see this exhibit stop long enough to wonder how this screw-bolt was made, when or where it was invented, or to realize that the very tools used to make it were hardly less interesting than the thing itself? Who taught its principle to the Romans? And was it because the Chinese preferred to use gunpowder for fireworks to amuse people rather than for bullets to kill them that they failed to develop the gun and thereby lost countless battles with the Western Powers?

Coming down to the end of the 18th century, we find that the construction of machine tools was considered an engineering art and the threading of bolts and nuts a great achievement. Even gear wheels were cut by hand. The circumference was laid out by compasses or dividers, holes were drilled round the rim and the cut-out sections leading into the holes were shaped by special files. Large machinery was all shaped out at the forge and by the file. Although they could not achieve tolerances closer than $\frac{1}{8}$ of an inch—and that at the cost of immense patient labor—their guns were beautifully made. Locks and trigger guards were engraved with exquisite patterns; stocks were richly inlaid with mother-of-pearl and ivory—even duelling pistols were works of art to be jealously treasured by their owners.

Then came the Industrial Revolution and with it the era of severe technical accuracy. Measurement became the task of science which, if not hostile, was at least indifferent to the demands of art. Exclusively utilitarian in purpose, the machine disregarded beauty in all the domains formerly ruled over by craftsmen, so that our modern American machine tools, from monkey wrenches to lathes, are marvels of effective design and precise workmanship—fitting implements of a nation that wears overalls on weekdays and drives expensive automobiles on Sunday. One has only to compare an old squirrel rifle, with its inlaid butt stock and forearm, with a modern rifle to note the difference. Ornamentation, once inseparable from a fine gun, has either completely disappeared or is little more than a spasmodic, usually feeble imitation of the past.

People no longer believe in the old hand operations in metal-working when a machine can be used more efficiently. It is possible, of course, with a file and a keen edge scraper and days of patient labor to produce two flat metal surfaces so perfect that when pressed together one piece will lift the other like two gaging blocks as manufactured by Brown & Sharpe. But this would be wasted labor when a surface grinder and a lead lap will do the

job as well in a fraction of the time. No longer are our military rifles built up at the Springfield Armory as were the muskets of a century ago, fitting part to part. By the employment of hundreds of special machines thousands of parts are forged and milled to shape, heat-treated, polished, blued, and assembled into our most modern military rifle. Comparatively unskilled workmen can easily be trained to handle most of these operations. Where exceptional skill is required is in the making of the special forming tools, cutters, reamers, dies, and precision gages accurate to within the ten-thousandth part of an inch. Thus human labor is concentrated more and more on tool design, on the making of tools and dies to close tolerances, and on supervision.

But machines cannot satisfy the human craving for art. The same man who may use tools in some form is by nature a creative being, eager to work with hands directed intelligently by the mind, never really satisfied until he becomes a craftsman. The contentment that man's nature demands is impossible until the creative drive can find expression in a harmony of hands and brain which leads to the parallel harmony of precision and craftsmanship, neither intruding on the domain of the other.

Knowledge and skill—these are the essential ingredients of craftsmanship. One maker of gun stocks has a skill peculiar to himself, using checking tools in a manner developed from long practice and not to be easily taught to or imitated by another. With a set of such tools an amateur would quickly learn the great difference in results from using dull or sharp-edged ones, pushing with or against the grain, etc.

No gunsmithing book, nor, for that matter, any book on craftsmanship, can possibly take the place of constant practice in the handling of tools. Skill must be learned at the bench. Even more important, by starting young and by study the chapters on stock making to help you in your home workshop, you will lay the foundations of a secure ability in your chosen field, as well as add to the richness of your life.

There are, indeed, many young boys who have a real desire to become craftsmen; they are physically apt and have mental faculties well developed to direct their hands in scientific and creative activities. The parents of such boys should encourage them in every way, presenting them with tools and apparatus selected according to the following simple principles:

1. Many of the things a boy needs can be easily supplied by bits of wood, metal, wire, string,

etc., provided that he has someone to give him useful hints on how to manipulate them.

