SMALL ARMS DESIGN AND BALLISTICS

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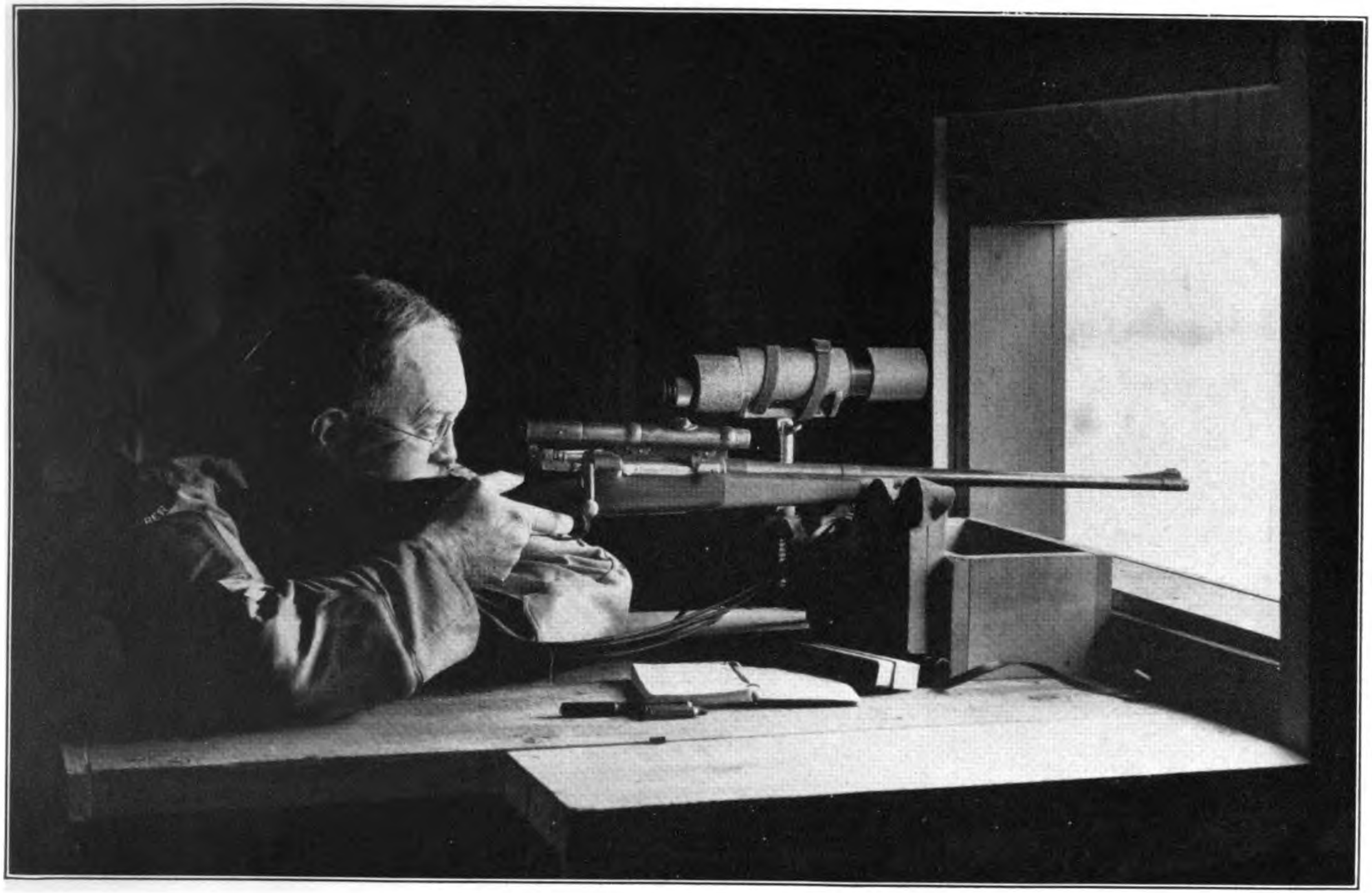
WHELEN



Colonel Whelen testing a rifle and load from his bench rest.

SMALL ARMS DESIGN AND BALLISTICS

Volume I

DESIGN

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Ordnance Department United States Army Retired

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"The right of the people to keep and bear arms shall not be infringed." Our Infantrymen, four million strong, courageous, skilled in their calling, and proud of their arms, are preserving for posterity our institutions and our homes. Our workmen, with equal pride, are producing the best arms the world has seen.

If ever our manhood ceases its interest in arms, its skill in their use, and the trade of the Gunsmith disappears, the Millenium will have arrived or we as a Nation will have ceased to exist.

Townsend Whelen

FOREWORD

I HAVE undertaken this work because I believe there is a decided need among all our citizens for the information I have tried to set forth in it. All my life an Army Officer, I have been most interested in National Defense, and nothing is more important in this field than that our citizens shall have a good knowledge of weapons, how they shoot and why, how they operate, and how best to use them.

The subjects treated here are not covered in any other book that I know of except that a brief mention of some of them is made in a few works on marksmanship or gunsmithing. The only worth while work in the English language on the important subjects of Interior and Exterior Ballistics is the "British Text Book of Small Arms, 1929" at present out of print, and so strictly mathematical in its handling of its subjects as to be far over the head of the average reader.

I believe that this information is needed by all our soldiers because they should have a knowledge of the design of small arms which contribute to their sure and easy functioning, safe use, and the flight of the bullet. Present military manuals cover only operation, care, and marksmanship. In order to be a good marksman a soldier should know how his bullets are affected by the force of gravity, air resistance, and wind, *and why*.

I know that the civilian rifleman and pistol shooter needs information on these matters for he usually rides his hobby to such an extent that intimate details concerning the design, construction, and ballistics of small-arms are very vital to him. The majority of our enthusiastic shooters are technically and mechanically inclined. They may design their weapons themselves and either make them in their own shop, or have them built by a gunmaker under their direction. Many have designed their own cartridges, thousands habitually hand load their ammunition, and there are hundreds of small experimental rifle and pistol ranges scattered over the United States.

American shooters have been obtaining their knowledge on these matters from the brief mention of them in existing books, from magazine articles, by correspondence, by word of mouth, and by bitter and expensive experience. The road has been difficult and tedious, and many erroneous ideas have been acquired by certain students. In the early days of fire-arms, science was also in its infancy, most matters were based on conjecture, and were usually one-hundred percent wrong. Modern science as applied to this subject has taught us the truth and the real reason for many things about which we knew little or nothing fifty years ago. We do not know it all yet, by any means, and this is one of the reasons why the subject makes such an interesting study and hobby. Our scientists and amateur experimenters are still making helpful discoveries.

In order to understand ballistics a certain knowledge of the materiel with which we work is essential. Therefore I have devoted the first volume of this work to materiel—that is, to its design and construction.

Pure ballistics is one of the most intricate sciences, based and formulated around higher mathematics. Not one American in a thousand has the mathematical ability to understand it. It is also too theoretical for practical use by the majority of our shooters, even if they should be able to understand it. Therefore I have endeavored to simplify the subject, and to include nothing that a reader having a hign-school knowledge of mechanics and arithmetic cannot easily understand. The nomenclature and definitions are those of the Ordnance Department of the United States Army and of our American Shooters.

There have been a number of developments in small arms design and in ballistics during the present war that are still considered as confidential and secret, and that therefore could not be included in this work. It is probable that when these can be released they will be described in the columns of the magazine ARMY ORDNANCE.

A word with regard to the drawings that illustrate this work. So far as possible these drawings have been reproduced accurately in shape, and dimensions, and in exact size. The chamber drawings in particular show the tolerances clearly, and the cartridge drawings are exact size, insofar as modern methods of reproduction will permit.

It is inevitable that there will be errors in a work of this nature attempted for the first time. Science will also probably prove some of our present theories unsound, just as it has in the past. I trust that my critics will be charitable, but will nevertheless call any errors to my attention so that they may be corrected in a possible second edition.

TOWNSEND WHELEN.

September 30, 1944

CHAPTER I

SMALL ARMS IN GENERAL

THE history of small arms shows that the demand has always been for more power, higher velocity, flatter trajectory, greater rapidity of fire, and better accuracy. The end of development in these respects is not yet in sight. We can still look for steady improvement in all these details. War is a great stimulant to such development.

But so long as powder gases remain the means of propelling the projectile, certain design of materials and certain laws of bullet flight will remain unchanged. No matter what the power and velocity of the cartridge, or what the operation of the weapon, this design and these laws cannot be violated without disastrous results or decreased effectiveness.

It is with this design and these laws that this work deals.

In order that a work of this nature may be understood by the novice, and so that we will all talk the same language, it seems desirable that we start at the very beginning. Even those with more or less experience may find definitions in this first chapter that will be helpful to a better understanding of the remainder of this work.

There are many kinds of *guns*. Some shoot bullets, some shot, some liquids, grease, or chemicals. Some use gunpowder as a propellant, some compressed air, springs, plungers, or levers. But in this work a *gun* is considered to be a firearm which projects its bullet or charge of small shot to a considerable distance, using as a propellant the force of expanding gas generated by the burning of gunpowder or smokeless powder.

Small-arms include those guns which can be handled, moved, and operated by one man. They include *shoulder-arms* (rifles, muskets, carbines, and shotguns), *hand-arms* (pistols, revolvers, and automatic pistols), and *machine-guns*. Machine guns, however, do not come within the scope of this work, and muzzle loading small arms are considered obsolete.

Every gun has a **barrel** which is a long, hollow cylinder of steel.

The hole through the barrel is termed the *bore,* the rear end in which the cartridge is inserted is called the *breech,* and the front end from which the bullet or shot emerges is the *muzzle.*

The bullet, the powder, and the primer or cap, in that order are loaded into the breech of the bore, and for convenience in handling and quick loading they are assembled into a brass, steel, or paper case. The assembly of bullet, powder, primer, and case is called the **cartridge,** or when dealing with shotguns—the *shell.*

A **breech-action** is attached to the barrel at the breech, behind the cartridge, and closes the rear end of the bore and supports the base of the cartridge against the pressure of the gases generated by the burning powder. The breech-action consists of a *receiver* con-

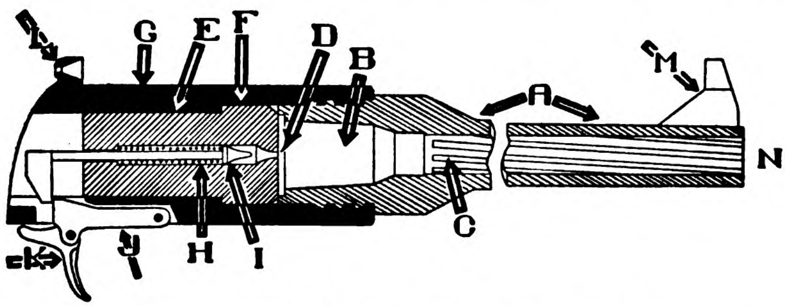

FIGURE 1. BASIC NOMENCLATURE OF A SMALL ARM

A—Barrel. B—Chamber. C—Rifling (Land). D—Breech. E—Bolt. F—Locking Lug. G—Receiver. H—Mainspring. I—Firing Pin. J—Sear. K—Trigger. L—Rear Sight. M—Front Sight. N—Muzzle.

taining a *block* or *bolt* which locks closed to sustain the gas pressure, and opens to permit the gun to be loaded by inserting a cartridge in the breech. The block or bolt is pierced in its center for the *firing-pin,* which, actuated by the *mainspring,* flies forward when the *trigger* is pressed and crushes the priming composition in the primer or cap. This composition, on being crushed, *explodes* and gives off a hot piercing flame which ignites the propelling powder. The powder *burns* and generates a very rapidly expanding gas which blows the bullet or charge of shot through the bore and out of the muzzle, and finally forward through space, with a very high velocity or speed so that the bullet or shot will fly a considerable distance and do more or less damage to anything it strikes.

A gun also has *sights* with which to direct or aim it so that its bullet will strike the target. Shoulder-arms have a *stock* of wood by means of which they can be held at the shoulder while being aimed and fired, and hand-arms have a *grip* for grasping with the hand for the same purpose.

Such in general is a small-arm. There are many kinds of small-arms such as shotguns, muskets, carbines, rifles, pistols, and revolvers.

A **shotgun** is a shoulder arm having a barrel that is smoothly bored inside, and is intended for the firing of a charge composed of one or more round balls or pellets of shot. Many shotguns are constructed with two barrels, side by side or over and under one another.

It has been found that a charge of shot when fired from a smooth bore barrel, the barrel being a true cylinder from breech to muzzle, will scatter over a circle approximately 50 inches in diameter at 40 yards (the standard shotgun testing distance), and moreover the pellets will not be uniformly distributed throughout the circle. Modern shotguns therefore have the bore very slightly constricted or reduced in diameter within an inch or two of the muzzle, which reduces the dispersion of the shot and makes it more uniform. This constriction is called the *choke*. The greatest practical choke is called *full-choke* and results in about 75 to 80 percent of the pellets in the shot charge striking within a circle 30 inches in diameter at forty yards.

Shot pellets and all round balls lose their velocity very fast due to the resistance of the air, this causing a quick reduction in penetration, and causing them to fall rather quickly to the ground. Due to the combined dispersion of the shot, and the rapid loss in velocity, fifty yards is, generally speaking, about the maximum distance at which birds can be struck and killed with a shotgun.

A **musket** is a smooth bored military shoulder arm, usually having a long fore-stock, and usually being arranged to take a bayonet at the muzzle. When rifling was first developed some muskets were made with rifled bores and these were termed **rifled muskets.** Strictly speaking, however, muskets had smooth bores without any choke, and commonly fired a single round lead ball. It has been found that single round balls projected from a smooth bore barrel have a dispersion under favorable condition of about 40 minutes of angle—that is at 100 yards a number of balls fired with the same aim will be dispersed over a circle about 40 inches in diameter. A round ball also loses its velocity of flight rapidly, as we have seen. Due to dispersion and loss of velocity, one hundred yards is about the maximum distance at which a target as large as the body of a man can be struck with a musket with even fair degree of certainty.

A **carbine** is a short barrelled musket or rifle having a barrel not longer than about 22 inches for convenient use by cavalry or men on horseback. Carbines, by reason of their light weight and handiness, are now being used to arm soldiers who are not regularly armed with rifles, and for this purpose are gradually replacing hand-arms in modern armies. A tommy-gun is a short barrelled carbine, usually functioning automatically. The carbine and the tommy-gun, generally speaking, have a sure hitting range on man targets of about 300 yards. Carbines are used quite extensively by deer hunters because of their handiness in thick woods.

A rifle is a shoulder arm designed to hit targets at a longer distance than is possible with a shotgun or smooth bored musket. The bore of a rifle has a number of shallow *grooves* cut longitudinally in the surface of the bore. These grooves, instead of running straight from breech to muzzle, are cut with a spiral direction so that the inside of the bore looks like a screw-hole that has been tapped with a very slow pitch or turn. The thread of an ordinary wood screw makes one complete turn in about $\frac{1}{16}''$ of the screw's length, while the grooves inside a rifled bore make a complete turn in about eight to thirty inches of the barrel's length.

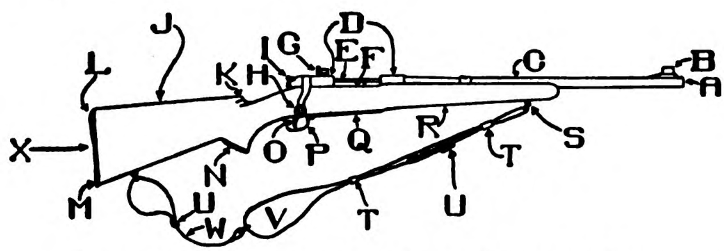

FIGURE 2. NOMENCLATURE OF MODERN RIFLE AND SLING

A—Muzzle. B—Front Sight. C—Barrel. D—Receiver. E—Bolt. F—Extractor. G—Rear Sight. H—Bolt Handle. I—Safety. J—Stock, or Butt Stock. K—Comb of Stock. L—Heel of Stock. M—Toe of Stock. N—Pistol Grip, or Grip. O—Trigger. P—Trigger Guard. Q—Magazine. R—Forearm, or Forend. S—Upper Sling Swivel. T—Keepers on Sling. U—Sling Claws. V—Arm Loop. W—Tail Piece. X—Butt Plate.

When a fairly tight fitting conical bullet or round ball if fired through a bore that has been rifled in this manner, the *lands* between the grooves cut into or engrave the surface of the bullet, and, holding it against flying straight forward, cause it to rotate and follow the twist of the rifling, so that as it passes up the bore it also turns spirally. As a consequence when the bullet emerges from the muzzle it is spinning like a top. Technically therefore the bullet when launched into the air becomes a small gyrostat which tends to keep in the same plane or direction during its flight through the air that it was given in the rifled bore. As a consequence the bullet flies much straighter than were it fired from a smooth bore, and if it be a conical bullet it also flies with its point to the front.

Certain long range rifles shoot with such accuracy, can be given such a high velocity, and their conical bullets maintain that velocity so well that a target the size of a man can surely be hit up to, say, 600 yards. Other rifles and cartridges are not designed for use at such long distances and are termed short range rifles.

There are many types of rifles, such as military rifles, sporting rifles, big game rifles, small game rifles, and target or match rifles.

A **pistol** is a hand arm having a short barrel, usually not over 10 inches long, with a grip designed so that it can be held in and fired from one hand with the arm more or less extended. While revolvers

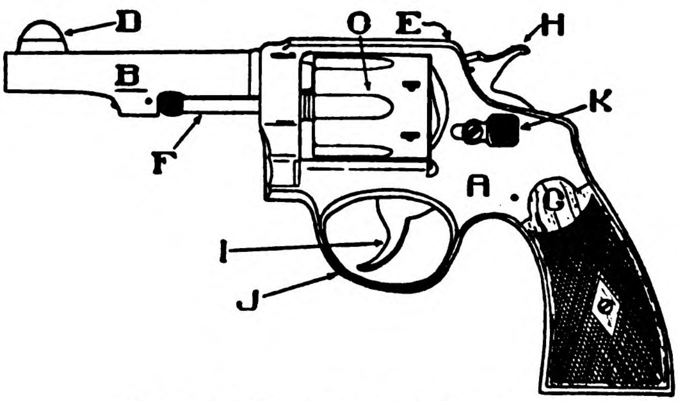

FIGURE 3. NOMENCLATURE OF REVOLVER

A—Frame. B—Barrel. C—Cylinder. D—Front Sight. E—Rear Sight (integral with frame in many revolvers). F—Ejector Rod. G—Grip. H—Hammer. I—Trigger. J—Trigger Guard. K—Thumbpiece of Cylinder Latch.

are often included under the general classification of pistols, we prefer to here define a pistol as a hand arm in which the cartridge is loaded directly into the chamber of the barrel to distinguish it from a revolver in which the cartridges are loaded into a cylinder in rear of the breech of the barrel. Pistols may be *single-shot* in which only a single cartridge is loaded and fired at one time, *repeating pistols* which have a magazine, and *semi-automatic* or *self-loading pistols*. Pistols usually have rifled bores, but by reason of their light weight use cartridges of moderate power, so that generally speaking their effective range is about 100 yards. Some pistols are also made with smooth bores to fire charges of shot.

A **revolver** is a hand-arm in which the cartridges, usually six or more, are loaded into a cylinder which revolves in rear of the breech of the barrel. Each time the mechanism is operated (cocked) a chamber of the cylinder is brought into line with the bore. When the revolver is fired the bullet passes forward out of the cylinder, into and through the bore, and out the muzzle. The process of cocking and firing the revolver thus permits the shots to be fired in rapid succession to the extent of the capacity of the cylinder. The muzzle of the cylinder is so close to the breech end of the barrel that only a slight amount of powder gas escapes while the bullet is jumping from cylinder to barrel and passing up the bore, and the velocity, as compared with a true pistol, is diminished only slightly, so that the effective range of the revolver is about the same as that of a pistol.

Ballistically, pistols and revolvers have a much longer effective range than 100 yards, depending upon the cartridge they use. But the difficulties of marksmanship with a weapon held in one hand, with arm extended, are such that the sure hitting range on man targets is about 100 yards, and frequently only half of this distance.

Caliber and Gauge

An important detail in any small-arm is its *caliber* or *gauge*—that is the diameter of its bore, and consequently the diameter of the bullet it uses.

In the United States and all English speaking countries the diameter of the bore of rifled small arms is designated in hundredths or thousandths of an inch. Thus we have rifles, carbines, pistols, and revolvers of .22, .25, .30, and .45 caliber, or .220, .257, .357, and .405 caliber, etc. On the continent of Europe and elsewhere the calibers of such weapons are designated in millimeters as 6.5 mm, 7 mm, 8 mm, 9 mm, etc. Generally speaking these diameters are the diameter of the smooth bore before it is rifled. There are many exceptions to this, however,

Strictly speaking, the ordnance engineer uses the expression *"Caliber .30"* to mean a barrel which has a bore diameter (before rifling) of .30-inch; and he uses the term *"thirty-calibers,"* usually with reference to cannon, to mean a barrel which is 30 times as long as its bore diameter. Thus a thirty caliber, 3-inch field piece would be one with a bore diameter of 3 inches and a barrel 90 inches long. In this work, however, the word "caliber" will be used to designate the diameter of the bore.

An entirely different system, going back several hundred years, is used to designate the diameter of the bore of the shotgun. The gauge or bore of a shotgun is that number which would weigh a pound if made up in round pure lead balls. Thus a 12-gauge gun is one having such a diameter of bore, in the early days of its origin, that 12 lead balls of the diameter to just fit it would weigh one pound. Today, this figures out in the following diameters in thousandths of an inch:

4 gauge	.935-inch
8 "	.835 "
10 "	.775 "
12 "	.729 "
16 "	.662 "
20 "	.615 "
28 "	.550 "
.410 "	.410 "

In England the word "bore" is used more often than "gauge" to designate the diameter of bore of shotguns. Also the older black powder English rifles were frequently designated by the above system of bore diameter, such as 4, 8, and 10 bore elephant rifles.

Do not confuse the words "gauge" and "gage." A *gage* is a small instrument or block of steel used to make standard dimensions.

Breech Actions

With respect to the handling of their cartridges, and to their rapidity of fire, small arms are classified as *single-shot, single* or *double barrel, repeating* or *magazine, self-loading* or *semi-automatic,* and *automatic.*

A **single-shot** gun, rifle, or pistol is one which loads with only one cartridge. To fire it a second time its breech mechanism or *action* must be opened, the fired case or shell extracted or ejected, another cartridge inserted in the chamber, the breech action closed, and finally the trigger must be pressed for another shot.

A **double-barrelled** small arm is one having two barrels, placed either side by side or superimposed (*over-under*), each having its own firing mechanism. When the breech is opened both barrels can be loaded, and after closing can be fired one after the other in rapid succession.

A **repeating** or **magazine** small-arm has a magazine or recess in the breech action, or under the barrel, or in the stock, which contains two or more cartridges. After a cartridge has been fired, hand operation of the breech mechanism causes the fired case or shell to be ejected, a new cartridge to be fed from the magazine into the chamber, and the breech action closed ready to fire the second or subsequent shot upon pressing the trigger. Such a small-arm can be fired quite rapidly to the extent of its magazine capacity.

An **automatic** firearm is a repeating or magazine weapon which utilizes the power of the recoil of the cartridge, or a portion of the expansion of the powder gases to extract the fired case and load the next cartridge from the magazine. Strictly speaking an automatic arm will continue to fire with great rapidity to the extent of its magazine capacity as long as the trigger is kept pressed. The machine gun is an example of the true automatic arm.

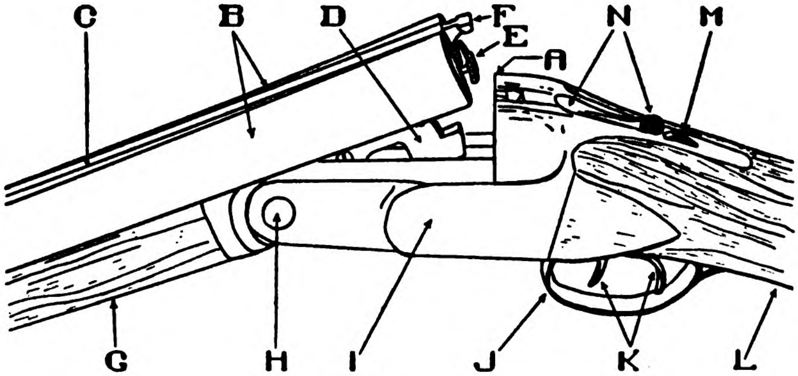

FIGURE 4. NOMENCLATURE OF THE DOUBLE BARREL SHOTGUN

A—Standing Breech, or Breech Face. B—Barrels. C—Rib. D—Barrel Lug, or Locking Lug. E—Extractor, also Ejector where the gun is fitted to eject fired cases automatically. F—Extension Rib, or "Dolls Head," or Top Extension. G—Forend, or Forearm. H—Hinge Pin. I—Frame. J—Trigger Guard. K—Triggers. L—Grip, or Pistol Grip. M—Safety. N—Top Lever.

A **semi-automatic** or **self-loading** small arm is one which is automatically operated by the ammunition it uses, but which fires only a single shot when the trigger is pressed. The trigger must be slightly released and then pressed again to fire a second or subsequent shot. Most of our automatic rifles, shotguns, and pistols are of this type, and can be fired with effect as rapidly as one's senses can recover from the disturbance of recoil. If a shoulder arm or hand-arm were made full automatic subsequent shots would be fired before one's body recovered its equilibrium after recoil, the body would be gradually pushed back and the barrel up, and the shots would strike higher and higher. However, some few military rifles and tommy-guns are constructed so that they will operate either semi-automatically or full automatic, at the will of the shooter.

Automatic arms are further divided into *recoil operated, blowback,* and *gas operated.* Our .45 caliber Colt Automatic Pistol is an example of recoil operation. The Garand rifle, and the Caliber .30 Carbine (Winchester), with which the United States Army is at present armed, are gas operated, a small amount of gas taken off through a port in the bore when the arm is fired being used to operate a piston which in turn operates the mechanism.

CHAPTER II

The Rifled Bore

WE HAVE already seen that a smoothly bored barrel cannot be relied upon to project a bullet with a satisfactory degree of accuracy to strike small objects at any considerable distance. With constant aim, bullets fired from a smooth bored gun will hardly average striking in a 40-inch circle at a hundred yards.

In order to make a barrel project a bullet more accurately the inner surface of the bore is cut with a number of spiral grooves and ribs, called **rifling.** The ribs between the grooves, or **lands** as they are technically called, bite into the bullet as it passes through the bore, and give it a spiral or turning motion which persists after the bullet leaves the muzzle.

A barrel to be rifled is first drilled with a hole slightly smaller than its completed smooth or bore diameter. Then this hole is reamed slightly larger, to finished bore diameter, to give it a smooth interior surface. At this point it is inspected for straightness of bore, and if not straight the barrel is slightly bent to straighten the bore. It is then rifled in a rifling machine with a cutter or broach which cuts or engraves the required grooves in the surface of the smooth bore, and at the required pitch or spiral turn.

Usually from two to eight grooves are cut equidistantly around the surface of the smooth bore. These grooves are cut from two to five thousandths of an inch deep, and are usually about twice as wide as the original surface of the bore, or *lands,* left between them. The distance or diameter from the bottom of one groove to the bottom of the opposite groove is termed **groove diameter,** and the diameter of the original bore before it was rifled, that is from the top of one land to the top of the opposite land, is termed **bore diameter** or **land diameter.** These diameters in the United States and England are measured in thousandths of an inch, and on the continent of Europe in millimeters. Generally speaking the caliber of a rifle is its bore or land diameter, although this is not always strictly adhered to in our descriptive nomenclature as we shall see later.

Thus our Caliber .30 army rifles have a bore diameter of .300-inch, and are rifled with grooves .004-inch deep, making the groove diameter .308-inch. The bullet for such a rifling is made slightly larger in diameter than bore diameter, usually about groove diameter. As a result when this bullet is fired through the barrel the lands cut into its surface and make it follow the twist of the rifling instead of driving straight forward. The bullet thus rotates or spins during its flight, either to the right or left, depending on the direction of the twist or spiral of the rifling. Almost all barrels made in

FIGURE 5. CROSS SECTION OF RIFLED BORE

the United States are rifled with a right hand or clockwise twist, and the bullet rotates to the right. About the only exceptions are the barrels of the Enfield 1917 rifles and the Colt revolvers and pistols which have a left hand twist. Enfield 1917 rifles were first made in the United States on British specifications which called for a left hand twist. When we came to manufacture them to supply our army in World War I we used the same machinery, hence the left hand twist. Colonel Colt manufactured his early revolvers in England, giving the rifling a left hand twist in conformity with the general practice there, and this custom still persists in the organization which he founded.

British gunmakers have usually preferred a left hand twist. They adopted it originally in order to compensate for the drift due to the rotation of the earth in the Northern Hemisphere. When a rifle is fired the bullet twists or rotates in one direction, and the barrel also rotates slightly in the opposite direction. This rotation of the barrel was quite noticeable in early days when firing large caliber rifles with very heavy bullets, but is hardly apparent in these times of smaller bores and lighter bullets. The stock, of course, rotates with the barrel. A left hand twist has the effect of twisting the butt of the rifle away from the firer's cheek instead of against it, and thus the twist is not so apparent or disconcerting to the firer. The writer does not know why the almost universal practice has been to use a right hand twist in America.

There is no difference in the effectiveness of the two directions of twist. One is just as good in all respects as the other.

It is the practice of our manufacturers to hold the bore and groove diameters to a tolerance of not more than .001-inch above the standard, although in time of war an extra thousandth of an inch may be permitted to facilitate quantity production. Thus with our Caliber .30 rifles made in peace time, the bore and groove diameters which are standard at .300 and .308 inch respectively, will seldom exceed .301 and .309-inch respectively. In time of war, however, barrels may be accepted where these diameters run as high as .302 and .310-inch. Before the development of modern precision machinery these tolerances used to be much larger.

It has been claimed that by having an odd number of grooves of rifling, instead of an even number, and cutting only one groove at a time, it is possible to cut the grooves to a more uniform depth and smoother because the rifling rod under the cutter has a more even and wider bearing on the bore diameter, and hence better backing. But the best barrels that the World has yet seen made by quantity production are those produced by Springfield Armory and the Winchester Repeating Arms Company. Together they hold practically every record for accuracy. All barrels made by these two manufacturers are cut with an even number of grooves, which seems to refute the belief.

It is also debatable whether it is best to, finish off the muzzle of the barrel perfectly square, with a sharp right angle terminating the grooves and lands at the muzzle, or whether to countersink the muzzle with a slight bevel. All of our manufacturers now countersink because a countersunk muzzle is better protected from any injury that might deform or injure it unevenly. Those custom barrels which have been purposely left square and flat at the muzzle do not seem to have gained any particular merit thereby. But the muzzle must certainly be even and symmetrical all around its diameter, otherwise just as the base of the bullet departed from the muzzle the powder gas would rush out on the short or more beveled side first, and would tip the bullet to the opposite side.

After the bore has been reamed and rifled some manufacturers, notably the Winchester Repeating Arms Company, polish their bores by leading them with a lead lap and fine emery, the lap following the spiral of the rifling, and polishing both on top of the lands and in the grooves. Other manufacturers, notably Springfield Armory, do not polish, but rely on the perfection of their cutters and reamers to produce smooth grooves and lands. Both practices, no matter how done, result in slight scratches on the surface. The scratches with the emery polished bore are finer, and are all parallel with the spiral of the rifling, hence they do not "file" the bullet, and there is less bore friction. If the bore be not polished, the slightly rougher scratches of the rifling cutter will also be in line with the spiral, but the scratches on top of the lands made by the turning reamer will be at right angles to the bore, and will cause friction with the bullet. In the days when cupro-nickel jacketed bullets were almost universally used, the writer believes that he shot more barrels made by both Springfield and Winchester through their accuracy life than any other rifleman, and he always cleaned these barrels perfectly, and he gained a distinct impression that the lapped barrels (Winchester) accumulated less metal fouling from friction than did the unlapped (Springfield) barrels. But he cannot say that one make of barrel presented any superiority in accuracy over the other. He has, however, gained the impression that the best practice is to lap polish the bores, although of course this increases the time and expense of manufacture. The owner can readily lap out his own rifle barrels to a higher degree of efficiency; instructions being found in any work on gunsmithing.

It is the general practice in the United States to manufacture the bullets for a rifle with a diameter as large or slightly larger than the groove diameter of the barrel. Thus Caliber .30 bullets are usually made with a diameter running between .308 and .309-inch. It is not possible to make either bores or bullets economically of an exact diameter as the rifling cutters and bullet dies wear with use, and the expense of new cutters and dies to surely hold to an exact diameter would be very heavy. But at present the best practice with our Caliber .30 rifles is to try in manufacture to hold the groove diameter as closely as possible to .308 inch, and the diameter of the bullets to .3087-inch, because this combination appears to give slightly better accuracy and barrel life. This is predicated on the use of a bullet of a certain hardness of jacket and core as will be explained later.

In England the practice is slightly different. There the Caliber .303 rifles are rifled with a standard groove diameter of .311-inch, and they endeavor to hold their bullets to a standard diameter of about .3095 inch, on the theory that when the lands cut into the bullet they should displace just enough of the bullet metal to make the grooved bullet just fit to the bottom of the rifling. To allow for this displacement of bullet metal they usually make their bullets with slightly softer jacket and core metal then we do. It is debatable which is the better system, but our ordnance engineers are of the opinion that we get better accuracy by making our bullets just slightly larger than groove diameter.

Round bullets are now more or less obsolete. If a spherical or cylindrical bullet be rotated with sufficient speed it becomes in effect a *gyroscope* or *gyrostat.* A spinning top is a good example of a gyrostat. A gyrostat tends to keep in the same plane as it was in when given its original rotating motion, and it strongly resists any influence which would tend to force it out of that plane. Thus the rotating bullet flies straight in prolongation with the axis of the bore in which it received its rotation, and also, if it be a cylindrical or conical bullet, it flies with its point to the front. As boys you have all of you played at spinning tops. If the top is spun just right it will spin straight upon its point, and if the floor be level it will spin on one spot. It appears to "go to sleep," or in other words it has *gyrostatic stability.* If it is spun too fast it will wobble a bit until its speed of rotation has fallen to the proper amount, when it will go to sleep until its speed of rotation has fallen too low, when it again begins to wobble and finally falls over. If the original rotation is not fast enough the top wobbles and falls over at once.

A spinning bullet performs in exactly the same way as the top. If the twist of rifling be just right, and if other conditions be correct, a cylindrical bullet will go to sleep when it leaves the muzzle of the rifle, and it will fly through the air with such gyrostatic stability that it will keep its point to the front and travel on a course through the air in almost exact prolongation with the axis of the bore (less the fall due to gravity and air resistance, and possible deflection by wind) to a very considerable distance. In fact its stability may be such that successively fired bullets may not have a greater dispersion than a minute of angle; that is they may group in a spot or circle not more than an inch in diameter at 100 yards, or ten inches in diameter at 1,000 yards. We have already seen (Chapter I) that a round ball fired from a smooth bore gun cannot be relied upon to group in much better than 40 inches at 100 yards, and it loses all semblance of accuracy shortly beyond that distance.

Finally, at a more or less greater distance, depending on the type of rifle and cartridge, the energy of forward velocity and the velocity of rotation fall off to such an extent that the bullet loses its stability, begins to wobble, then no longer flies with its point to the front, accuracy of flight disappears, the bullet encounters much air resistance, and finally falls to the ground.

The longer the bullet is with respect to its diameter the faster it must be rotated, that is the quicker must be the twist of the rifling, to give it stability. Also the slower the velocity of the bullet the quicker must be the twist. We designate different twists by the number of inches of barrel length in which the rifling makes one complete turn. A ten inch twist is one that makes a complete turn in ten inches of the barrel length.

As an example of twist let us take the case of our Caliber .30 army rifles. The original cylindrical bullet weighed 220 grains, had a diameter of .308-inch, and was about 1.25-inches long. Caliber .30 army cartridges are used in both rifles and machine guns, and while a rifle may not be used at distances over 600 yards in war, or in peace-time target shooting at over 1,000 yards, the machine gun must throw its bullets with a fair degree of accuracy to 2,500 yards or beyond. It was found by calculation as well as by experiment that the rifling of the barrel had to be given one complete turn in ten inches in order to maintain stability and accuracy to extreme machine gun ranges, and accordingly all barrels of U.S. Caliber .30 rifles and machine guns have been rifled with a 10 inch twist. However, while such a quick twist is not detrimental at shorter ranges, it is not really essential for rifles of this caliber which are not used at over 1,000 yards. It was demonstrated by H. M. Pope in 1904 that a 14 inch twist would stabilize a well made Caliber .30, 220 grain bullet to 1,000 yards at least when fired at a muzzle velocity of 2,200 feet per second.

The barrel of the .250-3000 Savage rifle was originally made with a 14 inch twist for a .257-inch bullet of 87 grains. This twist would stabilize a bullet as long as 100 grains to all sporting distances (500 yards at least) when the bullet was fired at M.V. 2,400 f.s.* or over. But this 14 inch twist would not stabilize the longer 117 grain bullet even to 200 yards unless it was given a muzzle velocity of 2,500 feet per second or over, and such a velocity was not practical in the Savage rifle within the limits of permissible breech pressure. In the .257 Roberts cartridge, which has a slightly greater powder capacity than the Savage cartridge, a 10 inch twist stabilizes this long 117 grain bullet at M.V. 2,500 f.s. to 600 yards at least. But this same 10 inch twist is a little too fast for the lighter and shorter 87 grain bullet which does not give its best accuracy in such a fast twist. Again we see the same laws pertaining as with the boy's top.

Take again rifles for the Caliber .22 rim fire cartridges. Barrels for the .22 Short cartridge, which is loaded with a short 30 grain bullet to M.V. 1,030 f.s., are given a 22 inch twist, while those for the .22 Long Rifle cartridge, loaded with a 40 grain bullet at M.V. 1,075 f.s., have a 16 inch twist. If we rechamber a .22 Short barrel for the .22 Long Rifle cartridge, and fire the latter cartridge in it,

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* The ordnance and ballistic engineer shortens the expression "muzzle velocity 2,400 feet per second" to "M.V. 2,400 f.s." This shorter method of expressing velocity will be used hereafter.

the bullets will "key-hole"; that is they will not fly with their points to the front, will make a hole in the paper target that looks like a key-hole, and will not shoot accurately. But we can take this same .22 Short barrel (22 inch twist) and rechamber it for the .22 Hornet cartridge which shoots a 45 grain bullet at M.V. 2,600 f.s., and get fair accuracy up to 100 yards at least, thus showing the part that velocity plays in selecting the proper twist of rifling.

In the appendix will be found a table giving the twist of rifling for all rifles, pistols, and cartridges of American make.

Besides the speed of rotation of the bullet, accuracy is also dependent on the uniformity and perfection of the bullet as it flies through the air, for it will not be a perfect gyrostat unless it is uniform as to shape and surface, and has its center of gravity in coincidence with its center of form. It is important, therefore, to have the well formed bullet pass out of the case, into the bore, through the bore, out of the muzzle, and finally into the air with as little deformation as possible. Also the powder charge should be such as will give uniform velocities from shot to shot, as well as a velocity suited to the bullet and to the twist of rifling. There are also many other small details connected with accuracy which will be discussed in their proper place.

Perfect bullets cannot as yet be produced in quantity, but skilled workmen with proper tools can produce wonderfully uniform bullets when they make the effort. Bullets as we obtain them today vary from poor and mediocre to extremely uniform and excellent. In fact with our modern precision machinery the bores of practically all rifles are so well and uniformly made, and so well designed, that accuracy is practically insured with good ammunition. Thus accuracy at present usually depends more on the bullet than on the barrel. Many fine rifles are condemned as inaccurate when the entire fault lies with the bullet or cartridge.

To pass through the bore with the minimum of deformity a bullet, before being discharged, should lie in the bore or throat of the chamber with its axis coinciding with the axis of the bore and with its start of *ogive* or curve of point impinging on the leade or origin of the lands. A perfect fit in these respects is thus far impossible with rifles and ammunition made by quantity production, but it should be approached as closely as practical. The following chapter discusses details of chambering.

The bullet must be of the correct diameter to fit the particular size and type of rifling used, and the rifling itself should be of a type best suited to pass the bullet through it with the minimum of deformity. There is a vast number of types of rifling, almost every conceivable shape and dimension of lands and grooves having been used and thoroughly tried at one time or another. Cross sections of

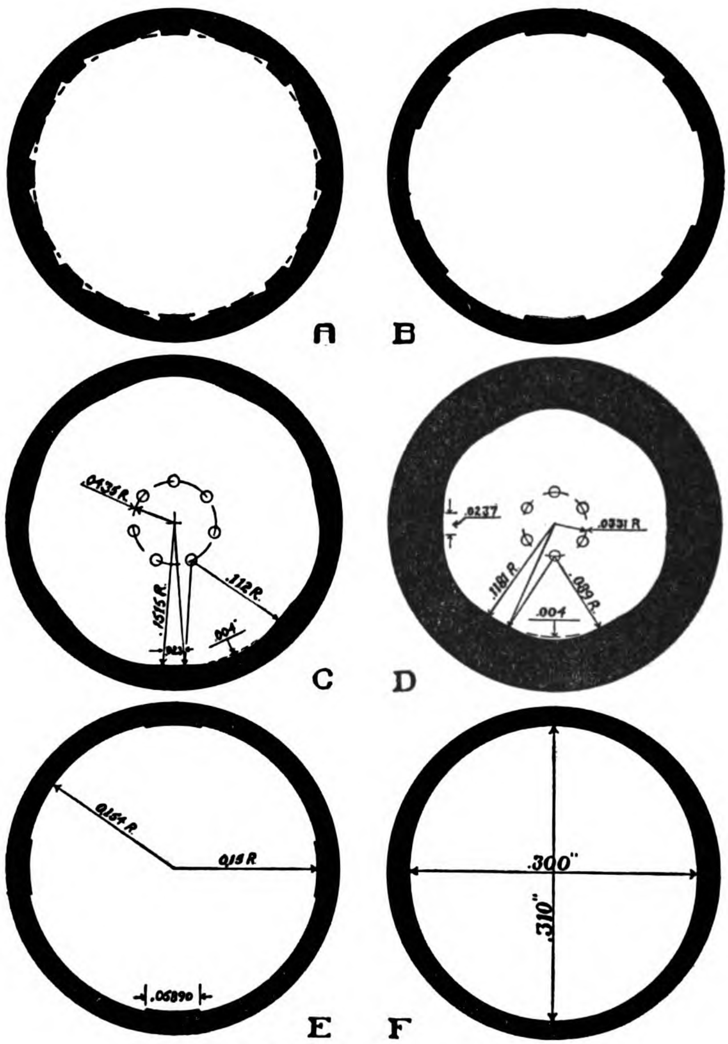

FIGURE 6. COMMON FORMS OF RIFLING

A—Schalk-Pope rifling. B—Enfield type rifling. C—Metford's rifling system. D—Metford type rifling as applied to the 6 mm Lee Navy rifle. E—Bore and rifling of the Model 1903 Springfield rifle, with dimensions. F—Newton-Lancaster type of oval boring, with dimensions for .30 caliber.

the three types of rifling which have been found to best meet modern conditions are shown here.

Generally speaking the **Pope system** has been found to be the best for lead alloy bullets. The inner dotted circle in the drawing shows the diameter of the bullet which just touches and rides on the top of the lands and the center of the flat bottom grooves. The corners of the grooves are slightly rounded. The black powder used in the older black powder—lead bullet rifles gives much more of a sudden blow to the bullet when it starts to burn as compared with the "shove" of modern smokeless powders. Each rifle being furnished with its own special bullet mould, the rifleman could cast his bullets to exactly bore diameter to fit this rifling. Thus the bullet was very accurately centered in the bore by its contact with the lands and the centers of the grooves, and when the blow of black powder came it expanded the soft lead bullet very evenly so that it exactly filled the rifling to the bottom corners of the grooves, and with practically no deformity of the bullet. With the Pope system the bullet was preseated in the bore ahead of the case, usually by muzzle loading of the bullet, although sometimes from the breech by means of a bullet seater. It is debatable if the Pope system would show its superiority with bullets seated deeply in the cases, or with bullets differing slightly in diameter as practically all commercially made bullets do.

The **Metford** form of rifling with slightly rounded grooves and lands was used almost exclusively for all the better English rifles in black powder days just preceding the introduction of smokeless powder and jacketed bullets. It was thought to be the best rifling for black powder and lead bullets where the bullet was seated in and fired from the case, particularly when the bore was not cleaned between shots. The black powder fouling did not seem to cake and accumulate in it as it did in other forms of rifling. For this rifling, generally speaking the diameter of the lead bullet should be a mean between bore and groove diameters.

The **Enfield** rifling with square cornered grooves and lands has proved to be the best, or at least as good as any other type of rifling, where modern cartridges loaded with smokeless powder and metal jacketed bullets are used. It is the easiest type to cut, and no other type has proved to have sufficient superiority over it to warrant the greater cost of production. Hence practically all modern American rifles have this Enfield type of rifling. Most of them are cut with either four or six grooves, although lately some barrels have been produced with only two grooves for economy of manufacture. Enfield rifling is used even in the best .22 caliber rim fire barrels, although for this purpose it is debatable whether the Pope or the Enfield type is the best. The lead bullets of the "match" varieties of the .22 Long Rifle cartridge are made much more uniform as to diameter than most other commercial bullets, and in loading the cartridge the bullet is pushed into the bore ahead of the case and chamber. We thus have a procedure well adapted to the Pope system.

With the Enfield rifling it is also debatable whether the diameter of the jacketed bullet should be slightly smaller than groove diameter, the same size, or slightly larger. British practice is to make bullets slightly smaller than groove diameter, with relatively thin or soft jackets and soft lead cores, so they will expand and fill the grooves. The American practice tends towards making the bullet just groove diameter. When using boat-tailed bullets it is thought that the best results are secured when the bullet is slightly larger than groove diameter, say a bullet having its cylindrical portion .3087-inch in diameter for a barrel with a groove diameter of .308-inch. The boat-tailed bullet does not receive a powder blow on a flat base to cause it to expand and fill the grooves as promptly or as surely as does the flat base bullet, and hence it should be at least groove diameter. The thought with modern cartridges is that the bullet should very promptly fill and seal the bore to the bottoms of the grooves, otherwise the extremely hot gases of smokeless powder will cut past the bullet, between the bullet and the bottoms of the grooves, deform the bullet more or less, and erode the rifling rather rapidly.

However, with barrels for very high intensity cartridges giving muzzle velocities of 3,500 foot seconds and over, and with breech pressures of 50,000 pounds per square inch and over, Ness and Barr, of the National Rifle Association, seem to have proved that under certain conditions gilt-edged accuracy may be obtained with bullets .0005-inch larger, or .004-inch smaller than groove diameter, and apparently without much greater barrel erosion where the smaller bullet is used.

CHAPTER III

Barrels in General

BECAUSE the barrel of the famous Kentucky rifle was very long, and because of that fictional character Hawkeye and his long rifle Killdeer, many persons think that a long barrel is necessary for best accuracy in a small-arm. This is not true. Our old muzzle loading rifles and shotguns had long barrels because they used black powder as a propellant. Black powder burned relatively slowly, and it required a long barrel to burn a large enough charge to give the required velocity.

Charges of modern smokeless powder are much faster burning, and the charge is completely consumed in a relatively short barrel. Accuracy depends not on barrel length, nor even in barrel straightness, but on the perfect delivery of the bullet-gyrostat into the atmosphere, and the perfection of that gyrostat.

The length of barrel required to give the maximum velocity with a given cartridge depends on the kind and amount of power loaded in that cartridge, and its bullet. Some powders burn faster than others, and some bullets offer more bore resistance and friction and consequently cause faster burning of the powder charge.

The little .22 Long Rifle cartridge attains its maximum velocity in a barrel only 18 to 20 inches long, depending on the kind of powder loaded in the cartridge. With the regular cartridge the velocity in a 4-inch barrel is about 850 f.s.; 10 inches, 1,000 f.s.; 16 inches, 1,030 f.s.; and in a 24 inch barrel only 1,000 f.s., showing that in the latter length the powder has been completely consumed, all the gas possible has been generated and expanded, and the friction of the bullet in the extra length of barrel is beginning to retard the bullet. Most .22 caliber rifles have barrels 24 inches long because that is the present "style." Our .22 caliber match rifles quite generally have 28 inch barrels. The only advantage of such a long barrel on these match rifles is that it gives a greater distance between front and rear sights, and thus a certain error of aim does not cause the shot to strike so wide of the mark; an advantage that does not hold with a telescope sight.