2. If and when you give him tools, give him real ones, not toys. He wants "thing-makers," not mere playthings.
3. He should also be provided with a reasonably dry and comfortable place to work in, and become acquainted with a good carpenter, tool-and-die maker, or gunsmith in the community.
4. He should never be allowed to work aimlessly with tools, but encouraged to design and construct something really useful, continuing with a job until it is finished.
5. The construction of laboratory equipment with which to explore simple scientific facts is more useful than making pipe holders for his father or plate racks for his mother.
6. Finally, the small sums spent in the above ways will keep many a boy from running wild, and when the time comes for making serious decisions he will thank the carpenter, toolmaker, mechanic, and gunsmith who helped to teach him the most important principles in the making of a scientist or craftsman.

If we compare the operators in our industrial organizations with the apprentices of medieval guilds, we would not find the lot of the former a very happy one, for our mechanized age is very exacting in its demands. He who serves a machine must be as automatic as the implement, and no less constant in the performance of his part of the labor, for it is all estimated on the basis of exact ratios—it is purely a question of figures and of producing parts. But for the more capable a remedy is at hand: not in legislation, nor in the labor unions, nor yet in the mere increase of wages, but in the wide diversity of craftsmanship that is rapidly springing up all about us since the Second World War, which insures freedom of occupation and happiness in work by multiplying the ways of earning a livelihood. It is not a new creation but a revival, and it promises to restore to ambitious young men a lost prestige.

Take the gunsmith who, in the days when the craft or trade was not a lost art, worked at his bench, filing his thoughts into the metal and his fancies into symmetrical forms; every task was a problem, every stroke of the file manifested skill; he was an inventor, a producer, a craftsman in the true sense. But machinery has supplanted all manual skill in this trade; the specialist now does little more than assemble the odds and ends; the master craftsman has now become a mere apprentice, for every article that formerly called for inventive skill in the making is now furnished by the manufac-

turer. The average gunsmith today is no longer a craftsman; he has become a mere jobber.

We have alluded to the trade of the gunsmith as a lost art, but it is reviving under the guise of a hobby, with the evidence of skill such as has not been apparent since the American Revolution. Restocked American military rifles may now be seen, here and there, amid the rubbish of re-stocked German and Japanese military arms, compelling one to pause and praise the skill of a revived craftsmanship that will surely tend to awaken a healthy ambition to excel. The cabinetmaker is coming to life again. He, like the gunsmith, got his materials ready-made from the mill; he could neither devise nor execute the simplest molding; he was literally a mere assembler, putting together materials already formed to a standard; and when completed, it was stained or varnished with the aid of a paint gun to give it either a polish or a dull appearance. As to invention or design, that is wholly gaged by mass production, which, as we have observed, operates on the mind as well as on the materials that come under its evil influences: thought, design, and product are alike mechanical, and therefore devoid of character. How effectively this has been accomplished may be seen in the unskilful work performed by the so-called craftsmen of the past fifty years, throughout all trades.

Taste dominates the emotions in craftsmanship, and reduces all to unity by means of harmony. In all its finer products design is the dominant influence, for good taste requires that every part shall be genuine. By educating the taste, a love for the genuine is encouraged; thus it becomes a matter of character and principle that everything shall frankly express what it really is, and the effect of striving for the attainment of the beautiful in all sorts of work tends to elevate the character of craftsmanship.

A mind formed by original observation and the study of facts will always secure attention for we seem to be brought in closer contact with truth and reality by its influence. The true scientist in his laboratory is continually occupied with things, and throughout his observations and experiment he is necessarily more or less involved with certain aspects of craftsmanship in constructing the necessary appliances for his investigations, often showing unusual ingenuity in devising the requisite aids and instruments, the hands and the senses continually working in harmony with thought and reflection. The employment of the senses in harmony with thought, and a more strict adherence to fact as a basis for theory, is the true safeguard against the wandering tendency of the human mind.