The disadvantage of a long barrel is also sometimes evident in revolvers using the .38 Smith & Wesson Special cartridge. Where a long or very heavy and soft bullet is used, the velocity is frequently greater in a 6 inch barrel than in one of 7½ inches, because the friction of the extra barrel length more than neutralizes the very slight increase in length of gas pressure.

With the original .30-40 Krag cartridge firing the 220 grain bullet the muzzle velocity in the 30-inch rifle barrel was 2,000 f.s., and in the 22-inch carbine barrel 1,920 f.s.

With the original .30-06 cartridge firing the 150 grain bullet, the standard M.V. 2,700 f.s., was obtained in a 24 inch barrel which is the standard length for Springfield '03 and Garand rifles. Increasing or decreasing the barrel length an inch increased or decreased the muzzle velocity 18 to 25 f.s., depending on the bullet and powder used. The increase per inch pertained up to a length of about 32 inches when apparently most powder charges were completely consumed.

Quite generally most modern rifles, both military and sporting, are now made with barrels 24 inches long which seems to be a happy medium, giving both handiness and good accuracy, with almost the maximum velocity in many cases. Formerly military rifles used to have very long barrels, 32.5 inches for the Springfield 1873 and 30 inches for the Krag rifle, with the carbines of these models equipped with 22 inch barrels. With the Springfield 1903 rifle a compromise of 24 inches was made with a view to having the same weapon for both Infantry and Cavalry use, and it proved so good that apparently it has established the 24-inch style as standard. One reason for the longer barrel on early military rifles was to provide a sufficiently long handle or reach for the bayonet.

Winchester standard barrel lengths for sporting rifles are now pretty generally 24 inches, with 20 inches for carbines. Exceptions are the .22 caliber match rifles which have 28 inch barrels chiefly because that is the long established style; and rifles for the .220 Swift and .300 H. & H. Magnum cartridges which are made 26 inches long to give certain advertised velocities to their cartridges. Extremely high intensity rifles of M.V. 3,000 f.s., and over attain their high velocity from relatively large charges of powder and light bullets, which combination requires a longer barrel to burn all the powder and give them their high velocity, so that 26 or 28 inch barrels seem desirable.

Standard shotgun shells give practically the same velocity, penetration, and pattern whether the barrel length be 26 or 30 inches, so the well informed shotgun shooter bases barrel length on considerations other than ballistics. A gun with 26 inch barrels handles faster, and is handier in brush and on most upland game. The long barrel swings slower and in the hands of many shooters is best on ducks, particularly in pass shooting. So the shooter who selects a long barrelled shotgun with the idea that he is thereby getting higher velocity, greater penetration, and a denser pattern is all wrong. The ultra modern long range 10 and 12 gauge magnum shells do, however, require around 30 inch barrels to give the maximum ballistic effectiveness which is the sole reason for such heavy loads.

While a moderately short barrel tends towards greater handiness, there are serious objections to a very short barrel which accentuates recoil and report, sometimes to a very objectionable degree. Except with very light cartridges, like pistol cartridges, with an extremely short barrel of only two or three inches, the powder blast at the muzzle may so upset and deform the base of the bullet just as it leaves the barrel so as to preclude any accuracy.

Weight

The weight, that is the outside diameters, of the barrel of a small arm depends on a number of things. Long experience has proved that a military rifle should not weigh over 9½ pounds.* Most sportsmen prefer that their rifles should not weigh over 8 pounds, although there is a class of hunter-riflemen who take pride in sure hits and clean kills at long distances, and who are willing to carry rifles weighing up to 11 pounds to obtain the better accuracy. Target shooters, also, have found that a rifle of about 11 to 12 pounds holds steadier than a lighter weapon, and of course they do not have to carry their rifles long distances over rough country. It should be understood that the heavier the barrel of a rifle, other things being equal, the more accurate it will be because it jumps less and more uniformly on discharge, and it heats up slowly and retains a more even temperature.

The barrel of a rifle or shotgun comprises roughly one-third of the weight of the entire arm, and in any given model of gun is about the only part that can be varied materially in weight, hence the importance of the weight of the barrel in determining the weight of the entire gun.

The experience of our pistol shooters has shown that for the best shooting, target or military; slow, timed, and rapid fire; a hand gun should weigh about 36 ounces. Very excellent revolvers are made to weigh as much as 44 ounces, but they have not proved popular among the best American pistol shooters because they are not "lively" enough in rapid fire. A ladies or boy's revolver for light

* In this work weights of complete small arms are weights without gunsling or telescope sight unless otherwise stated. Weights are always given without cartridges in barrel or receiver being included.

cartridges may weigh as little as 26 ounces, and pocket weapons for self defense at very short distances may also be light, but a master pistol shooter using a light weapon finds that accuracy and timing has been sacrificed. With a hand gun the receiver or frame is the heaviest portion, and the weight of the short barrel does not figure so prominently in the complete weight.

For upland game most shotgun shooters prefer guns weighing 6 to 7 pounds, while duck shooters prefer about 7¼ to 8 pounds. Long range shotguns for magnum shells usually weigh slightly over 8 pounds.

It should be said that these weights are the result of very long experience where not only personal preference, but also ballistic performance is considered. They are all compromises of course, because a man who has to carry his weapon all day naturally prefers the lightest weight possible, while maximum ballistic performance demands all the weight permissible. It would therefore be a mistake to design a small-arm differing materially from the above weights, except for some very special purpose.

Steel

The outside diameter of a barrel must be large enough so that its wall thickness is sufficient to sustain the breech pressure of the discharging cartridge without expanding or disrupting. The greatest breech pressure occurs at the breech of the barrel, particularly at that portion (chamber) which contains the cartridge, and for perhaps an inch forward of this portion, therefore the barrel must be thickest at the breech. As this portion of the barrel is also threaded to screw it into the receiver, the threaded portion must also have sufficient thickness. Hand-guns and shoulder-arms shooting light cartridges which give low pressures can have thin and light barrels even at the breech, but rifles using high pressure cartridges require much heavier barrels for safety if not for other reasons.

Of course barrel diameters also depend upon the physical properties of the steel used. A soft steel lacking in tensile strength and elastic limit would be compressed and enlarged in interior diameter, even if it did not burst, with the high pressures of certain modern cartridges, so that we must consider here the various steels used for the barrels of small-arms.

Normal charges of black powder give relatively low chamber pressures, seldom exceeding 25,000 pounds per square inch in the largest rifles, or 10,000 pounds in revolvers. In the days when black powder was the only propellant, that is before about 1892 in America, barrels of all small-arms were generally made of wrought iron or a simple, soft, carbon steel. Breech pressures were hardly a factor, and the chief consideration was a metal that could be easily machined, and which could be economically worked to a smooth, even, and uniform bore and rifled with the cutting tools then available. Such simple and soft steels of relatively low tensile strength answered all the requirements for rifle and pistol barrels in black powder days. Such soft steels are also still perfectly satisfactory for barrels of rifles and pistols using .22 caliber rim fire cartridges, and many such barrels are still made of these steels, because they can be so economically machined.

Shotguns have very large bores, and if their barrels were made of such steels as the above they would have to be given considerable wall thickness, that is be very large in diameter in order to stand the pressure, and the gun would be much too heavy. A 12 gauge shotgun barrel can hardly have a wall thickness greater than $\frac{3}{16}$-inch at the breech and $\frac{3}{32}$-inch at the muzzle, and still make up into a total gun weight not exceeding the limits already given. A tougher steel or greater tensile strength was needed. In early days the metallurgy of steel was not well understood, and our gunmakers arrived at the desired toughness and strength in shotgun barrel material by taking small strands of wrought iron and steel alternately, twisting them into a rope, flattening the rope into a band, and then winding and forging this band around a mandrel of slightly smaller than bore diameter. The mandrel was then withdrawn, leaving the rough bore in the center of the welded tube, which was then reamed out smoothly to bore diameter. The resulting barrel showed the finely interwoven bands of light and dark colored steel and iron, and the attractive pattern which is characteristic of the **Twist, Laminated,** and **Damascus** barrels seen on our older shotguns. Such fabricated barrels answered requirements perfectly in black powder days, but they do not have the tensile strength necessary for use with modern high-speed and high-velocity smokeless shotgun shells, and are decidedly unsafe with such modern ammunition. Today shotgun barrels, even in the cheaper American guns, are made of modern alloy steels having high strength and elasticity.

With the advent of high power cartridges none of the above steels would suffice for rifle barrels. High power cartridges at the start gave breech pressures of about 38,000 pounds per square inch, and with some of our more modern cartridges pressures now reach 55,000 pounds. These pressures were way above the tensile strength and elastic limit of the older steels. Also the new cartridges used bullets jacketed with cupro-nickel or a copper-zinc alloy without lubrication, instead of the lubricated lead alloy bullets used in black powder arms, and the friction of these modern bullets wore out the rifling in soft barrels. It was not long before our engineers developed a new barrel steel to meet these higher requirements, which became known generally as Ordnance steel.

Ordnance steel was used by a majority of American manufacturers of high power rifles, including Springfield Armory, the Remington Arms Company, and the Savage Arms Corporation, until the start of World War II, that is until about 1941. It proved to be a very satisfactory steel for all kinds of rifle barrels (except perhaps for the most ultra high intensity cartridges) and for shotgun barrels, being easily machined, having high tensile strength, and excellent wearing qualities. Its composition was:

Carbon	0.45 to 0.55
Manganese	1.00 to 1.30
Phosphorus (max.)	0.05
Sulphur (max.)	0.05

After being partly fabricated, the barrel is heat treated to increase its yield point and ultimate strength, which in the case of barrels manufactured at Springfield Armory for the .30-06 cartridge must be at least 75,000 and 110,000 pounds respectively.

Nickel steel was used by the Winchester Repeating Arms Company for all high power rifle barrels from about 1896 to about 1930, and also extensively by certain custom barrel makers, and it was and still is used extensively in England. It has, perhaps, slightly greater tensile strength, slightly better wearing qualities, and very slightly better resistance to corrosion than Ordnance steel. On the other hand it is more difficult to machine, and consequently more expensive. Rock Island Arsenal also used this nickel steel during a portion of the time that Model 1903 rifles were being manufactured there. It contained 3½ percent nickel and 0.30 to 0.40 percent carbon, and was made by the acid open hearth process.

Stainless Steel. Certain stainless or rust-proof steels were developed in and used to a certain extent in Germany from about 1910 to 1920. The more common ones were the Poldi "Anticoro" steel, and the Boehler "Antinit" steel. Neither of them was entirely rustless, but would give much greater resistance to corrosion than ordinary steels. For several years prior to 1930 the Winchester Repeating Arms Company supplied a "stainless" steel to a limited extent. It was really not a steel but rather a high chrome iron, its approximate composition being chromium 13 percent, carbon 0.10 percent, and copper 1.50 percent. Certain intricate heat treatment was necessary to make it both machineable and rust proof. It could not be successfully blued and was copper plated outside and then subjected to a treatment which turned the copper black. High cost of production and the advent of non-corrosive ammunition led to its discontinuance. As modern American small-arms ammunition is now all non-corrosive there is no longer any demand for a rustless barrel steel.

Chrome Molybdenum Steels. About 1930 the chemists and metallurgists of the Winchester Repeating Arms Company undertook a study of their barrel steels, resulting in a complete revision of their specifications, and it is understood that such study is continuous with a view to utilizing the most recent knowledge of metallurgy to provide the best steels possible; which is as it should be. These steels are termed "Winchester Proof Steel" which title does not mean any particular kind of steel, but rather "the best steel which Winchester has been able to find for the particular purpose." Thus the Winchester Proof Steel used in .22 caliber rim fire barrels may be entirely different from that used in high power cartridge barrels.

It is understood that the Winchester Proof Steel now being used in high power rifle barrels is an alloy steel containing chromium and molybdenum, heat treated to give the required physical properties. It is claimed, and it is believed to be a fact, that in all its qualities this steel is slightly superior to Ordnance steel and nickel steel. Chrome-molybdenum barrels have also been used to some extent for the past ten years by some of our custom barrel makers.

The .220 Swift cartridge erodes the barrel faster than any other commercial cartridge at present made, due to the heat evolved by the charge. To withstand this erosion better and give a longer barrel life, Winchester has recently developed a new steel which has considerably increased the life of barrels for this cartridge. Whether this is an entirely new steel, or merely a different heat treatment of their chrome molybdenum steel, is not known.

It is probable that the wonderful Ordnance activity and research of World War II will develop still better barrel steels, and that postwar manufacture will see a complete revision of our steel specifications.

Diameters and Shapes

We are now ready to consider the particular outside diameters and shapes of barrels for various types of small-arms. It is understood that in each case the steel used is a modern steel suitable for the breech pressure of the cartridge involved. The first consideration is that of safety. The barrel must be of sufficient diameter, that is wall thickness, over the chamber and breech portion to successfully withstand the pressure without any enlargement of the chamber, and of course without any danger of the barrel bursting. Every reputable manufacturer proof fires every barrel and gun he makes before he permits it to pass final inspection in his plant. Thus it is fired with one or more **proof cartridges** which are loaded to give a breech pressure about one-fourth greater than that given by the heaviest standard cartridge that can be used in that gun. The chamber is then gaged for dimensions, and if these are still within specifications the arm is considered to have passed the proof or safety test, and the barrel and action are then stamped at the breech with the manufacturers proof mark. This test proves the strength of both barrel and breech action and assures that the measurements are correct, and that there are no flaws in the steel.

A barrel for .22 rim fire cartridges can be very light and small in diameter and still be perfectly safe. In fact one American manufacturer makes the .22 Long Rifle barrel on his over-under gun with an outside diameter of only .50-inch at the breech tapering evenly to .45-inch at the muzzle. Such a thin barrel, if of good steel, is ample for safety with this cartridge, and also for the ordinary accuracy demanded of a short range .22 game rifle, but not for fine accuracy. A majority of the small, light .22 caliber sporting rifles have barrels measuring about .75-inch at breech and .50-inch at the muzzle, and give good accuracy when the method of holding is very uniform. The famous Winchester Model 52 Target Rifles, which are, generally speaking, among the most accurate .22 caliber rifles ever made by quantity production, are furnished with three weights of barrel, all 28 inches long, and all with straight taper from breech to muzzle. The "Standard" barrel which makes the complete rifle weigh about 10 pounds, has a diameter of 1 inch at the breech and .715-inch at the muzzle. The "Heavy" barrel, rifle weight 12 pounds, measures 1-inch at the breech and 7/8-inch at muzzle. The Bull Gun weighing 13½ pounds has a barrel 1⅛ inches at breech tapering to 7/8-inch at muzzle. There is practically no difference in the pure accuracy of the three weights of barrel when held and fired very uniformly in a cradle rest. But in actual match shooting the heavy and bull gun barrels are not so sensitive to slight variations and tensions of the firing positions, and they heat up slowly and maintain a more even temperature, resulting in very slightly better accuracy. Almost all our important matches at 50 yards and beyond are won each year with the heavier barrels, or with the Remington Model 37 rifle which has an equally heavy barrel. However, almost every year we see one or more important matches won with the standard barrel. The standard barrel rifles are usually preferred for gallery shooting at 50 and 75 feet because such shooting is usually done in the "three positions," that is prone, kneeling, and standing, and the weight and balance of the standard barrel 52 is such that most marksmen can hold it more steadily in the standing position. It is believed that the bull gun presents no advantage over the heavy barrel except that now and then a very powerful man may be able to hold it just a trifle more steadily in the prone position. All of the Model 52 rifles, as well as the Remington Model 37, frequently record 10-shot groups at 100 yards slightly under 1 inch extreme spread *when fired with the best match ammunition, in good weather conditions and at warm temperature, and after the barrel has been fouled and warmed by the firing of at least ten rounds of sighters.* The conditions in italics are very essential for super-fine accuracy in any .22 rim fire rifle.

Lever and pump action repeating rifles, and semi-automatic rifles, particularly those having tubular magazines under the barrel, generally have barrels with outside diameters of 7/8-inch to 1 inch at the breech, tapering evenly to about .55-inch at the muzzle. Such rifles are used with cartridges which seldom give a breech pressure in excess of 40,000 pounds per square inch, and barrels of this diameter, when made of Ordnance or superior steels have an ample safety margin. Usually a heavier barrel is not practical with such rifles without a redesign of the breech action, as the barrel and magazine threads or openings in the receiver are not sufficiently far apart to permit of a heavier barrel and allow space for the tubular magazine. Also a very high degree of accuracy is not demanded of such rifles, as they are intended and are used mainly for deer and other big game shooting at moderate distances seldom exceeding 150 yards. Indeed the light barrel, the free chambering, and the peculiar construction preclude very fine accuracy in most lever and pump action rifles, and particularly in those having tubular magazines. Fired under very uniform conditions of holding most of them will average grouping ten consecutive shots in about 3½ inches extreme spread at 100 yards, although those for very light cartridges, such as the .218 Bee, .25-20, and .32-40 low power may show as small a spread as 2 inches. Such rifles have considerable jump when fired, and a small variation in holding or other conditions will alter the point of impact considerably. Thus firing with the magazine empty or filled with cartridges, and with the barrel cold or quite hot, and combinations of these two variables may make a difference of six inches or more in the location of the center of impact at 100 yards. But under game shooting conditions when the hunter almost invariably fires only one, two, or three shots from a cold barrel, and starts with the magazine filled with cartridges, the accuracy is usually entirely satisfactory for big game shooting up to 150 yards.

With the modern bolt action rifle the breech construction is such that there is practically no limitation to the weight and outside dimensions of the barrels that can be used, except that imposed by the barrel thread in the receiver ring. The base of the barrel thread must terminate with a shoulder on the barrel slightly larger than the thread, so that the barrel can be turned up extremely tight in the receiver to a solid abutment against this shoulder. The barrel may be an extremely light one resulting in a weight of complete rifle as small as 6¾ pounds, or a heavy "bull" barrel making the rifle weigh about 13 pounds. Such modern bolt action rifles now often use cartridges of very high intensity, and with breech pressures running from 48,000 to 55,000 pounds, and quite generally various American manufacturers have standardized on a diameter at the breech of about 1.125 inches, or in the case of the very heavy "bull" barrel of about 1.25 inches. Diameters at the muzzle run from .55-inch in the extremely light barrel for small caliber cartridges to .875-inch in the bull barrel.

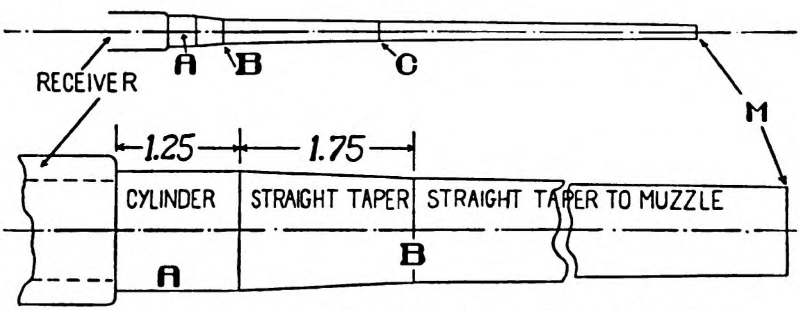

FIGURE 7. DIMENSIONS OF HIGH POWER RIFLE BARRELS

No.	Diam. at A	Diam. at B	Diam. at M	Remarks
1	1.00	.75	.50	Minimum weight .25 cal. barrel.
2	1.05	.850	.550	Minimum weight .30 cal. barrel. Accurate .25 cal. barrel.
3	1.14	.956	.647	Springfield .30 cal. service barrel. Diam. at C .77", C being 9.00" from receiver, B-C and C-M being straight tapers. Minimum .35 Magnum barrel.
4	1.14	.956	.647	Springfield .30 and .22 cal. sporting barrels.
5	1.18	1.00	.70	.35 Magnum barrel, minimum .375 and .400 Magnum barrels.
6	1.20	1.05	.75	.375 and .400 Magnum barrels.
7	1.25	....	.875	International Springfield Free Rifle barrel. Taper breech to muzzle.
8	1.05	....	.90	Winchester Single Shot No. 3 barrel, round, .30-40. Straight taper breech to muzzle.

Some years ago the writer published the drawing and tabulation shown in Figure 7, indicating the exterior diameters and shapes of barrels used in high power bolt action rifles. The well informed rifleman usually selects a modern bolt action rifle because he desires to use a cartridge of high velocity and flat trajectory in a rifle which will give at least good long range accuracy, and which will not be so sensitive to jump that centers of impact will change materially with changes in firing position. If these be the requirements, then it is thought that a barrel not lighter than that shown in Number 3, Figure 7 should be chosen. This is the dimension of barrel used in the Springfield 1903 service rifle shooting the .30-06 cartridge. With first class .30-06 ammunition such a weight of barrel is capable of grouping ten consecutive shots with only 1⅞ inches extreme spread at 100 yards, or in the bull's-eye (20 inches) at 600 yards, or in the bull's-eye (36 inches) at 1,000 yards. For all cartridges up to .30-06 in power and bore, such a barrel is ample for the military marksman (not sniper) and for the hunter rifleman who shoots in mountain or plains country and who demands good long range accuracy without excessive weight. With such a weight of barrel, changes in normal firing positions will not result in a change of center of impact of much more than 1¼ inches at 100 yards, and proportionately at other distances. With light cartridges such as the .22-3000 Lovell, and even the .250-3000 Savage, a barrel of this weight may group in 1⅛ to 1¼ inches at 100 yards when ammunition, particularly the bullet, is first class. The writer would like to pound in again the fact that with rifles manufactured as close to the ideal standard as modern bolt action rifles now are, the cartridge is responsible for at least half the accuracy or inaccuracy. Thus in describing accuracy attained it conveys very little information to the well informed shooter if only the make, model, and caliber of rifle is given. Intimate details of cartridge and bullet should also be given.

It has been stated that the heavier the barrel, other things being equal, the better the accuracy. Of course the power of the cartridge must be considered. The above barrel, Number 3 in Figure 7, would be a heavy barrel for the .22 Hornet cartridge, but a light barrel for the .30-06 or even the .220 Swift cartridges. As a matter of fact it is a little too light for really good long range accuracy and maintenance of center of impact with the .300 H. & H. Magnum cartridge, which is considerably heavier in power than the .30-06 cartridge. It is thought that a barrel for Magnum cartridges should not be lighter than No. 4, Figure 7, with a length of not less than 26 inches, for good and reliable long range accuracy and the moderate recoil necessary for fine marksmanship. Such a barrel in a bolt action rifle of usual sporting type will result in a complete weight of about 9¼ to 9¾ pounds. The .300 H. & H. Magnum cartridge, by reason of its flat trajectory, long sustained killing power, and lack of sensitiveness to wind is a very fine long range game load, but only in a fairly heavy barrel. Therefore it should be chosen only by the hunter who has the strength and endurance necessary to carry it all day in the wilderness without undue fatigue, and also who has such strength that the rifle is not "sluggish" when used on rapidly moving game.

The weights and dimensions of barrels furnished on the Winchester Model 70 bolt action rifles are an excellent guide as to sensible barrel diameters. This famous rifle is furnished with three weights of barrels.

The "Standard" barrel measures 1.125-inches at A (Figure 7), .95-inch at B, and .60-inch at the muzzle, and is therefore about the same weight as the Number 3 barrel in Figure 7. An exception is the standard barrel for the heavy .375 H. & H. Magnum cartridge which approaches the "target" barrel below in dimensions and weighs about one pound more than the regular standard barrel in other calibers. The standard barrel results in a weight of complete rifle of about 8 pounds (9 lbs., in .375 cal.). Weights of course vary a few ounces according to caliber as naturally where the outside diameter is the same a .22 barrel will weigh slightly more than one of .30 caliber. Also in all rifles there is a further variation of an ounce or two depending on the density of the wood in the stock.

The "Target" barrel has the same diameter at the breech (1.125-inch) as the standard barrel, but with a straight taper to about .75-inch at the muzzle. The length with both weights of barrel is 24 inches except for the .220 Swift and .300 H. & H. Magnum cartridges, where the length is 26 inches to give advertised velocities and minimize muzzle blast. In other than these two calibers, standard barrels only 20 inches long may be had by those who prefer carbine type rifles. The complete target rifle with this moderately heavy "target" barrel and very heavy target stock weighs about 10½ pounds except in .220 Swift caliber where the weight is about 11 pounds. This Model 70 Target Rifle is an exceptionally accurate arm for those who do not object to the moderately heavy weight, part of which is due to the barrel and part to the heavy target stock, which is designed for steadiest holding in the prone position.

The Winchester Model 70 Bull Gun is made in only .30-06 and .300 H. & H. Magnum calibers, and is intended only for long range (1,000 yards) target shooting. It has a typical "bull gun" barrel, diameter 1.25 inches at breech tapering evenly to .875-inch at muzzle, and 28 inches long. The complete rifle with heavy target stock is about 13¼ pounds. It holds all target records at 1,000 yards. There is no difference in accuracy with the two cartridges, other things being equal, but it is usually chosen for the Magnum cartridge which, by reason of its higher velocity, bucks the wind better, which quality contributes to higher scores.

There are two rapidly growing classes of riflemen in America who demand accuracy above all other considerations, that is both pure accuracy (grouping ability at a given distance) and the ability to make sure hits that comes from flat trajectory and wind bucking quality. The rifle and ammunition together give the first. The ammunition and bullet alone give the latter two qualities.

The varmint shooter's target may be crows and prairie dogs (presenting about equally small objects) which he desires to surely hit up to about 250 yards when he does his part correctly, woodchucks which he would like to hit to 350 yards, and coyotes to 400 yards. He usually chooses a modern, bolt action, telescope sighted rifle, with a barrel approaching bull gun weight, for such cartridges as the .220 Swift and .22 Varminter. The Winchester Model 70 Target Rifle (10¾ pounds) is a very popular rifle among varmint shooters, although many use custom built rifles for high intensity small bore cartridges of special design—"wild-cat" cartridges.

The military snipers requirements are very similar to those of the varmint shooter. The type of shooting he is often called on to do is about the same. His target may often be an aperture about 6 inches high and 4 inches wide in a parapet, pill box or aiming slit in an armoured vehicle, at distances seldom exceeding 400 yards. But he is usually restricted to the standard military cartridges.

The long range target rifleman now almost invariably uses the Winchester Model 70 Bull Gun (13¼ pounds) because he demands the finest long range accuracy. At one time Springfield Armory made the .30-06 Springfield Model 1903 rifle in long range target type, known as the Type T rifle, which approximated the Model 70 bull gun in design and dimensions of barrel.

The Garand semi-automatic rifle (U.S. Caliber .30, M1) which shoots the .30-06 cartridge, and is now the standard rifle of the United States Army, has a barrel approximately the same as that shown as No. 3, Figure 7, except that it is smaller, with a slightly concave contour from A to B. It is thought that could this barrel have been made as heavy as Number 4, Figure 7, the accuracy of the rifle would have been considerably improved, but the maximum weight of the complete rifle was fixed by important military considerations.

The question naturally arises, how much more accurate is a heavy barrel than a light one? What price do we pay for light weight in a rifle? The average accuracy for the light No. 3 barrel has already been given for both heavy and light cartridges. The writer has seen a number of rifles with barrels approximating the weight of the Winchester Model 70 "Target" barrel (1.125 inch to .75 inch) and using the .220 Swift and .22 Varminter cartridges which, with hand loaded ammunition and bullets known to be accurate, repeatedly gave 10-shot groups measuring ⅞-inch at 100 yards and 1⅞ inches at 200 yards extreme spread, with occasional groups both smaller and slightly larger. As a rule these rifles did not vary more than 3/4-inch to 1 inch in location of center of impact at 100 yards when shot from various normal firing positions. The Springfield Type T rifle (bull gun) when used with .30-06 Palma (long range target) ammunition, in its factory acceptance tests at 200 meters (218 yards) gave ten-shot groups running between 2 1/4 and 2 3/4 inches.

The standard test for accuracy in America is a 10 shot group. Many riflemen have lately come to firing 5-shot groups, perhaps for economy. Unfortunately they often publish these 5-shot groups as indicative of the accuracy of rifle and load. A 5-shot group bears no relation to a 10-shot group, almost invariably being very much smaller, and such 5-shot groups cannot be compared with official and authoritative 10-shot groups made in ballistic laboratories and fired from cradle rest with which the human error is excluded. The late Dr. F. W. Mann used to say that a 5-shot group did not prove accuracy, that there was too much of an element of luck in it, but it could prove if a rifle or ammunition or both were inaccurate and not worth proceeding further with.

The late Sir Charles Ross made the barrels for his .280 Ross rifle with a peculiar, part slope, part step shape between points A and B, Figure 7, which resulted in slightly more of an up-jump with cartridges having slightly lower muzzle velocity, and slightly more down jump with cartridges having slightly greater velocity than normal. It was hoped thereby to compensate for small variations in muzzle velocity in the same batch of cartridges. It probably worked out only for one certain cartridge, and not with other loadings. It is questionable whether such a property in a barrel is worth striving for as good modern ammunition is wonderfully uniform in velocity, and in any event it would probably work out with only one load. On the other hand such a property might be an advantage to the all-around hunter who used the same rifle with full charged cartridges for big game and reduced loads for small game, in that it might permit him to use the same sight adjustment at shorter ranges for both loads.

The peculiar shape of barrel on the Remington Model 30 high power bolt action rifle has been retained because it results in the various .30-06 Remington cartridges loaded with 110, 150, 180, and 220 grain bullets, with velocities from 3400 to 2300 f.s. shooting with practically the same sight adjustment for elevation at 200 yards. Most sportsmen think that this very concave shape from A to B is rather ugly, and it is questionable whether Remington did not lose more sales by reason of the ungainly barrel shape than they gained from any ballistic convenience.

Barrels for the German and Spanish Military Mauser Rifles, Model 1898, have been made with several rather abrupt shoulders from breech to muzzle, where the barrel changes considerably in diameter. Probably this was done to facilitate fitting sight bands and sleeves, and for other reasons of manufacture. Such shoulders seem to present no advantage, and indeed it may be otherwise as such rifles have never been noted for their accuracy.

Practically all our barrels are now turned to a round circumference or shape, concentric with the bore. Our old gunsmith makers of muzzle loading rifles almost invariably make their barrels octagon, or eight sided in shape, most likely because none of them had a modern lathe with which they could turn them truly round, and they found it easier to make the barrel uniform by forging or grinding it into an octagon. An octagon barrel has but one advantage—it calls attention to any canting, or sidewise tilting of the rifle when in the act of aiming, and it may have a disadvantage in that it may not expand equally when it heats up from firing. Many think that an octagon barrel presents a great deal of beauty, and it is doubtful if the disadvantages would be at all apparent in a heavy barrel, but the cost of making such a barrel today is rather excessive.

Our old gunsmiths also started the practice of fitting sights to barrels by cutting a dovetail slot across the barrel, and forming a similar male dovetail base on the sight; the sight was then driven into the slot. Sometimes a similar method was used to secure the forearm and tubular magazine to the barrel. Our present manufacturers still use this method of fitting sights to their cheaper .22 caliber rifles, and to some lever and pump action hunting rifles, but the practice is decidedly not a good one, and should never be permitted in a high grade arm. It weakens the barrel, makes it less stiff, and much more subject to excessive and varying jump, and hence makes for poorer accuracy, although a slot for front sight may not be objectionable in a heavy barrel. Sights and forearms should be secured to barrels by encircling bands or well fitting screws. If a screw is used, its threads should be particularly well fitting, and it should be driven home tightly otherwise it may gradually loosen due to the vibrations of recoil, and give unaccountable errors. The Winchester practice of turning an enlarged ring on the barrels of their standard Model 70 rifles at a point where rear open sight and forearm fasteners come, and then slotting this ring is not objectionable as the uniform diameter of the true barrel is not disturbed.

We sometimes see special barrels, particularly of foreign manufacture, with raised matted ribs on top of the barrel. Theoretically such a rib prevents the even expansion of the barrel when it heats up, and it is possible that some disadvantage due to this might be found in an individual barrel. But the writer has shot a number of such barrels through their accuracy life without being able to notice any disadvantage. In fact they seem to have been stiffened thereby, and apparently jump less. Most shooters think that such a raised matted rib adds to the beauty of a rifle, and men have sought for beauty in their arms since the dawn of history. Of course the rib adds greatly to the cost of manufacture, and it really presents no advantage other than beauty, and perhaps the quick alignment of the barrel for a snap-shot.

The best and the most common method of securing the barrels of rifles and pistols to their receivers is by means of a screw thread. The outside of the breech of the barrel is cut with a heavy thread, and above the thread there is an ample square shoulder. The receiver ring is likewise tapped with a corresponding thread. The barrel is then screwed into the receiver. The threads must be accurately cut, and it should be possible to screw the barrel into the receiver with strong hand pressure until it lacks about 1/8 in. on the circumference of screwing completely up to the shoulder stop. Then the receiver is placed in a strong and special vise, and a special wrench with a handle about three feet long is clamped on the barrel, and with heavy pressure on the long handle the barrel is screwed tight into the receiver until the index lines, which are stamped on both receiver and barrel, coincide. The barrel is then extremely tight on the receiver, and cannot be unscrewed without the aid of the special vise and wrench. There is no danger of such a barrel coming loose in the receiver.

This is the only proper method when reliability and consistent accuracy is desired.

About 1905 a fashion was introduced of cutting the barrel and receiver threads without such a tight fit, and sometime with interrupted threads, so they could be screwed together by hand. The owner could then screw out the barrel, to which the forearm was attached, and pack the arm in a satchel or trunk, and it would go in any container which had an inside length equal to that of the barrel. Rifles constructed in this manner were called "Take-down" rifles.

Other rifles were made to take-down by screwing the barrel tightly into the receiver, but making the receiver in two pieces—the upper and barrel portion containing the bolt or breech block, and the lower or guard portion containing the trigger and carrier mechanisms. The two portions fitted together with a sliding dovetail or tenons, and a thumb or coin slotted screw on the left side of the receiver secured them. By unscrewing this screw the receiver would be pulled apart, and the taken down rifle could be packed in a container with inside length equal to that of the barrel and receiver.

Because of their convenience in travelling and in packing, such take-down rifles became popular among a class of sportsmen who were not good rifle shots. But it was soon found that if the take-down rifle was one using a cartridge of greater power than the .22 rim fire, no reliance could be placed on its consistent shooting. That is, it would not consistently shoot in the same place. With a constant sight adjustment and aim the location of the center of impact varied considerably, particularly when the rifle was fired in different position, or held with even a little variation in tension or pressure. The take-down rifle would also vary in where it shot from day to day because the tension of holding was not the same from day to day even when the same kind of a firing position was assumed.

The writer made a large number of tests of many take-down rifles of various makes and types, with most of them it was possible to fire a fairly small group of shots provided that no change was made in the firing position from shot to shot, and great care was taken to assume exactly the same position, with equal tension of holding, from shot to shot. But the least change of position enlarged the group considerably. If a group was fired, and then the shooter changed position, or even if he relaxed, got out of position, and assumed the same position again, and fired another group, the second group was just as liable to center on the target ten inches away from the first group at 100 yards as to center in the same place. Thus even when the hunter did his part correctly he could not rely on even striking the body of a deer at a greater range than about 75 to 100 yards with a high-power take-down rifle.

It made no difference whether the rifle was taken down between days or shots, or whether it was always kept tightly assembled. This unpredictable variation in center of impact would occur very frequently—so frequently that no reliance could be placed on the shooting of the rifle. It was due to a relatively weak joint in the vital center of the rifle. This weak or loose joint made the rifle jump excessively, and the least variation in holding caused the jump to vary greatly. To jump or vibrate consistently when fired a rifle should be very stiff, as stiff as it can be made, from muzzle to butt. There must be no loose place such as slightly loose threads between barrel and receiver, or looseness in the receiver, or loose tangs attaching the stock to the receiver, or tang screws not turned up very tightly.

However, with rifles shooting .22 rim fire cartridges the effect of the take-down was not nearly so apparent. It would be apparent enough to be very undesirable on a .22 match rifle, but for the ordinary plinking or hunting .22 rifle it is not prohibitive as the variation in location of center of impact at 50 yards is scarcely ever more than three-fourths of an inch when the rifle is fired in various firing positions unless one uses a tight gunsling in one position and not in another position, when the variation may be greater.

Shotgun barrels are all made to take-down conveniently, and no similar objective occurs here because variations of the center of the pattern of even as much as 10 inches at 100 yards would mean absolutely nothing in a shotgun, assuming that it could shoot that far effectively.

Chambers

We now come to one of the most important details in the design and manufacture of small-arms barrels. Cartridges and shells are larger in diameter than the bore and groove diameters of barrels. The cartridge case that holds the bullet must be the same diameter

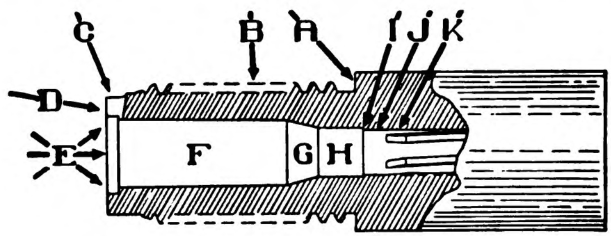

FIGURE 8. NOMENCLATURE OF RIFLE CHAMBER

A—Barrel shoulder. B—Receiver threads. C—Extractor slot. D—Breech face. E—Chamber (rim) counterbore. F—Chamber. G—Shoulder. H—Neck. I—End of chamber. J—Throat. K—Leade. (J and K together are sometimes referred to as the "bullet seat").

inside its neck as the bullet, and therefore the outside of the neck of the case is considerably larger in diameter than the diameter of the bullet or than the bore or groove diameter of the barrel. In addition the body of the case is often made of still greater diameter to hold the powder charge desired. Therefore the bore of the barrel, originally drilled and reamed to a stated diameter, must be enlarged or reamed out at the breech to contain and fit the cartridge or shell. This enlarged portion is termed the **chamber.**

The exact shape and dimensions of the chamber with respect to the cartridge or shell to be used is extremely important. On these dimensions depend the safety, normal and smooth operation, accuracy life, and sure-fire of the arm, and these dimensions are one of the factors which determine whether the barrel will be accurate or not. The chamber must be a proper fit for the cartridge.

Cartridges of a given caliber and model are never absolutely uniform as to dimensions because it is impossible to make them so when produced in quantity. Therefore ammunition specifications prescribe maximum and minimum dimensions for cartridge case, bullet, and loaded cartridge. The chamber must be of such dimensions that the maximum cartridge will enter it without undue force, it must fire with safe pressure, and the fired case must extract without undue force. Likewise the chamber must not be so large that a minimum cartridge would mis-fire, or the case rupture, or gas escape to the rear, and the minimum cartridge must give satisfactory accuracy. To give an idea how individual cartridges of the same size may differ, there are some where the differences between max and min are as much as .004-inch for the outside of the neck of the loaded case, and .009-inch for overall length of case. These would seem to be very small variations, but they are all important when working with a gas pressure of around 50,000 pounds per square inch, and particularly with a gas as hot as that generated by smokeless powder.

Variations as large as the above will seldom be found, even when examining large batches of cartridges, except perhaps with military cartridges made in great quantities and speed in war, for manufacturers have ideal or standard dimensions to which they try to adhere as closely as possible and with very considerable success, particularly in these days of modern precision machine tools. But the manufacturer who makes his arms for public sale must make them, including the chamber and bore, so that they will be safe and function perfectly with both the max and min cartridges, because he can never tell when the ultimate user of the arm might fire such a cartridge. The technical rifleman who hand loads his own ammunition can, however, afford to use a chamber with closer dimensions because he can inspect the components which go into his cartridge and throw out all that do not gage within his established dimensions.

Figure 10 shows the shapes of the common varieties of cartridge cases for rifles. We will discuss first the various diameters of chambers for the corresponding diameters of cartridge, and afterwards will consider the length of the chamber for each type of case.

Figure 9 shows the shape and dimensions of the standard .30-06 chamber as made at Springfield Armory for the Springfield rifle, and of the standard .30-06 cartridge as made at Frankford Arsenal. This drawing is an excellent guide for the design of other chambers *for modern bolt action rifles* and other cartridges, because it presents ideal dimensions and permissible variations where the cartridge used is one produced in quantity—factory ammunition.

Notice that the neck of the chamber is .0008-inch larger than the neck of the maximum cartridge, thus assuring a sure fit of this occasionally very much oversize cartridge. As a matter of fact one seldom sees a max cartridge. The writer has never seen one, although they are known to occur, particularly in ammunition fabricated during wartime. This is as much about neck diameter as

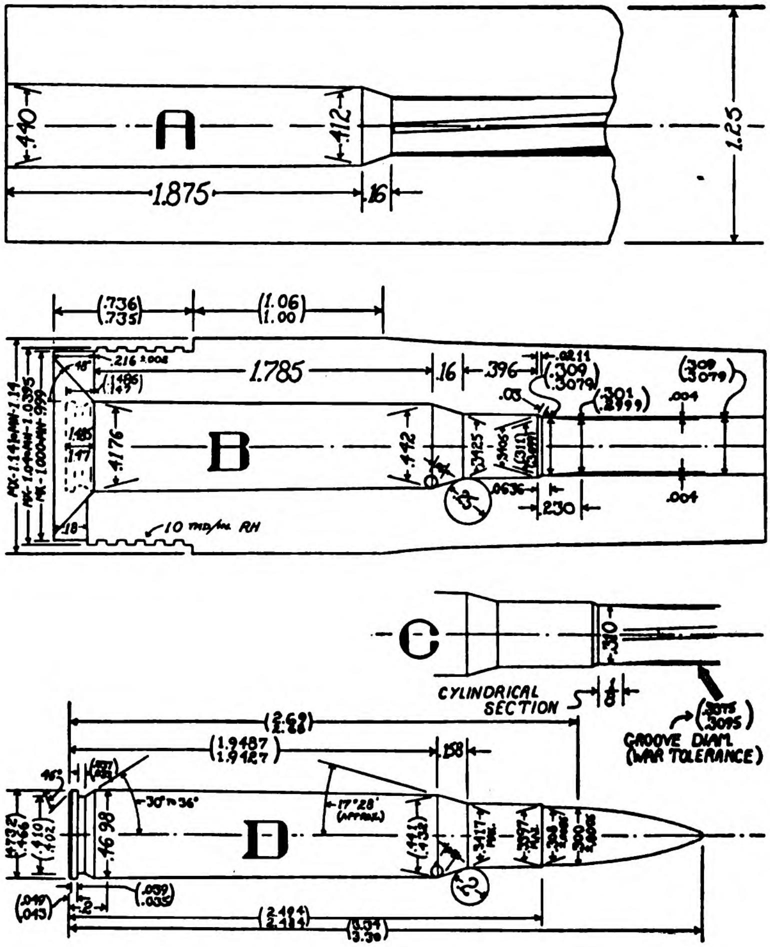

Figure 9. Chamber Boring and Reaming

For .30 Cal. Model 1906 Cartridge

A—The boring dimensions and shape of chamber, before it is reamed and finished to dimensions shown on B.

B—Finished chamber for the .30'06 cartridge, with both minimum and maximum dimensions shown.

C—This insert sketch shows "War Tolerance" specifications now permitted manufacturers of .30 rifles for the U.S. Government. The cartridge loading companies needed more tolerance in the length of the loaded round, so the bullet seat had to be increased accordingly, as is shown above.

D—The .30'06 Springfield cartridge, with minimum and maximum dimensions permitted.

can be told from the drawing, but actually we find in practice that the great majority of Springfield .30-06 chambers, and the great majority of .30-06 cartridges, both military and sporting, have such neck diameters that the neck of the chamber is about .0035 to .004-inch larger than the neck of the average loaded cartridge. This is good practice with .30 caliber chambers, although the clearance with those of .25 and .22 center fire cartridges may be a trifle less, say about .0025-inch.

Normally the .30-06 military cartridge is loaded with a metal cased bullet of a diameter between .308 and .3087-inch, to which must be added the thickness of the walls of the case neck at each side to arrive at the outside diameter of the neck of the loaded car-

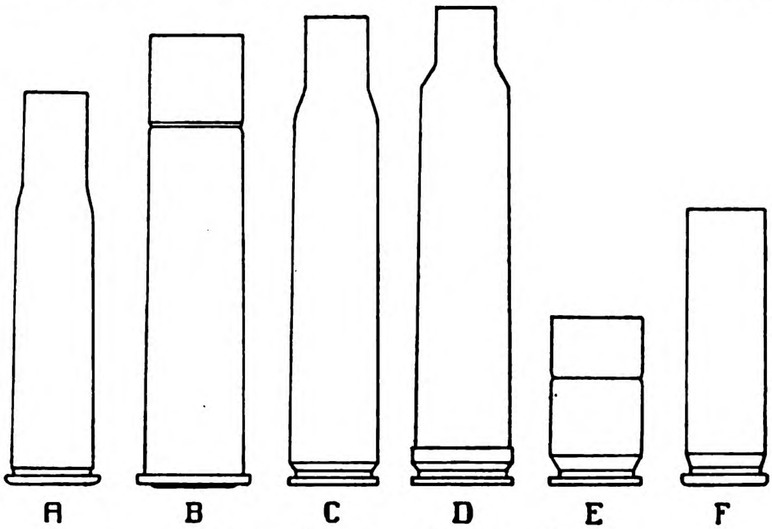

Figure 10. Shapes of Cartridge Cases

A—The rimmed, bottlenecked .30/30 case. Note that a slight groove has been turned out at bottom of case body against the rim; not all batches of cases have this groove present, it may or may not be present on a certain caliber of case; it depends upon the dimensions and type of head-turning knife selected for finishing off the cases. This groove is probably an advantage on some calibers in that it permits the point of the extractor to set in further and get a better grip on the case rim for extraction. This rimmed type of cartridge positions against its rim when in the chamber of the rifle and also uses this rim for extraction purposes.

B—Another type of rimmed case, the straight-sided .45/90 case. This rimmed case does not happen to have the groove against its rim, as shown in A. It does have a bullet stop ring below the case mouth, intended to prevent the bullet from receding into the case when smokeless powder is used in charges which do not fill the case to capacity. The .45/90 case both positions and extracts by means of the rim.

tridge. Usually case necks vary in diameter more than do bullets from any one lot. Springfield .30-06 chambers will practically always accept a cartridge which is loaded with a .311-inch lead alloy bullet without any noticeable neck friction, and it is common practice to use lead bullets of this diameter in this caliber. Occasionally a Winchester .30-06 chamber will be found which will not accept cartridges loaded with .311-inch bullets without squeezing effort. Winchester sporting and target chambers seem to be cut just slightly smaller at the neck than Springfield chambers, probably because their max cartridge specifications are slightly smaller than Government specifications.

If the clearance between the neck of the cartridge and chamber be too small the breech pressure will be increased, it may be difficult to load the cartridge into the chamber, and extraction of the fired case may be difficult, particularly when the barrel has become hot from rapid firing. If the clearance be too large gas will flow back around the outside of the neck of the case when the rifle is fired, the neck of the brass case may split, and the accuracy may be poor. The fired case often presents proof of proper clearance. It should be expanded to such an extent that a normal bullet will be an easy push fit into the neck, and the outside of the case neck should be very slightly blackened by the powder gas, but this black-

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C—The rimless, bottlenecked .30'06 case. When loaded into the chamber it positions against the shoulder of the case and the groove turned into the head of this case is for extraction only.

D—A belted, bottleneck case for the .275 Hoffman rifle, practically the .275 Holland and Holland case; which firm invented the belted cartridge. This belted type of case positions against the forward rim of the belt when in the chamber, the groove is for extracting.

E—The rimless, straight pistol cartridge case for the .45 Colt Automatic. This is a true rimless case, with straight sides and a rim which does not protrude beyond the diameter of its body. It positions against the mouth of the case when in the pistol chamber. Such cartridges cannot be crimped over at the case mouth as they must present a square, positive edge to insure accurate positioning. The bullet is invariably seated friction tight, against a bullet stop ring, as shown above, to prevent the bullet from receding into the case. The base groove is for extraction only.

F—A semi-rimless, straight-sided case for the .401 Winchester Self Loading rifle. This looks like a rimless case but is not, its rim extends out beyond the sides of the case body; when loaded into the chamber the cartridge positions against this protruding rim, which is also used for extracting the cartridge. Manufacturer's practice, when loading the series of cartridges for these self-loading Winchester rifles, is to load a charge of smokeless powder which fills the case, allowing no air space, and to then retain the bullet in position with a very heavy crimp; this crimp assists in the proper ignition and initial combustion of the powder charge.

ening should not extend more than 1/8-inch back from the mouth of the case. If the blackening extends all the way down the neck to the shoulder it indicates that either the neck of the chamber is too large, or the case is abnormally thin at the neck, provided that normal diameter of bullets are used. The diameter of the chamber cannot be told from measurements of fired cases, because when fired the case does expand to fill the chamber completely, but afterwards, when the gas pressure ceases, the brass case springs back slightly. In fact it must spring back to a slightly smaller diameter than the chamber or extraction of the fired case would be extremely difficult.