When it is recognized that there is equal dignity in all labor that engages the mind and hand in a common purpose, craftsmanship will recover its lost prestige and will be found, as in the past, a source of more contentment in many homes. The present revival of the home workshop, extending as it does to amateur gun craftsmanship, is also reaching into other fields and thus recruiting a great number of people into the skilled trades. Of course, it will naturally appeal to the more intelligent, capable, and skilful, for it is a matter of personal enterprise and individual qualifications. No mere words can transform an individual into an artisan, nor muscle into skill—an apprenticeship must be served to gain experience and achieve mastery.

It is a correct aim to seek happiness in work, to find some sort of occupation the reward of which is not completely gaged by monetary profit. But in order to find that happiness one must first find a hobby or a craft that is suited to one's temperament, and this is not discovered by aimless groping but by obeying the promptings of an early instinct. If there is a strong liking for firearms, fishing or hunting in early youth, a firm will and steady purpose will enable you to rise above all obstacles and stand upon your feet against all opposition.

Of talent it is hard to judge until the dormant capacities are brought to light; then it is as much a surprise to you as to your acquaintances. There must be occasion and opportunity to favor special aptitudes. Those who are successful usually began their hobby under the conditions in which they were placed by natural antecedents, aided by sound instinct and good judgment rather than by any so-called accident.

This may be verified by studying the construction of a firearm, which involves the crafts of machinist, toolmaker, diemaker, and woodworker; and, in the field of research, the engineer, designer, chemist, metallurgist, physicist, and ballistics expert. This should greatly interest the more than fifteen million gun users throughout the United States, among whom we may find a large number of artisans. Many of these men also have their own workshops and have shown great ability in constructing their own gun stocks for obsolete military arms as well as for factory models.

These worked-over military and factory productions which have been brought to my attention these last few years are worthy of the greatest praise, representing as they do the work of amateurs from every walk of life: businessmen, lawyers, teachers, physicians, dentists, clergymen, bankers, stockbrokers, accountants, right on down to the fellow who works on a farm. Many recognized their lack of foresight and experience and yet, in

every case the effort showed signs of where, by a little experience with tools and much application, each could have developed into a skilful craftsman. A sustained trial will often reveal to a man that he is not nearly as helpless as he may suppose.

A shop of some sort has been the aim of the artistically inclined since the days of Homer and the ancient Greeks. Many of the old masters, as the museums show, devoted their talents not only to statues of marble and bronze, to fine paintings and silverware, but also to the production of finely engraved firearms. Benvenuto Cellini made a gun complete with lock, stock, and barrel; he also made his own gunpowder and cast his own bullets, stating that "I brought down pigeons at remarkable distances, around and about the city of Rome."

There are, of course, more critics than craftsmen in the world, proof of which may be seen in the clumsy restorations in a number of museums in the United States and Europe. We see this evidence in reproductions of delicate artwork and in the large collections of objects in wood and stone, of Indian pottery and relics, weapons, etc., which are supposed to be beyond repair when they might, with the proper knowledge, be easily restored. If one is in doubt one need only visit the "dead rooms" of a number of museums in the United States, where will be found abundant evidence to prove that, of all the crafts, that of restoring damaged or broken antiques is the least understood and the most strangely neglected.

But unfortunately such antiques do not exist ready to hand, they must be hunted down. As our experience increases so do our methods of seeking them improve. Every collector can find a fertile field in almost any shop that sells antiques, especially in the smaller and humbler kinds off the beaten track.

On the other hand, there is hardly a town so small in the United States where an enterprising craftsman could not create a very good business by repairing and restoring all kinds of antiques, from guns to watches. Of course, in the larger cities the demand for such work is much greater, for we find there many amateur collectors who will seek your services. But before you open your place of business you must first build up your ability and knowledge from craftsmanship gained by long experience. Such ability is easily acquired by those who are gifted with ingenuity, artistic temperament, or just common sense.