The head of the max case just in front of the extracting groove is shown as measuring .4698-inch in Figure 9, while the corresponding diameter of the chamber is .4716-inch, indicating a clearance of .0018-inch between max cartridge and chamber. The normal and usual cartridge is, of course, several thousandths smaller than the max, so that in common practice there will almost always be a clearance of about .005 to .007-inch here.

This head clearance is also very important. If it be too small then it will be difficult if not impossible to get many of the cartridges fully home in the chamber, as the breech action does not have sufficient power to swedge down this thick portion of the car-

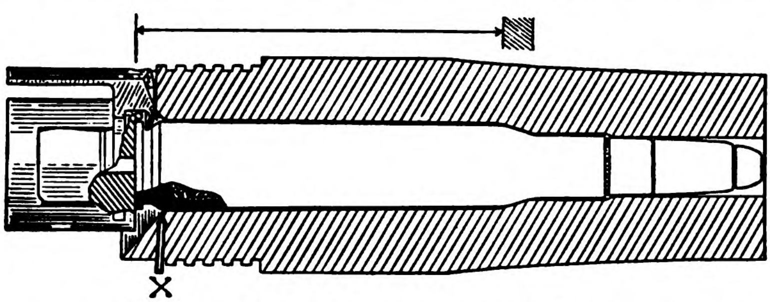

FIGURE 11. CHAMBERING OF A RIMLESS CARTRIDGE

Showing why the cartridge maker has a continuous headache while loading rimless ammunition. Note that in the above illustration the cartridge is positioned, not by a flange meeting a shoulder as is the case with a rimmed cartridge, but by a pair of mating tapers. There is no certainty as to what point along these tapers the exact bearing will take place and were it not for the fact that considerable latitude is allowed through the camming action of the locking lugs—which permits a somewhat overlength cartridge to be forced into the "cone"—it would be almost impossible to maintain correct headspace and firing position.

As it is, the rimless case is really only adapted for use in the "back and forth" actions; the conventional turning bolt actions and the automatics and repeaters which have a reciprocating motion to their breech block. A tridge case. There will also be difficulty in extracting the fired case, particularly in a hot barrel. If the clearance be too large a positively dangerous condition will exist. The head of the case will expand in the large chamber, the primer pocket may enlarge and result in leaking and blown out primers, and indeed the entire head of the case may fuse and rupture, blowing out and allowing intensely hot gas to escape to the rear. This gas may leak past the bolt or breech block and seriously burn the shooter's face or eye. The case will be welded in the chamber and may require a gunsmith to extract it. Blown out primers remaining in the breech mechanism may also jam the rifle. A large amount of gas escaping in serious cases may entirely disrupt and wreck the breech mechanism, no matter what its strength, and also splinter the stock, and may seriously injure if not kill the shooter. Any or all of these troubles may occur with cartridges loaded to entirely normal pressures if the head of the chamber be too large or the head of the case too small.

Similar clearances must exist between the body of the chamber and the body of the case, about .004-inch in the .30-06 chamber, or there will be serious extraction difficulties. When the clearance is too small here, very decided bright longitudinal scratches will be in evidence on the body of the fired case, although some very roughly reamed chambers may scratch every case here.

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rimless cartridge should never be specified for use in a double or three barrel gun as in such actions it is impossible to give that final shove to the cartridge so as to position it firmly into proper firing relation, and if the cartridge or its shoulder taper be the least bit short it will slip forward from firing pin impact and a misfire result. Nor can the rimless case be extracted with certainty from such actions, nor from the falling block actions where a wedge action extractor is employed; it takes a real "hook" extractor to pull out a rimless case with sureness and regularity. The writer knows that there are various trick spring-gadgets used in such rifles, but none is worth a damn, so far.

Note the general all-around good fit of the above chamber, which, incidentally, happened to be an ordinary run-of-the-mill barrel from a .30'06 rifle made by Springfield Armory in the year 1917. This shows about as good commercial chambering as can be looked for. However, also note X, which marks the danger spot at the head of any rimless case where all hell breaks loose on those very rare occasions when the case head blows out from defective brass, or from a thin sidewall, or through a flaw in the brass of that portion of the case. This is the one weak spot of a rimless cartridge.

Also note the long headspacing dimension, from base of the case to a spot on the shoulder taper, generally meeting at the widest point of the taper. As stated above, this long dimension makes the manufacture of rimless cases very difficult for the ammunition maker and constant surveillance is required to keep this length within the required tolerances.

Finally, if the chamber be too large in diameter for the cartridge, then when the cartridge is placed in the chamber and the breech mechanism closed, it will gravitate to the bottom of the chamber, or be forced to that side of the chamber towards which it is pressed by the spring of the extractor. That is, the axis of the cartridge will not be in line with the axis of the bore, the bullet will not be started in true alinement into the bore, and poor accuracy will result.

So far we have discussed chamber diameters only for modern bolt action rifles. A chamber cut with such small clearances would be decidedly unsatisfactory for a lever or pump action rifle, due to extraction difficulties. When a rifle is fired rapidly the barrel heats up, and it is far more difficult to extract a fired case from a hot barrel than from one that is cold or only slightly warm. In fact if .30-06 Springfield, Winchester Model 70, Remington Model 30, or Mauser rifles, with their powerful extracting mechanism, are fired very rapidly for fifty rounds it will be almost impossible to start the bolt open and extract the fired case in the usual manner by hand, and the bolt handle must be almost pounded up with a wooden mallet. Modern bolt action rifles have such design and slope of insertion and extraction cams on bolt and receiver that a certain pressure on the bolt handle exerts about five times that force on the head of the case to either insert or extract it from the chamber. Thus 25 pounds pressure on the bolt handle will result in about 125 pounds push or pull on the case. But the construction of the usual lever and pump action mechanisms is such that pressure on the lever or slide handle results in never more than about twice that amount on the case. Therefore chambers for such rifles must be cut with considerably more clearance over the cartridge than with bolt action rifles just discussed. Generally speaking the clearances should be increased about one-third.

If a lever or pump action rifle were provided with a chamber cut with the small diameter clearances specified for bolt action rifles there would be so many failures, not only to extract, but to insert slightly large, dirty, or corroded cartridges that easy operation would be impossible much of the time, and no one would want such a rifle. Moreover factory cartridges for use in lever and pump action rifles are loaded to a chamber pressure measured in the large chamber in which they are used, and such cartridges would sometimes give excessively high pressures in a tighter chamber. Incidentally, one of the reasons why lever and pump action rifles cannot be made to give quite the fine accuracy of bolt actions is because of their larger chambers. Chambers with large clearances are not conducive to the best accuracy.

Even the bolt action chamber as above described is large in diameter for all but the absolute maximum cartridge, and such a cartridge is very seldom seen. The question therefore arises, why not cut our chamber to a close diameter fit on the usual or normal cartridge and thus obtain better accuracy? It can be done to a slight extent if the owner of the rifle will be extremely careful with the selection of his cartridges and the components thereof, and under-

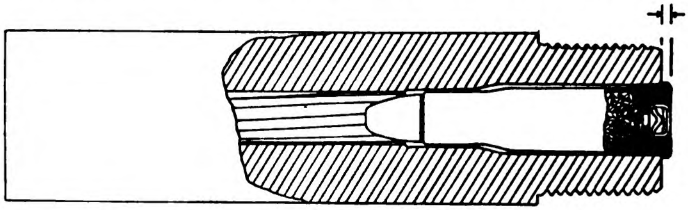

Figure 12. Chambering of a Rimmed Cartridge

An example of ordinary, commercial chambering as turned out for the average "hunting" rifle, in the above case a factory job for the .25/20 Repeater cartridge. This is rather sloppy chambering for this day and age, but I have seen many that were much worse than the example shown. Note that a rimmed cartridge positions entirely by the rim of the case and in a poorly made chamber such as this the cartridge "sticks up" into the chamber neck with no other support, unless it drops to the bottom of the chamber which it probably does if not held off by pressure from the extractor.

Observe how poorly the bullet fits up into the leade of the above chamber; with such a long jump as this it is to be expected that much leakage and gas-cutting would occur. After being fired in an oversize chamber such as this, the empty case would look entirely different from an unfired sample and full-length resizing would be almost a necessity if the case were to be reloaded and fired again.

Headspace, as measured, is shown by the dotted lines above rim of cartridge. Rimmed cartridges are much easier to manufacture to exact specifications than is the case with rimless ammunition, the vital headspace tolerances being so much easier to meet.

The rimmed cartridge is suitable for use in the "up and down" actions, such as the falling block S S, the tubular magazine and lever action repeaters, double barrel rifles, and three barrel guns. By its use chambering difficulties are reduced to a minimum, and extraction is more easily effected by means of hook or wedge action extractors.

stands thoroughly the limitations of such a chamber. But a very tight chamber would be unsatisfactory for the ordinary user, who would expect his rifle to function perfectly and be safe with any factory cartridge of any make, and of the proper caliber.

Chambers cut with extreme accuracy as to diameters, and with only a "push fit" clearance have been tried quite extensively, notably by the Niedner Rifle Corporation, although that firm have cut such chambers only to special order. Every case was reamed in a lathe to be of uniform wall thickness of neck, and the neck of the

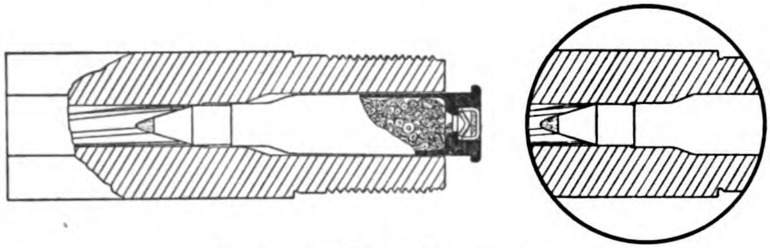

FIGURE 13. TIGHT CHAMBERING

A good example of "tight chambering" is shown by the above wildcat, the .22 Koshollek, a special cartridge designed and worked out in shooting form by Emil J. Koshollek, the well-known gunmaker of Stevens Point, Wisconsin. Back in 1918, Koshollek took the regular .25/20 Repeater cartridge, necked it down to .22 caliber, worked up a high-velocity load together with a rifle to shoot it, and has been using it ever since.

This cartridge is an absolute fit to its chamber and no headspace indicator can be added as it positions on everything in sight except the chamber's end which is relieved about .02". Case mouths are reamed out to an accurate bullet fit and the cartridge is a real "push fit" into the chamber. In the drawing above we show this cartridge only partially seated into the rifle chamber as the fit is so tight the different lines could not be accurately drawn with cartridge fully seated. Insert is to show how closely the case neck and bullet fits up into the leade.

Note how well base of this cartridge is protected from case head blowouts, by the length to which the heavy brass web portion of the case extends into chamber when cartridge is fully seated; this is one reason why these small .22 high velocity cartridges and rifles are so safe despite the extreme pressures they develop.

Such tight and accurate reaming of case necks to uniform wall thickness, and then chambering tightly for that reamed case had several advantages. It often gave exceptionally fine accuracy and gas did not escape past the bullet as it left the case neck due to the tight fit. This latter made for exceptionally long barrel life as there was no gas cutting. All gas being confined back of the bullet, and there being no expansion of the case on firing, a smaller charge of powder could be used to give velocity equal to that given to a cartridge of similar design but with a commercial chamber. In fact the charge had to be reduced to keep the pressure within safe limits. But these reamed cases and tight chambering had disadvantages as well, and these proved so insurmountable that such chambers are now seldom seen. Not all commercial bullets could be used because not all were of exactly the right diameter for the reamed case and tight chamber neck. If the bullet was the least bit too large the loaded cartridge would not go into the chamber, or else gave extremely high and very dangerous pressures. If the bullet was a little small it acted just like the commercial or standard chamber. Any dirt on the cartridge or in the chamber precluded insertion of the cartridge. If the pressure developed was very high, extraction of the fired case was exceedingly difficult. This may be termed a "labratory" method of chambering, quite impractical in the field.

chamber was then cut to be just a push fit on the neck of these cases when bullets were seated in them. The diameter of the rear of the chamber was also decreased to be a closer fit on the head of these selected cases, and great care was taken to ream the axis of the entire chamber in exact alignment with the axis of the bore. When great care was taken in selecting and preparing the cartridge components and assembling them, such chambers gave very superb accuracy, did not give serious extraction difficulties in cool barrels, and had long accuracy life. They gave velocities equal to those obtained with normal chambers with about two grains less powder. There was practically no expansion of the neck of the case when it was fired in such a chamber, hence no powder gas escaped past the bullet (see under "Interior Ballistics"), which escape reduces velocity and increases erosion. But such close and accurate chambers have been found rather impractical for the following reasons:

1. They would not accept factory ammunition, or even factory cases unless the latter were reamed at the neck.

2. The bullets had to be of the exact diameter for which the chamber was designed, and it was extremely difficult to surely get factory bullets of this exact diameter. If bullets were as much as .00025-inch oversize dangerous pressures, as well as insertion difficulties, arose.

3. Extraction difficulties became prohibitive in a hot barrel or with slightly corroded or dirty cases.

So no one except the experimenter uses such tight chambers today, and best practice is to adhere very closely to the chamber diameters already described. Indeed we think at the present time that the above bolt action chamber clearances are about the ideal, and cannot be improved on from the standpoint of accurate shooting. At least we have innumerable instances where barrels with such chambers have given "minute of angle" groups regularly. But, as stated before, it takes the best ammunition, as well as a good barrel, to give such accuracy.

Chamber Lengths and Headspace

Now we turn to the various lengths of chambers for rifles. Both cartridge case and entire loaded cartridge, as commercially produced, vary slightly in length as well as diameter, and the chamber must be long enough to take the maximum cartridge case. But if it is longer than this then, with the normal or minimum length cases, gas in abnormal amounts will escape at the mouth of the case where the case ends and the chamber is larger, and will cause faster erosion and mediocre accuracy. Also in certain cases (see Sketch E, Figure 10) where the mouth of the case supports the cartridge against the blow of the firing pin, mis-fires and hang-fires may occur. Also with straight cases having no bottle-neck the case may stretch in a long chamber, and rupture, and we may have the same dangerous condition and liability to serious accident as when the chamber is too large in diameter at the rear.

The length of chamber is important also when the shooter reloads his ammunition. When fired, the case expands slightly in length, and after it has been loaded and fired a number of times it will have lengthened materially. Usually the lengthening of the case that occurs through firing it seven or eight times (three or four times with the .220-Swift and several other cartridges) is not so great but that chambers properly cut in length for the max car-

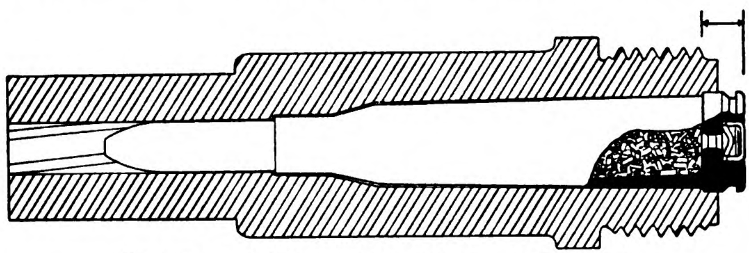

FIGURE 14. A WILDCAT CARTRIDGE AND CHAMBER

This drawing was made to exact scale from the actual model of a cut-open .276 Dubiel chamber, a rechambering job to an old 7 mm Spanish Mauser rifle. The model and weight of rifle was by no means suitable for this job of rechambering, but the owner went ahead and had the job done and shot the rifle extensively. A heavier weight of barrel and a stronger action is to be recommended for this .276 Dubiel cartridge, however.

This shows a belted case which has been fitted into a chamber of splendid dimensions for the cartridge, with one exception. The mouth of this case fits entirely too snugly against the end of the chamber and a considerable rise in pressures could be expected if these cases were fired without their neck length being trimmed back about .02″ by an accurate neck trimmer. Users of these powerful wildcat combinations will do well to have a sulphur cast made of the chamber of their rifle and to check same carefully against the cartridges used, and then put a neck trimmer to work if its use is indicated.

Note how snugly the bullet fits in the leade or bullet seat, and the close fit of the rim and rear of the body of the cartridge in the rear of the chamber, thus straightening up the entire cartridge in line with the axis of the bore. Also note that there is a slight clearance between the forward body and neck of the case and the corresponding chamber walls, allowing these portions of the case to expand when fired. The slight expansion of the neck allows the bullet to leave the case neck easily without running the pressures up. Also when gas pressure drops to zero after the bullet has left the muzzle, these forward portions of the case spring back and free themselves from the chamber walls, and extraction of the fired case is easy.

tridge case will take this slightly lengthened case. But if one continues to reload his cases a large number of times, he finally has to trim them at the mouth to bring them back to standard length so they will be a proper and safe fit in the chamber. If a cartridge having a case slightly too long for the chamber is loaded, the bolt may force the cartridge up so tightly against the mouth or front end of the chamber as to crimp the mouth of the case so tightly on the bullet, and the chamber mouth so firmly support this crimp against any expansion when fired, that chamber pressure will be dangerously increased, and also poor accuracy will result.

New cases, even of war manufacture, will seldom differ more than .010-inch in overall length between max and min. Except with cases like Sketch E, Fig. 10, in the absence of an authoritative drawing of the cartridge showing max and min lengths, if a number of new and unfired and unloaded cases be measured for overall length, the longest may be taken as a maximum. Then the chamber may be cut with a length from face of breech bolt or block to front end where the neck of the chamber begins to bevel to bore diameter, about .015-inch longer than this assumed max length of case.

There is another very important length measurement of the chamber, so important in fact that we will have to discuss it at some length. It is obvious that the cartridge case must be fully supported against the face of the breech block or bolt, both in order that the firing pin can strike the primer a hard sharp blow, and so that there will be no looseness between the face of the bolt and the head of the case that might be the cause of an accident such as previously described. The support within a tolerance of .015 to .020-inch furnished by cutting the chamber to correct overall length is not sufficiently close enough for this purpose. The head of the case must be held back tight against the face of the bolt by a shoulder on the case which abuts against a similar shoulder in the chamber. The location and character of this chamber shoulder differs with each of the various types of cartridge cases shown in Figure 10. The distance in length from the face of the breech bolt or block to this shoulder is known as "**headspace.**"

In a barrel which uses a rimmed cartridge (Sketches A and B, Figure 10, and also the semi-rimless case F) headspace is the distance from the shoulder of the chamber on which the forward surface of the extracting rim of the cartridge rests to the front face of the breech block or bolt. It should not be greater than the max thickness from front to rear of the rim of the cartridge case; in fact it should be this exact dimension so that the block or bolt will close tight on a cartridge head of maximum thickness. If this headspace be too great mis-fires and hang-fires, poor ignition, and poor accuracy will occur, particularly if a rim-fire cartridge is used. If it be too small then it will be frequently impossible to completely close the breech mechanism on a cartridge that has a thicker rim than normal.

Continuing with the chamber for the rimmed cartridge, after the barrel has been drilled, reamed, and rifled the breech of the bore is reamed out roughly to a slightly smaller size than the eventual chamber as shown in A, Figure 9. Then the barrel is threaded at the breech and screwed tightly into the receiver. Next the finishing chamber reamer is run into the rough chamber, and frequently gaged for depth with the headspace gage until the actual bolt or breech block to be used in the completed rifle will just barely close on the gage. The bolt should close on the gage without any compression, but just a slight "feel" of the gage in the final closing of the bolt. A gunsmith making a single barrel may examine a large number of cartridges of several makes until he finds one that has slightly larger dimensions than normal, and use this for a max gage, but this is not good practice, and should not be used in quantity production, or in making a rifle for any but a very well informed shooter.

A word here as to chamber and headspace gages. In proper practice the original designer of a cartridge constructs at least two chamber gages for it, a max and a min gage, or a GO and a NO-GO gage. These original gages are deposited in the gage laboratory of the factory that makes the cartridge and rifles for it, are termed **"master gages,"** and are used only for reference to be certain that the **"working gages"** are of absolutely correct dimensions and shape. Chamber gages are shaped just like cartridges, and are made of hardened and seasoned steel with great care to $1/_{10,000}$ inch by a gage maker, the highest type of machinist. When not in use gages should be coated with a rust inhibiting grease, and should be wrapped in greased paper. They must be handled with great care, should never be dropped, and when used the extractor should always be removed from the rifle. To remove a gage from a chamber push it out gently with a cleaning rod used from the muzzle. The bolt or block should never be closed down tightly on a gage that appears to be a little large for a chamber as that would often so compress the gage as to ruin it. In usual practice there are GO and NO-GO gages, and there may be others also as will be seen below. The bolt or block of the rifle should close easily on the GO gage, showing that the chamber is large and deep (long) enough, but it should not close on the NO-GO gage, which will show that the chamber is not too large or long.

A headspace gage is similar to a chamber gage, but is constructed to measure the headspace only, all other dimensions being smaller than normal so they will not interfere. A gage will show a chamber of its exact dimensions if, when the bolt is closed the last small fraction of an inch with very gentle finger pressure, the bolt face can be felt to just touch or barely press on the head of the gage. Again, *never press down hard on a gage.*

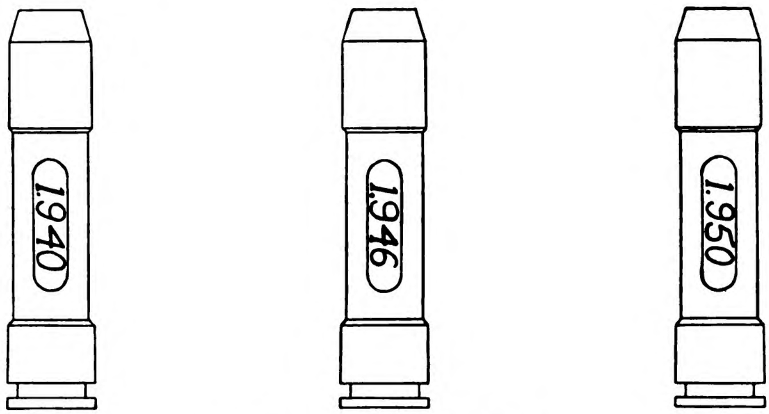

FIGURE 15. HEADSPACE GAGES

These are the usual standard Government headspace gages commonly used for the inspection of rifles of .30-06 caliber. They are constructed of hardened and seasoned steel, and their length from shoulder to base is exact with the master gages retained in the gage labratory. They must be handled carefully, no force or compression must be applied on them when the bolt is closed, and they must not be permitted to rust. They have an extraction groove at the base, but in practice it is best to remove the extractor from the rifle bolt when using them, and to push them gently out of the chamber after use by a cleaning rod inserted from the muzzle.

The 1.940 gage is the minimum gage. Every rifle must accept this gage, and the bolt must turn down easily and completely on it to indicate that the chamber and headspace are not too tight and that the rifle will accept normal cartridges.

The 1.946 gage is the maximum gage. No "cleaned and repaired" rifle is permitted to leave an arsenal if it will accept this gage. Also if a rifle will accept this gage its action or chamber have worn enough so that accuracy will have fallen off slightly, but the acceptance of this gage does not indicate that the rifle is unsafe or unserviceable.

The 1.950 gage is the absolute maximum gage for field use. All rifles in the hands of troops are inspected annually by Ordnance Officers, and all that will accept this gage are withdrawn from service and returned to an arsenal for repair or salvage. Acceptance of this gage indicates that the rifle is unsafe and unserviceable.

During manufacture still another gage measuring 1.943 is used. After a new rifle, presumably constructed with a headspace of 1.940, has been proof fired it must not accept this 1.943 gage, thus indicating that there has been no appreciable enlargement of the chamber or set-back of the bolt incident to the proof firing. New rifles should thus have a headspace between 1.940 and 1.943.

Headspace with a rimless cartridge is adjusted and measured very differently from that of a rimmed cartridge. See Sketch C in Figure 10, and also sketch in Figure 11. Here the shoulder of the case holds the case back firmly against the face of the bolt, and the headspace is the distance from the sloping shoulder in rear of the neck of the chamber to the face of the breech bolt. Due to the slope of the shoulder this distance cannot be measured with any usual measuring instrument, and so it is measured only with a headspace gage such as is shown in Figure 15. In the manufacture and maintenance of the .30-06 Springfield rifle four headspace gages are used (only three of them are shown in Figure 15). The barrel is drilled, reamed, and rifled, and then a rough chamber is reamed out as shown in A, Figure 9. The barrel is then threaded at the breech, and screwed tightly into its receiver, then the finishing chambering reamer is run into the rough chamber, with frequent trials with the

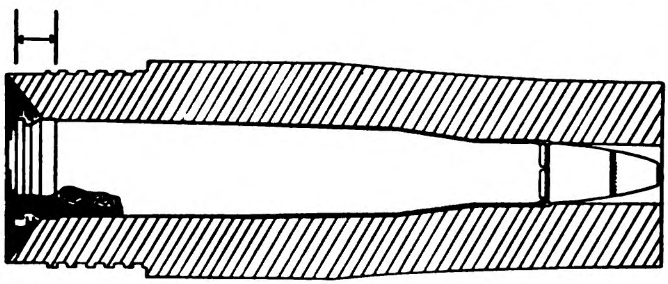

FIGURE 16. CHAMBERING OF THE BELTED CARTRIDGE

The most modern and safest cartridge cases of today are of the belted type, designed by Holland and Holland, the famous British gunmakers and the .300 H. & H. Magnum, shown above, is one of the most popular of the series. It is a very accurate long-range target cartridge and, when loaded with expanding bullet, a most deadly and powerful hunting cartridge.

The belted cartridge positions on the front ledge of its belt, as shown; it is a rather easy headspace dimension to meet. Best of all, this type of case is particularly suited for use with heavy powder charges developing extreme pressures. Note the exceptionally thick area of brass in the head of this case, sidewalls as well as base, and note how slight are the chances of the case head blowing out through the bottom of the lug well as can happen in the fitting of the rimless case.

The chamber shown above is a good example of proper cartridge fit and positioning; note how accurately the bullet is seated up into the chamber leade. This represents average chambering for such a cartridge, as a rule such rifles run into money and they are finished properly in all such respects, all work being performed by master gunsmiths, stockers and barrel makers. Such powerful cartridges should only be used in rather heavy rifles having barrels of sufficient diameter for the ballistics developed.

identical breech bolt that is eventually to be used in that rifle, until the bolt will just barely turn down with very slight feel but no compression on the 1.940 gage, which is the min gage. After the rifle has been proof-fired the bolt should close down easily on the 1.943 gage, which is .003-inch longer than the 1.940 gage, showing that there has been no excessive enlargement or lengthening of the chamber by the high pressure proof cartridge. No repaired rifle is ever sent out from the factory which will accept the 1.946 gage. Springfield rifles in the hands of troops are inspected annually by an ordnance machinist, and at this time each chamber is gaged. If the chamber of a rifle will accept the 1.950 gage it is condemned for service, and

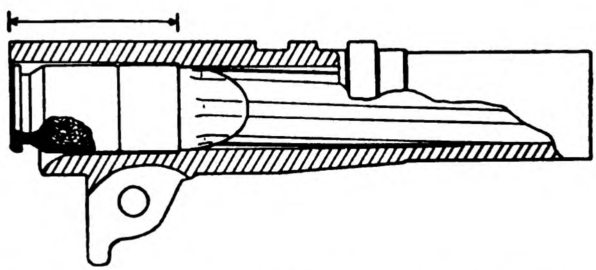

FIGURE 17. POSITIONING OF A CARTRIDGE ON THE CASE MOUTH

This drawing illustrates the actual chambering of a cartridge which seats on its case mouth, it also illustrates the head spacing of such an assembly which is actually the entire length of the case. Drawing was made from a cut-open barrel of a Colt .45 Automatic pistol, the dimensions of which were closely followed so as to also show the principle of making such chambers tapered so they will more readily take and seat cartridges more freely from the automatic action of the arm. The dimensions and tolerances shown are actual, as can be seen by inspecting the barrel from a .45 automatic pistol and checking with a live cartridge.

Note how fully this cartridge seats up against the front edge of the chamber, where it positions for firing. The actual assembly, when tested by hand, is very interesting on account of the extreme "wabble" of this .45 cartridge when in position in the chamber. The .38 Super Colt is a much closer fit, with less than half as much free play.

Observe from the cut-open area of this cartridge that the rear end of the .45 case must take its part in retaining pressures from the burning powder charge of the .45 Automatic pistol; the entire rear end of the lower portion of the cartridge is unsupported by any retaining walls of steel, as is the case with the conventional rimmed chamber; this practice would not be possible with a cartridge developing probably 30,000 or more pounds pressure, yet in the case of this .45 Auto cartridge the brass case walls are amply sufficient to retain what the ballistic engineers term "residual pressures." At that, some of the .45 Automatics throw out cases pretty badly swelled around this under and exposed portion of the fired case.

is returned to an arsenal for repairs. Thus a headspace of 1.950-inch, or .010 inch longer than the minimum, indicates an excessive and dangerous headspace. With a 1.950 headspace there is danger that primers may leak gas or blow out, or that the case may rupture and wreck the breech mechanism, and the accuracy will be mediocre. Accuracy tests at Springfield Armory do not show any difference in accuracy between chambers that gage 1.940 and 1.943- but do show a falling off in accuracy for 1.946 chambers.

Never change bolts on a rifle.

Next there is the belted case as shown in Sketch D, Figure 10. Headspacing on the shoulder of the rimless case is not an ideal

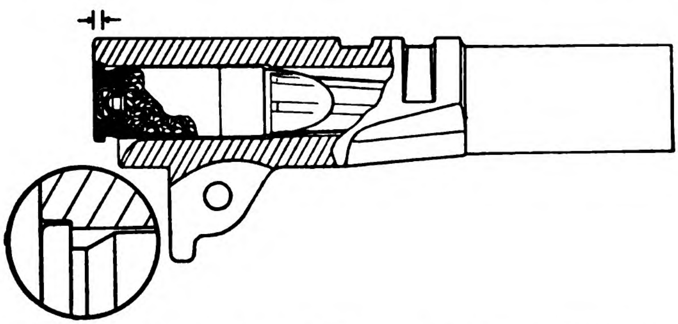

Figure 18. Chambering of a Semi-rimless Pistol Cartridge

This drawing illustrates the seating and positioning of the .38 Colt Auto cartridge, which is a semi-rimmed case. But in this particular instance, the seating principle is not any too clearly illustrated, as only a very small segment of the case rim is used to position the cartridge; however, this fact alone makes the drawing of interest. Note, from the insert drawing, how small a contact holds this cartridge in proper position for firing, and note also that the forward mouth of the case does not bear against the end of the chamber.

The .38 Auto Colt is not a cartridge whose manufacturing and chambering tolerances are stipulated by the Military and the Colt Company therefore chambers its automatic pistols to much closer dimensions than is the case with the .45 Automatic pistol. Note that this .38 Auto is much more closely chambered than the .45 Auto shown in Figure 17.

method, and the belted case was produced first by Messrs. Holland and Holland, British rifle makers, to give more positive headspacing with a type of case that would feed perfectly through the double column type of magazine seen in Mauser and similar bolt action rifles. As will be seen in Sketch D, Fig. 10, there is a shoulder on the case at the front of the head and slightly in front of the extracting groove. This shoulder abuts and stops against a similar shoulder in the chamber. Headspace is measured from the face of the bolt to the shoulder in the chamber, and is obtained in the same manner, and should have the same relative tolerances as with a chamber for a rimmed cartridge.

We have still a fourth type of case to consider, namely the rimless straight case that headspaces on its mouth and on the front end of the chamber as shown in Sketch E, Fig. 10, and the 45 pistol sketch in Figure 17. Examples of this case and cartridge are the .45 caliber Colt automatic pistol cartridge and the U.S. Carbine, Caliber .30, M1 cartridge. The case is rimless without any shoulder and almost straight sides, and it depends on abutment of the mouth of the case against the front end of the chamber, as shown in the chamber sketch in Figure 17, to hold the head of the case tight against the face of the bolt. Therefore the overall length of the chamber is the headspace. This should be cut very accurately to just the length of the max cartridge case, and the cartridge cases must be held to a close variation of not more than .005-inch in length so that the min case will not be too short in this chamber.

Leade

The **leade** may be considered a portion of the chamber in a sense because it is cut with the finishing chambering reamer although it is ahead of the chamber proper. The leade is that slight recessing and shaping of the bore just in front of the chamber end to accept and fit that portion of the bullet that extends beyond the mouth of the case in the loaded cartridge. It is shaped and dimensioned to fit that portion of the bullet extending beyond the case mouth which is larger than bore diameter.

The front end of the chamber ends with a slightly beveled shoulder. Forward of this shoulder the bore is made full groove diameter, smooth and without any rifling, for a short distance, then the lands begin and slope up gradually to their full height. This slope up of the lands should be of such angle and length that the ogive of a max bullet in a cartridge of max overall length will just touch the slope of the lands evenly over the entire slope. The **ogive** of a bullet is its curve of point from the front end of its cylindrical portion or greatest diameter to its point. This type of leade is shown in Figure 9. American riflemen have found it entirely satisfactory for all practical purposes, and gilt edge accuracy is obtained right along with barrels cut with this type of leade. It would be ideal if the leade were cut so that the ogive of the bullet always impinged on the land slope, and the bullet was straightened up in the bore thereby. But this ideal condition is not possible with factory ammunition because the leade, like the remainder of the chamber, must be made to accept the maximum cartridge. If the leade be too short, that is the lands slope too far back, then it will be difficult to insert a loaded cartridge in the chamber and fully close the bolt, and in extracting such a loaded cartridge, particularly one a little longer than normal, the bullet may pull out of the case and remain in the leade, and the powder may spill in the chamber and breech action. Riflemen should be on the lookout for such an occurrence in a rifle having a very short leade, and if it happens push the bullet out with a cleaning rod, used from the muzzle, then clear any spilled powder out.

Riflemen who load their own ammunition habitually seat their bullets to such a depth in the case neck that when the cartridge is inserted in the chamber the bullet ogive just touches the slope of

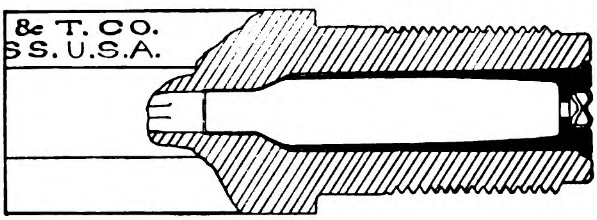

FIGURE 19. CUSTOM BUILT RIFLE CHAMBER

Above is drawing made from a cut-open barrel from one of Hervey Lovell's rifles, his old .22 Hi-power. The inside of the neck of this case is not reamed out to fit the bullet. Cartridge positions upon its rim, but chambering is so accurate that it also positions upon shoulder of the case. These .22 Lovell rifles are intended to be used with handloaded ammunition, naturally the case expands to a perfect fit of the chamber once it has been fired.

All Lovell rifles are chambered along lines shown above and his present .22 R2 Lovell is one of the most popular and accurate varmint rifles now being used by American riflemen.

Note that the case is a snug fit for the chamber at the neck and rear of the body, thus assuring that the whole cartridge is accurately alined with the axis of the bore. But there is a little clearance between the forward body of the case and the corresponding chamber wall so that this portion of the case expands slightly on firing, relieving pressure, and then after the bullet has left the bore, the case springs back again from the elasticity of its brass, frees itself from the chamber wall, and makes extraction easy.

the lands. When the loaded cartridge is extracted very faint land marks, perhaps discernible only with a magnifying glass, should be seen on the ogive of the bullet. A bullet thus seated will not pull out of the case when the cartridge is extracted because it just touches, but is not forced into the lands. Of course to seat a bullet out in this manner the bullet must be long enough so that a fair portion of its base will still remain in the case neck to insure a firmly assembled cartridge. Bullets so seated may increase the overall length of the cartridge to such an extent that the cartridge will be too long to fit into and operate through the magazine of the rifle. The .30-06 Palma Match ammunition for long range target shooting used to have its bullets seated far out of the case in this manner, so that the ogive touched the lands, and this ammunition had to be used single loading.

Springfield Armory at one time conducted experiments to determine the effect of leade on accuracy. The leade in a barrel was progressively cut further forward during a series of accuracy tests. As the leade was lengthened the extreme spread of the groups increased proportionately.

The .22 Long Rifle cartridge is loaded with an outside lubricated lead bullet, with only a reduced portion of the heel inserted in the case, and all the full diameter portion of the bullet extending beyond and outside the case. The leade is cut very short so that when the cartridge is pushed fully into the chamber the lands will cut into the lead bullet. Cartridges extracted from the chamber should show the land marks pressed right into the cylindrical portion of the bullet almost up to the mouth of the case. Manufacturers, to secure the finest accuracy, let the slope of the lands come as far to the rear as they dare and not have the bullets stick in the leade when a loaded cartridge is extracted. Such a pulled out bullet will occasionally occur in a well chambered .22 rifle and should be watched for. Always extract a loaded cartridge from such a .22 rifle with the muzzle pointed straight up, so that if the bullet sticks the powder will not spill in the chamber and breech. If no cleaning rod is at hand to push out a stuck bullet, pull a bullet out of a loaded cartridge without spilling the powder, and with the muzzle up, insert the case with its powder in the chamber and shoot the stuck bullet out.

Nothing has been said thus far about the chamber for the .22 Long Rifle cartridge. This chamber is seen at its best in Winchester Model 52 and Remington Model 37 rifles, and it is thought that this chamber should be duplicated exactly when best accuracy is desired in a rifle barrel. Most of the bullets now used in the best Long Rifle ammunition measure .224-inch, and the technique of manufacture of the cartridge is such that best accuracy is obtained with barrels having .222-inch groove diameter. Springfield Armory cuts their barrels with a groove diameter of .223 to .2235-inch, but they use much wider lands than other manufacturers. Barrels for .22 automatic pistols have chambers cut about .003-inch larger in diameter at the front and .007-inch larger at the rear than the closest target rifle chambers, so as to insure perfect automatic functioning.

Sir Charles Ross used to cut the leade in his .280 Ross long range match rifles (but not in sporting rifles) on a different principle. He had a long and smooth portion of the bore ahead of the chamber just exactly groove diameter, which was very slightly larger than the cylindrical diameter of the long 180 grain bullet. This smooth, cylindrical portion of the leade was just the length of the cylindrical maximum diameter of the bullet, and the bullet was a push fit in it. Forward of this the land slope was cut to correspond with the ogive of the bullet. The bullet, when it left the case, was completely seated its full bearing in this cylindrical portion of the leade, and thus trued up with its axis in line with the axis of the bore, before it entered the rifling. Very excellent long range accuracy resulted. But Sir Charles could and did control the exact diameter of his bullets, and these match rifles were made in such small quantities that the leade could be cut to exact push fit diameter of the bullet.

German manufacturers commonly cut their chambers for center-fire rifles with a very long, smooth, cylindrical leade quite similar to the .280 Ross match barrel leade, but not with such extreme accuracy, and neither was the exact diameter and length of the cylindrical portion of the bullet assured. American riflemen have never found that this long German leade was any advantage. In fact we have never obtained what might be called gilt edge accuracy from German high power rifle barrels. This may be due to the fact that almost invariably such German barrels seen in America have been very light sporting barrels, and the assembly of the complete rifles have been such that they could not be held in a cradle rest for a conclusive accuracy test. To demonstrate the value, if any, of this long German leade we should have a number of barrels of proper weight and type for use in the Mann "V" rest, cut with this leade.

Revolver Chambers

Revolvers almost invariably use cartridges of very low breech pressure. Indeed a revolver would be an impossible weapon when used with cartridges that even approached the pressures of the more moderate high power rifle cartridges. The regular revolver cartridges seldom exceed 15,000 pounds per square inch pressure. Those that do exceed it, notably the .38-44 Smith & Wesson and .357 Magnum cartridges, are used only in very heavy revolvers constructed of steel of very high tensile strength. Revolver chambers must be of such dimensions and type that the weapon will function easily and smoothly with finger manipulation alone. The small clearances between chamber and cartridge necessary in rifles are not essential in revolvers, which have relatively much looser chambers and larger clearances, and this makes for easy functioning. Almost all revolver cartridges have rimmed cases with straight bodies and no shoulders, about the only exceptions being the .32-20, .38-40, and .44-40 cartridges which are slightly bottle necked. Chambers for straight center fire cartridges are cut in diameter and length to easily accept the max cartridge case. At the end of the case portion of the chamber there is the usual shoulder, and forward of this the diameter of the chamber reduces to bullet or groove diameter to the front end of the cylinder. There is no leade or rifling in the cylinder.

The .22 Long Rifle chamber is cut smooth from rear to front of the cylinder, with no shoulder where the case ends.

Normally there is no recess in the chamber for the rim of the case, the forward surface of the rim resting, stopping, and abutting against the rear surface of the cylinder. Headspace is measured from the rear surface of the cylinder to the surface of the frame in rear of the cylinder, and is relatively quite large, with a clearance of about .020-inch over the rim thickness of the case so that the cylinder can rotate freely. Such large headspace is made possible by the light breech pressure of the cartridge. However, chambers for .22 Long Rifle cartridges are now often recessed for the rim of the case to give side support to the rim, this having been found desirable since the introduction of the high velocity .22 Long Rifle cartridge to reduce liability to finger injury should the head of such a case rupture.

The revolver barrel at its breech in front of the cylinder has a leade very similar to the rifle leade, the extreme breech end of the barrel being groove diameter or very slightly larger than groove diameter, and the lands then starting and sloping forward and up to their full height.

Shotgun Chambers

A shotgun chamber consists of a recess for the extraction rim of the shell, a body which is almost cylindrical with very slight taper, and a leade or "cone" where the chamber tapers at a more abrupt angle from the front body diameter to bore diameter. Besides being designated by gauge, shotguns of various bores are also distinguished by the length of the shell for which they are chambered. The standard chamber lengths used by practically all American shotgun manufacturers are:

10	gauge	......2⅞	inches
12	"	......2¾	"
16	"	......2¾	"
20	"	......2¾	"
28	"	......2⅞	"
.410	bore	......2½ and 3	inches

One manufacturer furnishes a 10 gauge shotgun with a 3½ inch chamber, and several furnish 12 gauge guns with 3-inch chambers.

Shotguns are chambered to handle these lengths of shells before they are loaded and crimped. The loaded length of the 2¾-inch shell, for example, depends upon the amount and kind of powder, shot, and wads placed in it, and the type of crimp used, but is approximately 2½ inches for the standard turn over crimp, and approximately 2⅜ inches for the wadless crimp. Loaded shells are always referred to by their unloaded length.

In firing the crimp is ironed out and the shell returns to approximately its original unloaded length, the forward end extending slightly into the leade of the chamber. Thus the nearly cylindrical or body portion of the chamber is not quite as long as the unloaded length of the shell. Figure 20 shows a typical chamber for a 12

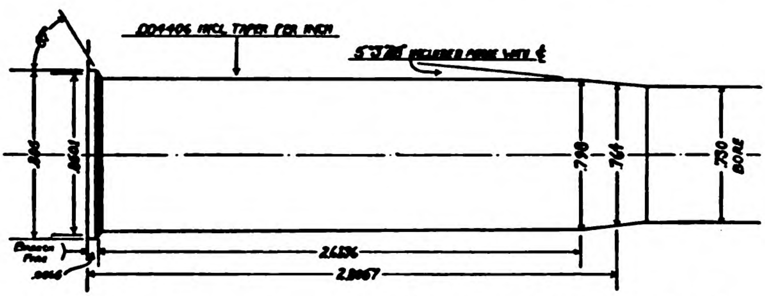

Figure 20. Chamber of 12 Gauge Shotgun for 2¾ Inch Case. Minimum Chamber

gauge 2¾ inch shell. Note that the body diameter is 2.6136 inches long, and the length of the leade which is sloped on an angle of 5° 3′ 28″ depends on the exact bore diameter, which later diameter in quantity production may vary several thousandths. The shell, when it is ironed out by firing thus extends about .136-inch up into the leade. The conditions resulting from this particular type of chamber have been found by many years of experience to deliver the shot charge from the shell into the bore with the greatest uniformity and with a minimum of deformed shot pellets.

Pope Rifle Barrels

A treatise on barrels would not be complete without reference to Pope rifle barrels. Mr. Harry M. Pope had the reputation of making the finest rifle barrels the world has ever known. There has long been a tendency among certain writers to state and insist that modern rifles have never equalled the accuracy obtained with the old percussion lock, and particularly with the Pope breech-muzzle loading rifles. Pope rifles were always acknowledged to be the most accurate of this old class of rifles. Mr. Pope guaranteed his rifles to shoot into a 3 or a 2½ inch circle at 200 yards, and stated relative thereto: "It will be noticed that two guarantees are given as to the size of group at 200 yards. There is absolutely no difference as to the quality of barrel or workmanship. I have a long trip to make to test, and in my guarantee have to make allowance for adverse weather conditions, sometimes having to make several trips to the range to secure the desired results. I never alter a barrel in testing, it is a matter of ammunition only. If tested you see what has actually been accomplished with fine appliances and know exactly what load did it."

Mr. Pope's success was due to two things. First his adoption of a system of rifling (see Chapter II) that was superior to all others for lead bullets and black powder. Second, to his manual skill, patience, and integrity which permitted him to make his barrels with a far closer adherence to the desired dimensions than was possible for the large factories to do with the type of production machinery that the large factories had available at the time that Mr. Pope made his reputation. Likewise Mr. Pope made the bullet moulds to cast bullets for his rifles with equal precision, and therefore was able to control this most important link in accuracy.

In very recent years modern precision machinery has made it possible to manufacture barrels in quantity with the same adherence to the desired dimensions as it was possible for Mr. Pope to do with his skilled hands and by spending a week in the making of a single barrel, and several of our large factories do now manufacture their best barrels with as close adherence to the ideal dimensions.

Those who assert that the old muzzle loaders, or even the old Pope barrels, excelled the best of modern rifles in accuracy have based their claims on the evidence of a few selected groups fired under the best weather conditions, and even so they are wrong, for modern barrels have often exceeded these old selected groups. Reviewing the tests made by modern riflemen with modern rifles in the past five years the writer has seen, not a few selected, but literally hundreds and hundreds of groups shot at 200 yards, many under varying weather conditions, and with modern high intensity rifles and fixed ammunition, which measure under two inches extreme spread as compared with the 2½ inch groups claimed by Mr. Pope. And he has seen many selected groups which measured under 1.5 inches.

CHAPTER IV

Manually Operated Breech Actions

SINCE firearms using gunpowder to drive the projectile appeared many hundreds of years ago, inventors and designers have had three separate problems to deal with in improving and developing these weapons. The first, of course was the arrangement of barrel, breech, and stock which would permit the projectile to be fired safely, reliably, and accurately. The second was providing a system of igniting the powder charge, and of incorporating the igniter with the powder and projectile into a fixed cartridge for easy, effective, and rapid breech loading. These two problems were more or less solved by the end of our Civil War. Those interested in these two stages of development should examine the Ralph G. Packard collection of small arms in the Smithsonian Institution at Washington, which includes the outstanding and best examples of all developments of barrel, breech, stock, and ignition systems since the invention of gunpowder.

The third problem was the design of a breech mechanism which would permit of firing successive shots rapidly as demanded in both war and sport, but impossible of solution until the cartridge problem had been solved. This third problem is still in the process of solution and development. A great many more or less successful breech actions have been designed and produced in quantity, and some of these have withstood the test of many years of successful use. But the breech action is a mechanical problem, and of mechanical ingenuity there is no end. Breech actions come and go. The better ones stay in service and popularity for some years until a still better invention displaces them.

Such a multitude of breech actions have been developed since the introduction of the metallic cartridge that it would take a work of many thousand pages to describe them all, and such a work would be obsolete before it was completed because of new actions invented in the interim. We can merely call attention here to certain principles which should be incorporated in any breech action in order that the weapon shall be satisfactory from both the practical and ballistic standpoints. But first of all the writer thinks it would be helpful to list certain actions which have been successful enough in the American service to have lived through a long life of usefulness.

Outstanding Breech Actions

Starting soon after the invention of the metallic cartridge certain types of single loading breech actions were introduced. In these a single cartridge, or two cartridges in the case of a double barrelled weapon, were loaded by hand into the chamber, and the breech action was then closed manually to lock the weapon ready for firing. After firing, the opening of the breech action by hand extracted the fired cartridge case, and the weapon was again ready for loading. In single barrelled weapons this permitted about twelve aimed shots per minute to be fired, a considerable improvement over the muzzle loader which could hardly be loaded and fired more than once or twice a minute.