It is a great mistake to suppose that manufacturers are necessarily good repairers of what they produce. I have found, as many others, that even the large gun companies may not be safely trusted with the restoration of one of their own models. In

nine cases out of ten it is some humble gunsmith with a flair for antiques who will restore an obsolete model into a museum piece. This is true of most trades, for which reason I believe that a really accomplished craftsman, earnestly devoted to his calling, could make a very good living at this work. We can make every part of a gun or clock by machinery, but the machine cannot repair it when broken.

The fact is that almost everything people have been using for years can be made stronger, more simple, more beautiful by competent hands in a shop of your own. There is no reason why an antique dinner table cannot be fundamentally beautiful, or why a door on a corner cabinet cannot be repaired so that it swings at the touch of a hand. If you will learn to put screws in oak without splitting the wood, and provide accessories of your own creation, your craftsmanship will be wide demand.

As types of breakage and decay are numerous, so the art of restoring damage may be separated into various processes, such as joining, soldering, nailing, inserting, finishing, the use of clamps and of cements and adhesives. Glue or gum, when combined with powdered chalk or glass, make a cement, such as Portland cement, mortar, plaster of Paris, and putty—which last are often used by themselves to form objects and models.

So many formulas for adhesives are now available that the craftsman and practical mechanic can easily learn from experience which will give the best results in working with different materials in the course of his restoration efforts.

Apart from these strictly technical details, it is possible to develop gunsmithing so that it becomes a specialized activity of the highest value, as we have tried to show throughout this work. It is also possible to show how, in its various phases, craftsmanship becomes the first stage of elementary training in the arts to meet the higher skills requisite in any mechanical undertaking. So we see the attainment of balance by the alternation of different interests affecting the problems we encounter and select from day to day.

It is my own impression that if a boy at the age of games and sports does not learn to play baseball, to shoot, fish, or hunt, he will probably be sedentary to the end of his days, and even if the best opportunities be presented to him for acquiring a craft of some sort, it is a hundred to one that he will pass it up and shrink from the necessity of taking the first steps which, at an earlier age, might have filled him with a sense of delight.

However, let us see in what respect the trained and experienced mechanic differs from the novice or

beginning amateur. First of all, we note that the raw sensations and drives of the non-mechanical disposition must be trained to make it possible for the individual to fabricate essential articles with the tools at his command and to serve their intended purpose. A glance at the modern manufacturing establishment shows that the functions of our senses have been taken over by a collection of extremely complex, intricate, and specialized machinery, contrived and constructed solely to turn out a given product at high speed and in the most economical manner.

Since the product manufactured in that establishment is, in the last analysis, dependent upon individual efforts, every discovery made by an individual in that factory has significance for the well-being of the organization as a whole. This gives the beginning craftsman, pondering over the problem of using his tools successfully in the quiet seclusion of his home workshop, the assurance that every genuine discovery will win the recognition of his family and friends far and wide, and in this feeling of the importance of our creative work lies our happiness. It usually compensates us fully for all the sacrifices which we have made in training our minds and hands to produce something useful that others can admire.

Of course, in each of us a saturation point is often reached in our home workshop, the impetus of our purely creative zeal expires, and unless the hobby be one associated with some urgent personal need that keeps our wits constantly whetted, we settle into a stalemate, and tinker from day to day on this, that, or the other, without adding anything significant to our store of knowledge or skill. Unfortunately, to such men—aside from their own business—the ideas gained by them before they were twenty-five are practically the only ideas they will have for the rest of their lives. They cannot create anything new. Disinterested curiosity fades, the mental grooves are set, the power of assimilation and creation wanes and dies. If by chance they ever do learn about some entirely new craft or hobby they are likely to be afflicted with a strange sense of helplessness and insecurity. But with craftsmanship learned in the impressionable days of instinctive curiosity we never quite lose our sense of being "at home" in our workshop or laboratory. There remains a kinship, a sentiment of close acquaintance with tools, instruments, and apparatus which, even though we have failed to keep abreast of the subject, flatters us with a sense of power through hard-won experience and makes us feel not altogether out of place in this world.