In America the outstandingly successful single loading actions were the Sharps, Ballard, Remington, Springfield 1873, and Winchester for rifles, and the "tip-up" action with both single and double barrel for shotguns. When the writer was a boy the above rifle actions were preferred to all others by skilled and discriminating riflemen, both military and civilian. They had found the early repeating mechanisms unsatisfactory in that they frequently jammed (that is, malfunctioned), they lacked fine accuracy, did not use long range cartridges, and were poorly balanced. But gradually, with the perfection of repeating actions, these single shot weapons died out. The last, the Winchester Single Shot, was discontinued in 1920 because in the previous year its sale had dropped to under one hundred. Old actions of these types are still used to a considerable extent by "rifle cranks" for special and experimental purposes.

The tip-up shotgun action is still with us, and shows every indication of continuing in popularity indefinitely for sporting purposes. From time to time it has been improved by making it hammerless, by incorporating automatic ejectors to throw out the fired shells, and by a single trigger.

The introduction during the Civil War of the Spencer and Henry repeating rifles, in which the mechanism was operated by a finger lever, started our inventors to producing many types of repeating lever actions. This was a type of action which particularly appealed to American hunters of deer and larger game by reason of its convenience, ease of operation, and neatness. The first really successful lever action repeater, which almost completely supplanted the single shots, was the Winchester Model 1886. Almost two million of

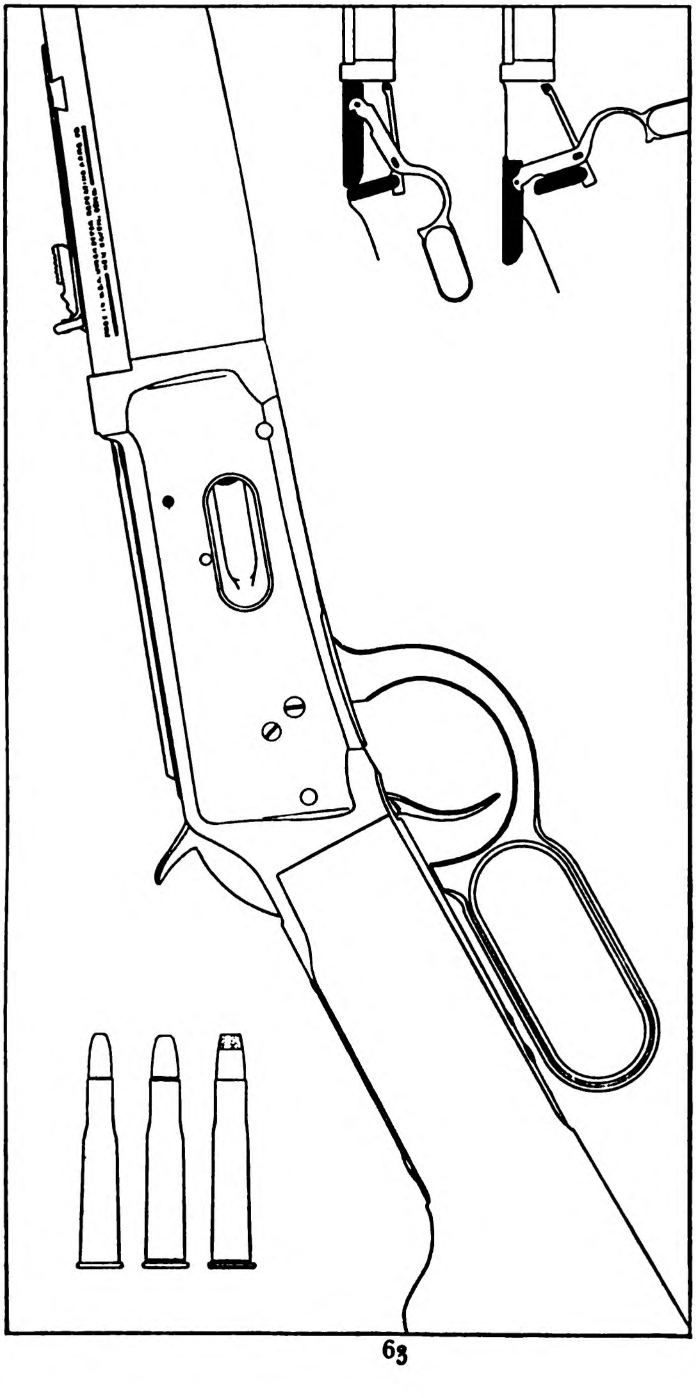

FIGURE 21. WINCHESTER MODEL 1894 RIFLE
Showing breech section and details of locking this action, also three very popular cartridges it is chambered for; the .25/35, .30/30 and .32 Special.

this action, and its modern variations, the Models 1892, 53, 65, and 71, have been manufactured. Other outstanding lever actions are the Winchester Model 1894 and the Savage Model 1899, together with recent slightly improved types of these. These actions have proved most successful and popular for hunting purposes at moderate ranges. It is conservative to state that, excluding purely military breech actions, ten times as many of them have been produced, and are still in use, as any other type of rifle breech action. They will probably continue in popularity for a long time although they may be supplanted for sporting purposes by semi-automatic actions unless the latter are legislated against for deer shooting. No army had adopted a lever action, except temporarily and as a stop gap, because all existing designs are unsuitable for breech pressures in excess of about 42,000 pounds which precludes the use of modern long range cartridges, because these actions lack power to surely load and extract oversized and dirty cartridges or to operate when very much overheated, because the mechanisms cannot be dismounted and assembled by hand, and because the resulting accuracy is rather mediocre. None of these are serious drawbacks from the viewpoint of the deer hunter.

Starting in 1885 pump or slide action shoulder arms began to appear. The first was the Colt Lightning Magazine Rifle. The repeating mechanism is operated by a sliding forearm, and permits faster operation and firing than any other manually operated firearm. Many different actions of this type have been produced for both rifle and shotgun. The slide action has been most outstandingly successful for shotguns, the Winchester Model 12, and the Remington Model 31 being types which will probably retain their popularity for many years because of their suitability for field and marsh shooting. Incidentally, by reason of their design and careful fabrication, these two models have the reputation of being the most durable shotgun actions yet developed. Pump action rifles, mostly .22 caliber, seem destined for a much shorter life, chiefly because the design does not lend itself to the finest accuracy, nor to the attainment of a high degree of skill in practical marksmanship. They are still fairly popular in shooting galleries and with "speed fiends."

The one most outstanding manually operated mechanism for rifles the World over for the past fifty years has been the Mauser Bolt Action Rifle, Model 1898, together with the numerous slight modifications of it. It has been adopted by twenty-one of the leading nations of the world for army and navy use, although it is probably destined to be more or less displaced in the immediate future by semi-automatic types. It has many sterling qualities and few drawbacks, except its lack of rapidity of fire as compared with semi-automatic rifles. In expert hands a rate of fire of about sixteen aimed shots per minute is possible, or the first six shots can be fired in about ten seconds. Its outstanding features are its strength and reliability under all conditions of military service, and it lends itself to assembly in a complete rifle capable of being adjusted for the very finest long range accuracy. Our Springfield Model 1903 rifle is a Mauser, and the Winchester Model 70 is an example of the most improved type. It is becoming increasingly popular all the time for sporting purposes, particularly where flat trajectory coupled with the finest accuracy is desired. It has been reported that the Winchester Repeating Arms Company could have sold upwards of one hundred thousand of their Model 70 rifles for sporting purposes during the years 1942-1943 had they been available. Popularity is mentioned here because in America, where the buying public is well educated in the intimate construction and performance of rifles, it is indicative of real mechanical and ballistic excellence.

The same details of complete assembly—barrel, breech action, and stock—which result in such superfine accuracy with certain rifles having Mauser type actions and with high intensity cartridges, have been found to be equally important in super-accurate match rifles for the .22 Long Rifle cartridge. In general the only action which will insure our small bore riflemen that accuracy which they demand is the carefully made and designed bolt action. It is probable that the Winchester Model 52 and Remington Model 37 .22 caliber bolt action rifles will remain in demand so long as men are interested in serious competitive rifle shooting.

The tip-up shotgun action is a development from the double barrelled muzzle loading shotgun. A steel frame or receiver replaces that portion of the wood muzzle loading stock from a point about three inches forward of the breech of the barrels to a point about two inches in rear of the breech. The barrels are hinged to the forward end of this frame, the muzzle dropping down and the breech rising to load. As generally made for a double barrelled gun the barrels are secured in firing position to the frame by one or two lugs on the underside of the barrels locking into the frame, and often by an extension rib on top of the barrels locking into the top of the frame. With a well constructed gun it is probably necessary to lock or bolt the barrels to the frame at only one of these places, and where both are used in the same gun it is usually to increase sales rather than to assure safety. Actions were first made with outside hammers and locks as on muzzle loading guns, but practically all double barrelled guns are now made hammerless. Two types of locks, that is firing mechanisms, are in vogue. The box lock or Anson and Deely lock, has the firing mechanism inclosed in the frame or receiver. The side lock has the firing mechanism applied to the sides of the frame as on a muzzle loading or hammer gun. American manufacturers usually prefer the box lock, while British gunmakers are about equally divided in their preference between the two types. A careful analysis shows that the frame can be made slightly stronger when the side locks are used, but the choice between the two types has lost its importance in recent years because with modern alloy steel and proper heat treatment either type of lock has an ample safety margin. About twelve years ago the Winchester Repeating Arms Company instituted a new procedure in fabrication by which they secured the two barrels to each other without the application of heat that would nullify the heat treatment of the barrels, and they also applied a very modern steel and heat treatment for all parts. Such guns (Model 21) have been tested by firing 2,000 rounds of high pressure proof shells in a single gun without developing a particle of looseness in the hinge or between standing breech and barrels. When this test was conducted it was found that the firing of ten such proof loads would develop some looseness in practically every shotgun made at that time—even in the most expensive imported guns.

The tip-up shotgun action will probably continue in manufacture and popularity indefinitely.

The revolver, designed by Samuel Colt in 1836 has remained a standard American design to the present day, but now seems about to be obsoleted for military and target uses, although it will probably continue in manufacture for many years for police use. Its drawbacks as we now see them are the difficulty of manufacture with strict interchangeability of parts, inability to dismount and assemble by hand alone, and the shifting of the hand grasp to manually operate the weapon. The latter drawback greatly increases the amount of training necessary to develop skill in really accurate rapid fire.

As the writer reviews all the small arms actions known to him, the above are really the outstanding ones. The list does not include all good actions but it does those that have proved superior enough to have had very long periods of manufacture and satisfactory use, or that would seem to have an extended future life. The list also includes practically all outstanding foreign actions. Foreign inventors have not been nearly as prolific as American in the production of breech actions. For years sportsmen abroad have been quite content with the tip-up action for both shotguns and rifles, and repeating actions were developed almost exclusively on the bolt action for both military and sporting purposes, culminating in the final development of the superior Mauser 1898 action.

As stated, it is impossible to describe all these breech actions in detail here, but they will be found completely described in official ordnance and army publications and in their manufacturers literature. Anyone who aspires to design a new breech action, or to modify an existing action for any reason, should make a complete study of these outstanding actions, as well as make himself more or less familiar with the general principles of breech action design.

General Principles of Breech Action Design

A manually operated breech action for a small arm should include the following features.

1. Proper and safe support for the cartridge to be used, including proof cartridges with a 25 percent overload. Safety and durability involve both design and materials.

2. Efficient mechanical operation, including sure functioning under service conditions. Positive insertion and extraction of loaded cartridges and fired cases, with ample power to accomplish this under all probable conditions of use.

3. Proper mechanism for indenting primers.

4. Suitable trigger pull.

5. Easy and fast operation.

6. Design adaptable to modern marksmanship methods.

7. If the above details are incorporated the safety factor is assured.

We will discuss each of these features in turn.

1. **Breech Support.** In all manually operated single shot and repeating breech actions the breech block or bolt, or the standing portion of the receiver breech, must support the head of the cartridge solidly against the pressure of discharge. Under the high pressure of burning powder gases there must be some elasticity and "give" to the materials, which in time will result in a permanent set-back. This elasticity should be as small as possible, and in the case of high intensity cartridges it is essential for safety and durability that we reduce it to a minimum by employing proper design and materials. The designs which result in minimum elasticity and set are those in which the breech block or bolt is uniformly supported close to the head of the cartridge, and they therefore rather restrict the design of the breech action to certain lines, in general it may be said to the bolt action and the falling block action.

When the breech pressure of the cartridge is not so high certain liberties may be taken, not perhaps as to solidity of support, but rather as to its uniformity and distance from the head of the cartridge, and this gives the designer more latitude. Thus when pressures do not exceed about 42,000 pounds per square inch we may lock the breech block at a point several inches from the head of the cartridge, and in some cases we may support it by only one locking lug on one side of the block instead of using two lugs to uniformly support it.

When the conventional cartridge or shell is discharged in a normal and properly breeched chamber a sudden pressure of gases occur which quickly reach a peak of about 10,000 to 50,000 pounds per square inch, depending on the characteristics and loading of the cartridge or shell. The back thrust on the breech block or bolt thus depends upon the area in square inches of the head of the cartridge case. The friction between the walls of the chamber and the body of the case also enter into the problem but we will disregard these for the moment. The head of the .30-06 case, for example, is approximately .47 inch in diameter and thus has an area of .1735 square inch.* If the breech pressure is 50,000 pounds per square inch then the back thrust on the head of the bolt will be 8,674 pounds per square inch. Such a back thrust requires a bolt solidly and uniformly supported close to the head of the case.

On the other hand the head of the rimmed .30-30 cartridge measures approximately .50-inch, and this cartridge is usually loaded to a pressure of about 38,000 pounds, so that the back thrust on the block is about 7,461 pounds, and we can take more liberty in the design of our action and lock the bolt several inches from the head of the case.

Breech pressure alone is not a safe guide to the strength of action required. The little .22-3000 Lovell 2R cartridge, for example, is frequently loaded to a pressure close to 50,000 pounds, but the diameter of the head of the case is only .37 inch, and the maximum back thrust only about 5,300 pounds, so that not so strong locking is required as for a .30-06 cartridge.

Figure 22 shows a number of types of breech closures or locking systems. The first, A, the Mauser type of bolt, has two locking lugs, diametrically opposite, at the head of the bolt, and fitting accurately with equal bearing, into recesses milled in the receiver ring. Sketch B shows similar lugs on the Ross and Newton bolts, but the lugs are cut with threads instead of being solid, as is frequently seen in cannon. If these threads and their seats were cut with extreme precision the closure would be slightly stronger, but this would greatly increase cost of production, and generally speaking the advantage of these threads has not paid for their cost. Sketch C shows the breech closure of the falling block, high sidewall Winchester Single Shot, Sharps Borchardt, and Remington Hepburn actions. The solid breech block slides vertically in grooves in the receiver, being lowered to load, and raised to close the action. The

* To find the area of a circle, as the head of a case, square the diameter and multiply by .7854.

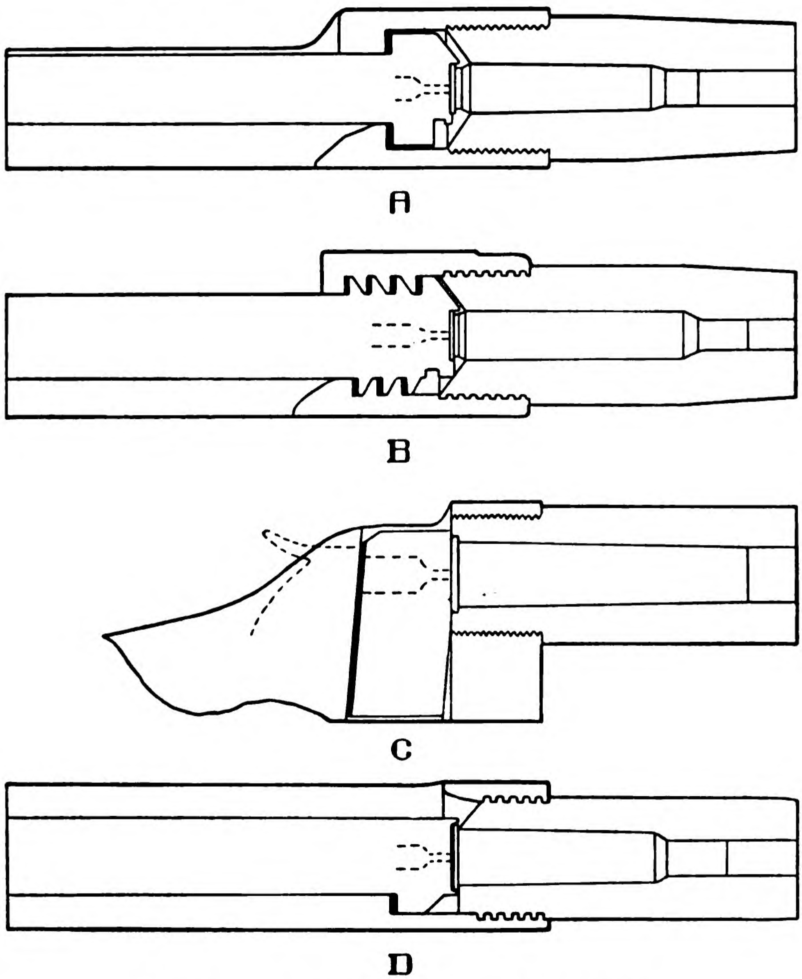

FIGURE 22. BREECH ACTION LOCKING PRINCIPLES

The heavy lines show the surfaces, shoulders, or lugs on the receiver, and on the bolt or breech block which take up the back thrust or recoil of the cartridge.

A—The Mauser type of breech action. Two locking lugs at the head of the bolt and on opposite sides of it lock against corresponding shoulders in the receiver ring, and strongly and uniformly support the bolt face. Provided that the two lugs bear equally on their receiver shoulders, this is one of the strongest and most satisfactory locking systems.

B—A modification of A as seen on the .280 Ross and some Newton rifles. The locking lugs on the bolt are in form of threads. Stronger than A when perfectly constructed, but it was very costly to machine so that each thread rear surface of the grooves in the receiver uniformly support the block about three-quarters inch behind the head of the case. These are the types of closures that should be used for best results with high intensity cartridges giving pressures of 42,000 pounds and upwards.

Sketch D shows the Krag-Jorgensen and Remington Pump Model 14 methods of locking with only one lug close to the head of the bolt. The bolt is thus not uniformly locked on both sides, and the one lug has to take all the back thrust. This system has proved quite successful where the back thrust on the bolt head is not particularly heavy, but with average size cartridges has shown an increased percentage of failures when the breech pressure exceeds about 42,000 pounds, which is regarded as the maximum pressure for the Krag Jorgensen action. The lugs are liable to crack off at higher pressures. Such cracking might, however, be obviated by improvement in the steel and its heat treatment, both of which are rather antiquated in the Krag Jorgensen action.

Sketch E shows the type of locking seen in many .22 caliber rim fire bolt actions, with a simple locking surface at the rear end of the bolt, often provided by the rear surface of the bolt handle fitting into a groove in the receiver. Where the bolt fits closely throughout its well in the receiver this has proved entirely adequate for safety and accuracy with rim fire cartridges.

In Sketch G the Winchester Models 1886 and 1894 repeating actions are locked by means of locking bolts which rise into slots cut in the rear end of both receiver and breech block. The locking is thus several inches from the head of the case, and we have several inches of receiver steel, and several inches of breech block steel between the origin of the pressure at the head of the case and the locking surfaces. The combined elasticity or "give" of all this steel is relatively considerable. With pressures of 38,000 pounds and over there is enough give or stretch on firing so that the fired case can

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bore perfectly in its seat in the receiver, and unless so constructed it was much weaker than A.

C—The Winchester single shot and other falling block breech actions. The vertically sliding breech block is uniformly supported against shoulders in the receiver slot through which the block slides.

D—A bolt with but one locking lug as seen on the Krag Jorgensen, Remington slide action, and many other rifles. The bolt is supported on one side only, and the cross strain may introduce a peculiar jump to the barrel which sometimes causes quite different zeros for cartridges of varied loadings. The Krag action with case hardened low carbon steel was not safe with pressures exceeding 42,000 pounds. However, a number of very successful actions have been locked on this system, using cartridges of moderate loadings.

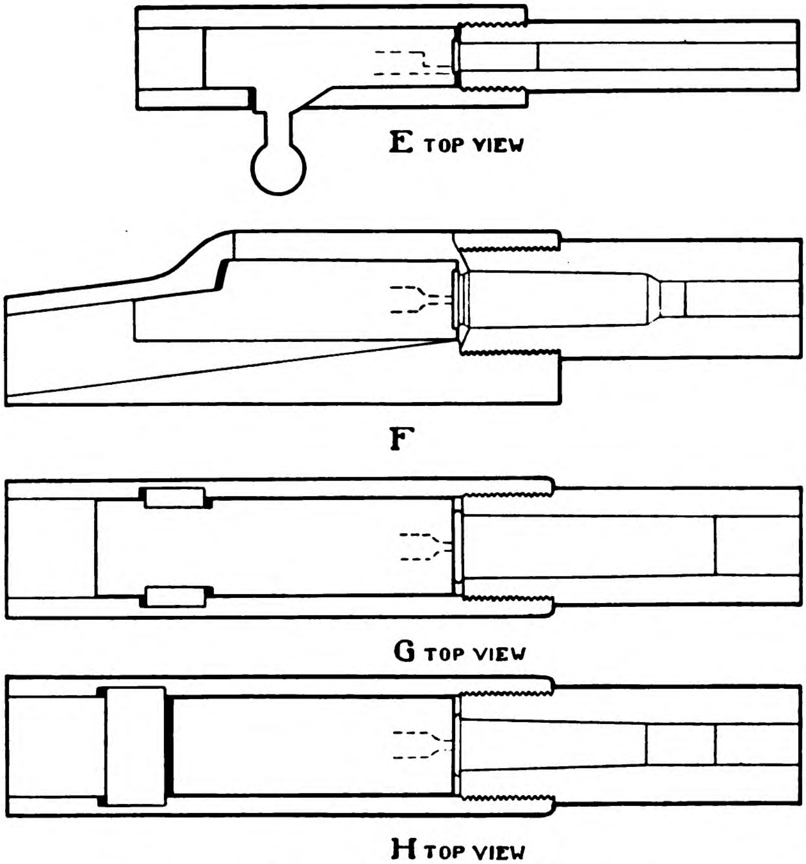

FIGURE 23. BREECH ACTION LOCKING PRINCIPLES

E—Breech block locked toward its rear end, the base of the bolt handle forming the lug which turns down into a recess or slot cut in the receiver. Used successfully on many .22 rim fire rifles, but not strong enough for high intensity cartridges.

F—A shoulder at the rear of the breech block wedges up against a corresponding shoulder at the top of the receiver opening. A toggle connected with the lever or slide (not shown) keeps the block up in position. The block also fits snugly against the sides of the receiver opening preventing slipping or slide play. This is the system used on the famous Savage Model 1899, and later on some new Winchester self-loading actions. A strong closure when constructed to give a perfect fit.

G—Lever action locking as seen on Winchester Models 1886 and 1892 actions. As the breech block closes two locking lugs rise up into slots cut in both block and receiver, locking the block at its rear end. Suitable for stretch enough in length so that it cannot again be inserted into the chamber without prohibitive force, and cartridge cases fired in these actions have to be resized in length and carefully gaged for headspace before they can be reloaded. As a result of continued firing of such actions the elastic stretch gradually results in a permanent set and increase in headspace. Such increase in headspace seldom or never results in a dangerous increase during firing which would wear out one barrel, therefore the action has a useful life equal to its barrel life. No trouble from this cause will be experienced by those who confine their firing to factory cartridges, and it is only experienced by those who reload their ammunition.

Sketch F shows the locking system of the Savage Model 1899 and new Winchester self loading actions (the latter a tentative design). The breech block rises in rear to lock, and abuts against a broad surface at the rear of the receiver opening. Owing to the size of parts and the absence of separate locking bolts, this system appears to be stronger than that used in the Winchester 1886 and 1894 actions, and is satisfactory with slightly heavier loads, approaching the Mauser and falling block actions in its strength.

As a further comparison between these various types of closure it may be said that roughly speaking the closures shown in Sketches A and B will have such strength and lack of stretch that the actions will wear out three or four barrels before they stretch enough from repeated firing to become unserviceable, while those shown in Sketch G will often become unserviceable from the wearing out of a single barrel, the steel and its heat treatment being the same in each case. We refer to the barrel wear due to erosion, and not to that due to lack of care.

Of course the strength of any breech action depends not only on

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pressures not to exceed 42,000 pounds with case heads the size of the .33 and .348 Winchester cartridges.

H—Locking system as seen on Winchester Model 1894 action. A vertically moving breech block rises through slots in the inside of the receiver wall, and covers and supports the entire rear of the breech block. Like G should not be used for pressures exceeding 42,000 pounds.

F, G, and H lock at the rear end of the breechblock and there is 2½ to 3 inches of bolt and receiver metal between the face of the block (source of the back thrust) and the locking surfaces. The elasticity of this amount of metal, particularly that of the thin receiver walls, is such that there is a little spring-back of the block on each discharge. In practice, cartridges loaded to pressures over about 32,000 pounds stretch lengthwise from this spring-back so that they cannot be reloaded without full length resizing and headspacing if they are bottle neck cartridges. Headspace in these actions is liable to increase rather rapidly and should be watched. With modern ammunition it is much the better practice to lock uniformly on either side of the *head* of the bolt.

its design, and the dimensions of the metal involved in the parts under stress, but also on the physical properties of the material used. In the days of black powder when breech pressures did not exceed 25,000 pounds per square inch and were usually much less, any good machine steel was regarded as entirely suitable for parts of actions, and heat treatment was unnecessary. Indeed in some early actions malleable iron castings, and even gun metal, an alloy of copper, tin, and zinc, were sometimes used. But with the great increase in pressures incident to the use of modern smokeless powders the use of heat treated alloy steels in the vital parts—barrel, receiver, and bolt—has become absolutely necessary to insure the tensile strength and elastic limit required for a suitable factor of safety.

The best practice is to so design the breech action and prescribe the materials that the completed weapon will successfully withstand a pressure fifty percent in excess of that given by the normal cartridge. Thus the .30-06 cartridge has a breech pressure of from 42,000 to 50,000 pounds depending on the particular loading, and the Springfield 1903 rifle designed for it was proof fired with two proof cartridges giving 68,000 pounds pressure. The requirement of this proof test was that a rifle with original headspace measurement of 1.940 must not take the 1.943 gage after the proof firing.

We think it best to avoid giving or prescribing the alloys of steel and their heat treatment to be used in modern breech actions because of the very great increase of our knowledge of the metallurgy of steel during the past few years, and particularly now occurring under the impetus of World War II. Any composition or treatment that could be laid down at this date would likely be obsolete a year from now, and the post war period will almost certainly see a remarkable improvement in strength of materials. Any metallurgist can write a formula for a suitable steel for use under present and past conditions, but he cannot predict the conditions of the future.

Under present design and working conditions the brass of the cartridge case is the weakest link in the withstanding of pressure. Cartridge case design will be discussed in its proper chapter, but it will be well to consider here what takes place relative to both breech action and brass case when a small arm is fired.

The primer ignites the powder, and the powder in burning generates a gas which expends tremendously in volume and with great force in all directions. The bullet is the easiest thing to move, and that flies through the bore and out the muzzle. The bolt, of course, is locked and cannot move—at least in a manually operated action it should not move. The gas presses the walls of the brass cartridge case tight against the walls of the chamber. The walls of the case at its mouth are thinner than in its body and head, and they quickly expand and hug the neck of the chamber tight enough to prevent the gas, issuing from the mouth of the case, coming back around the case and entering the chamber. But the body portion and base of the case is constructed with much thicker brass, and usually of brass that does not have as much elasticity and ductility as that at the mouth, and it does not hug the chamber walls as closely as at the mouth. Therefore, on firing, if there is any give or stretch to the breech block or bolt, or any excessive headspace, the neck of the case sticks tight to the chamber wall, but the pressure forces the rear of the case to the rear to the extent of this possible looseness. The case is thus stretched longitudinally, and if it is stretched enough it will separate, or split, or enlarge at the rear. Examples are where the case pulls in two just in front of the head (a separation), or where the head splits, or the head swells, or the primer pocket enlarges and leaks and the primer blows out. Any of these occurrences may permit the gas to escape back into the breech action with more or less disastrous results. A small amount of gas escaping to the rear may rush back around and through the bolt and may injure the shooter's eye. An enlarged primer pocket may permit the primer to drop out and jam the action. A swelled case head may jam or weld the case so firmly in the chamber that it cannot be extracted or the weapon opened. So much gas may escape that the gas port is unable to exhaust all of it, and enough escapes down into the inside of the receiver, wrecks things there, and perhaps splinters the stock around the receiver. And finally enough gas may escape to shear off the bolt lugs, split the receiver, and blow out the bolt.

The amount of looseness or set-back of the bolt which can be permitted without danger of some such accidents depends on the breech pressure and the design of the case. With the normal .30-06 cartridge any play or looseness of bolt or chamber in excess of .01-inch above the normal and minimum 1.940 headspace gage is absolutely dangerous, and anything over .006-inch results in more or less unsatisfactory performance. Thus if a rifle is found in the hands of troops which will accept the 1.950 gage it is at once withdrawn from use and is shipped to an arsenal for repair. No "cleaned and repaired" rifle is issued from an arsenal which will accept the 1.946 gage, nor does a new rifle pass inspection if it will accept the 1.943 gage. With proper ammunition and care, starting with the rifle new, a Springfield rifle can be fired to the full accuracy life of its barrel without approaching a 1.946 headspace measurement. A Winchester Model 52 or Remington Model 37, .22 caliber match rifle can be fired about 75,000 rounds before the increase in headspace begins to make itself manifest in lowered accuracy, and then the bolt can be tightened up and the rifle be as good as new. The accuracy life of the barrel is practically unlimited when non-corrosive cartridges with lubricated lead bullets are used, and there are records of rifles having maintained gilt edge accuracy for 250,000 rounds with occasional tightening up on the headspace, using the .22 Long Rifle, regular, lubricated cartridge.

We cannot state what is the strongest breech action without first asking what is the strength of the brass case. Cases differ greatly in their strength and anneal and ability to stand high pressures. No normal case, as now made, will successfully withstand 75,000 pounds pressure. Proof cartridges of that pressure are made with special and very strong cases. It is also conceivable that any of the types of breech closures described here may be constructed with such large dimensions of parts and of such materials that it will be stronger than any existing action. But from experiments conducted with actions regularly manufactured up to 1940 it is quite clear that the Mauser type is slightly stronger than any other. In experiments which did not involve the strength of the case such actions have sometimes successfully withstood a pressure of 125,000 pounds. A Springfield 1903 action (which is of Mauser type) when constructed of the most recent steel and heat treatment, will successfully withstand the seating of a 172 grain M1 bullet in the bore just ahead of the chamber, and then seating a normal M1 cartridge back of it, thus firing the service powder charge with two bullets ahead of it. The same rifle will, however, be entirely disrupted by firing a single 8 mm Mauser cartridge in it. The .30-06 bullet has a diameter of .308-inch, while the 8 mm bullet measures .324-inch. It happens that the 8 mm cartridge can readily be inserted in the .30-06 chamber and the bolt closed on many rifles of this caliber.

The most prevalent flare-backs of gas are those that occur from punctured or leaky primers, the exhaust from which is most liable to enter the firing pin hole in the face of the breech bolt or block. Then the gas, if not diverted or dissipated, may travel the full length of the firing pin straight into the eye of the shooter. To divert or dissipate this gas every action for high power rifle cartridges should have one or more gas ports. Those provided in the German Mauser Model 1898 action are regarded as being very effective. On the left side of the bolt are two oblong ports, about .20″ by .45″, the forward one starting about .75 inch in rear of the bolt face. Each of these ports extends through the wall of the bolt into the firing pin hole. Any gas escaping into the firing pin hole will largely exhaust through these ports into the groove in the receiver through which the top of left locking lug slides to the rear, and will pass to the rear through that groove and out the thumb cut on the left side of the receiver. To divert any gas that might pass to the rear along the outside of the bolt, the forward surface of the bolt sleeve is formed like a shield, and would divert such gas to the side instead of allowing it to come back into the eye of the shooter. Other actions commonly have a small hole drilled through the bolt wall into the firing pin hole about half an inch in rear of the bolt face. When the action is closed this hole registers with a similar hole in the side of the receiver, through which the gas will pass off to the outside.

So far as permitted by non-interference with the interchangeability of parts, our Springfield 1903 Service Rifles, and indeed all other weapons manufactured by the Ordnance Department of the Army, have been improved from time to time. For example, the materials of which it has been made have been improved now and then as our knowledge of the metallurgy of steel increased. And, about 1934 an improvement was made by increasing the size and improving the location of the gas port, much in line with those seen in the Mauser Model 1898 rifle. Similar improvements were made in the gas ports of the Winchester Model 54 rifle, and these were incorporated in their Model 70 rifle. If we examine any American breech action which has stood the test of long years of successful use, we will see that some arrangement has been made to safely exhaust the gas that might escape from a punctured, leaky, or blown-out primer. Even the old Winchester Single Shot rifle, which dates back sixty years, had a gas port from the firing-pin hole that exhausted out of the top of the breech block. On the other hand we see certain defunct breech actions which did not have any such provision. The otherwise rather popular Stevens Model 44½ action is an example; gas escaping to the rear in that action would be directed through the firing-pin hole almost directly into the shooter's eyes.

This matter of gas ports and the deflection of escaping gas is extremely important because when it is not properly attended to there is great danger that sooner or later the shooter's eyes may be seriously injured, if indeed he does not lose his eyesight. With properly made American factory rifle ammunition, used in American rifles in good condition, leaking primer malfunctions do not occur oftener than perhaps once in ten million rounds. If we assume that the owner of a rifle averages firing ten rounds from it annually, then in a year his chance of experiencing such an occurrence is one in a million. The point, however, is that there is a chance, and when the eyes are concerned it does not pay to take any chances. Practically no chance is taken if the rifle has a properly designed gas port. Usually the shooter would be unaware of such a malfunction unless he examined the fired cartridge case.

This matter becomes of increasing importance to those shooters who use hand loaded ammunition or "wild cat" cartridges, and

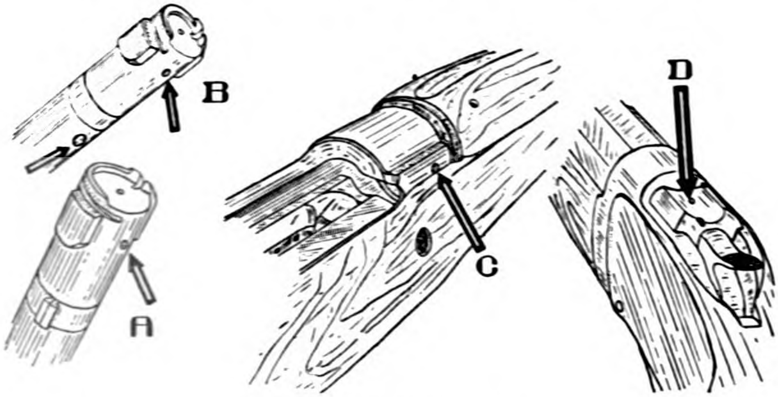

FIGURE 24. GAS PORTS

Study the above drawings closely and note those small apertures which lead into the bolt head and firing pin channel of the rifles depicted. These holes were not put there to save weight or to carry out some featherbed tradesunion rules—they were put there for the safety of the man shooting the rifle. They are known as gas ports and their function should be more clearly understood by riflemen, particularly by those riflemen who indulge in handloading their cartridges to the last pound of permissible pressure . . . and mebbyso a few thousand pounds beyond.

These small holes or gas ports exhaust gas that may leak back from a punctured or blown primer, or from a case that does not obturate properly. Such small escapes of gas occur more frequently than is generally realized, but pass unnoticed through these ports. However, these ports are never large enough to exhaust the far greater volume of gas that rushes to the rear from a case head that "lets go" due to very excessive pressure, this usually wrecking the breech action and often resulting in serious injury to the shooter. Beware of excessive pressure which is pretty sure to result sooner or later from a powder charge which exceeds the maximum, sometimes by not more than half a grain.

A—Shows the gas port in the bolt of earlier Springfield 1903 rifles, although those of more recent manufacture have two of these ports as in **B.** This single gas port exhausts gas that might rush back into the firing pin hole into the large well in the receiver where the two locking lugs on the bolt turn to lock. From there this gas, as well as any that might leak back around the rim of the head of the case, is exhausted through the receiver port seen in **C.**

B—Shows the two gas ports in the bolt of the Model 1917, or "Enfield," rifle, the rear gas port exhausting into the slideway on the left side of the receiver where it is dissipated through the thumb slot on that side. A similar port on the more recently manufactured Springfield 1903 bolts exhausts through a port in the left receiver well which registers with the bolt port.

D—Shows the gas port on the top of the breech block of the old Winchester single shot rifle which exhausts gas that might enter the firing pin custom built rifles, when the proportion of primer malfunctions is very much larger than with standard factory goods. It is also important to experimental riflemen who are shooting new and untried rifles and ammunition. In fact, the writer does not know any well informed experimental riflemen who do not invariably wear large shooting glasses when firing, to safeguard their eyes. It is not only that hot gas may flash to the rear through poorly designed mechanisms and from defective cartridges, but mixed with this gas are usually small metal particles of the primer and case that might penetrate deeply into the eyes and face.

In order that the reader be not unduly apprehensive the writer must hasten to state that when the shooter confines himself to fairly modern American rifles and factory ammunition, or to those rifles and ammunition made by the Ordnance Department of the Army, the chances for an accident from such a cause are so extremely remote that it does not pay to even wear shooting glasses. But in this work we are to a large extent concerned with amateur and professional gun designers and experimenters, and it is trusted that a word to the wise is sufficient. Do not neglect an efficient gas port in any new design, and wear shooting glasses in experimental firing.

Handling of Cartridges. This is a purely mechanical problem. A repeating or magazine breech action must handle its cartridges with perfection from magazine into chamber, and extract and eject the fired case whether it be operated fast or slow, in any position, muzzle up or down or upside down, in cold as well as warm temperature. A military arm must do this in the presence of a certain amount of sand or dirt, when the weapon is very hot from repeated firing, and with cartridges that are slightly oversize or slightly dented.

Furthermore it must be possible to surely and quickly load cartridges or a clip into the magazine. In tests, all this must be performed without malfunctions, or with a very small percentage of malfunctions for a large number of rounds, usually for what is calculated to be the life of the barrel.

It is conceded that the breech action must be fully operated for each shot. Almost all repeating mechanisms will jam if the action is only partly opened or operated and then closed.

We often speak of the reliability of our old single shot, falling block actions such as the Sharps, Ballard, and Winchester. But really they are much less reliable than our more recent repeating actions when it comes to handling cartridges. If the cartridge is

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hole upward into the air, thus preventing it flashing back to the rear and possibly injuring the eyes of the shooter. Other similar gas ports will be found on almost all modern center fire rifles.

slightly dirty, or corroded, or oversize it must be forced to almost a complete seating in the chamber by finger pressure which is a very weak method that often fails. The extractor is weak and it withdraws the fired case only about 1/8 inch and does not eject it, and finger nails often fail to complete the extraction. If a telescope sight be used on such a rifle it is difficult to get the fingers under the scope tube for effective loading and extraction. It often becomes almost impossible to load or extract cases when the hands are numb with cold or when gloves are worn. Automatic ejectors are effective on tip-up shotgun actions only because the fired paper case is very easy to extract.

Magazines are of five general types, the tubular magazine either under the barrel or in the butt-stock, the box magazine with cartridges in single column, the double column box magazine, the revolving box magazine, and finally the box magazine in which the cartridges are contained in a clip. With tubular magazines cartridges must be fed singly into the magazine which is a slow process, although sometimes they can be poured in from a loading tube. Box magazines of military rifles are usually arranged for clip loading, and the magazine can be filled in about the same time that it takes to insert a single cartridge into the tubular magazine.

For small .22 caliber rim fire cartridges the tubular magazine has proved to be much more reliable in its functioning than the box magazine, and they are much more easily filled. Frequent jams occur with box magazines as it is difficult to accurately position the top cartridge in the magazine so that the bolt will push and slide it smoothly out of the magazine into the chamber. The small cartridge with its lead bullet rather loosely inserted in the case is liable to get out of alignment during the movement and jam. Twenty-two caliber box magazines are usually made detachable from the receiver so that they can be more readily filled with cartridges. This type is almost imperative in a small bore magazine rifle designed for fine accuracy as the tubular magazine in any rifle interferes with that uniform jump so necessary for super accuracy. Five or more cartridges in a clip magazine can be inserted into the receiver box with one motion, but when it comes to filling the magazine with single cartridges the detachable box magazine is slower than the tubular magazine.

For larger cartridges, breech actions using single column box magazines are simpler in construction, and they and the revolving box magazine are the most efficient and freest from liability to jam when rimmed cartridges are used. The double column box magazine as seen in Mauser type rifles is at its best with rimless cartridges, and it is difficult to make rimmed cases function perfectly in it. Even for rimless cartridges it has to be made to very close dimen-

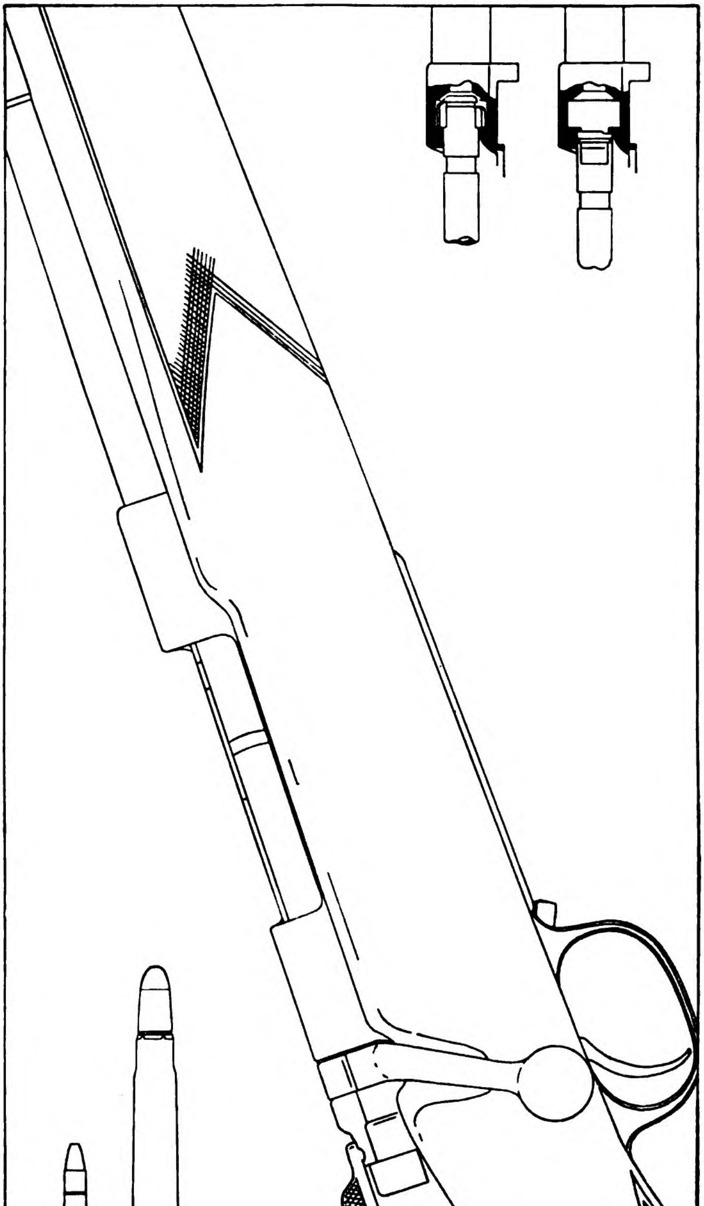

FIGURE 25. THE MODEL 70 WINCHESTER RIFLE

Showing the .375 H. & H. Magnum (the largest) and the .22 Hornet (the smallest) cartridges for which this popular rifle is chambered. The principle of bolt head locking by means of opposite lugs close to the head of the cartridge is shown.

sions, but when so made it is very efficient, and it has the advantage that for all but the very largest cartridges it can be made to hold five rounds without projecting below the normal bottom line of the forearm. The revolving box magazine as seen on the Savage Model 1899 and Mannlicher-Schoenauer actions is a very attractive and efficient type, and deserves more popularity than it has attained, although in a military arm it is rather difficult to keep it free from dirt, and it is a rather expensive design to produce. The box magazine into which the cartridges are fed in a clip, in which clip they remain until the last cartridge is fired, when the clip is automatically ejected, has had a rejuvenation by its adoption for the Garand rifle, but will probably be confined to military arms.

Because of the size of shotgun shells the tubular magazine is the only one adapted to them without making the outline of the assembled arm bulky and ungainly. It is fortunate for the design of the semi-automatic pistol that the grip offers such a convenient place in which to locate a single column box magazine of ample cartridge capacity. In a revolver the cylinder of course is the magazine, and incidentally contains the chambers as well.

In designing any magazine and the mechanism which positions the top cartridge so that the bolt will smoothly push it into the chamber, dimensions and shape of parts are very important. A difficult problem may occur here when we try to adopt an existing magazine and action to handle a smaller or larger cartridge than the one for which it was designed. It is sometimes possible to do this, but it involves much cut and try methods. If a double column magazine, for example, be a little wide for a certain cartridge, the cartridges will wedge and fail to rise; and the follower also must be of exact shape. If the upper lips of any box magazine be not so shaped that the topmost cartridge will always rise to exact position so that the bolt will engage sufficient of its head to slide it smoothly out of the lips and forward into the chamber, jams will occur. Between the forward end of the box magazine and the chamber a ramp must be arranged in the receiver which will guide the point of the bullet straight into the center of the chamber. Detachable box magazines are made of thin metal, and the lips are liable to become deformed and cause trouble. This is a frequent cause of malfunctions in detachable .22 caliber box magazines, and with the magazines of automatic pistols, and this is the first place to look for trouble in such magazines. The lips can usually be bent back again into proper form, but this may involve many trials.

In the early days of tubular magazines breech actions were usually so designed that they would handle only cartridges of standard overall length (examples, Winchester Models 1873 and 1876), but most later designs will handle indiscriminately cartridges that differ materially in overall length. Thus many tubular magazine .22 caliber rifles will now handle without adjustment either the Short, Long, or Long Rifle cartridges, and most lever actions will handle cartridges with bullets seated much deeper in the case than they are in the maximum length cartridge. The Winchester Model 70 (Mauser type) rifle is made for a number of cartridges which have the same head and body diameters, but which differ considerably in overall length, and the same magazine is used for all. But for the shorter cartridges the magazine is blocked at the rear with a piece of sheet metal so that it is just long enough for the max overall length of that cartridge, and the bolt stop is so arranged that the bolt retracts only far enough to the rear to just engage the head of that cartridge as it lies in the top of the magazine. If, however, it should become desirable to increase the length of this magazine for a slightly longer cartridge it is an easy matter to remove the piece of sheet metal that blocks the rear of the magazine or move it further to the rear, and the bolt stop can also be cut back slightly. In designing a new breech action it is well to construct it so that it will handle a cartridge considerably greater in overall length than what for which it was originally conceived, for no one can foretell what changes may be found desirable in length of bullet and depth of seating as a result of continued experience with the rifle and cartridge.

We must now consider the matter of the extraction and ejection of the fired cases and loaded cartridges. There are two phases of this extraction movement. First the primary extraction in which considerable force may be required to free the fired case from its grip on the walls of the chamber. By reason of a dirty or oversized cartridge, a cartridge case of soft anneal, or a roughly reamed chamber, primary extraction may be difficult, necessitating considerable pull on the head of the case to start it out of the chamber. This difficulty of primary extraction becomes very great when a rifle is fired so rapidly and continuously as to considerably overheat the chamber. It may then require three to ten times as heavy a pull as normal to extract. As will presently be described, all existing lever, pump, and many automatic actions lack power to extract as compared with some bolt actions, and this is why we see most chambers for such actions cut with larger dimensions than is the practice with bolt actions, so that the cases will not stick so tenaciously when the rifle is fired rapidly.

A number of times the writer has engaged personally in tactical problems which involved the firing of seventy-five to one hundred service cartridges from the Springfield 1903 rifle in the space of a few minutes. This rifle has very strong primary extraction. With the first twenty rounds there was no difficulty whatever, the bolt operating easily, but as the rifle became hot it was increasingly difficult to raise the bolt handle to start the fired case out of the chamber. Great effort was required to start the bolt open. After fifty rounds had been fired (in perhaps five to seven minutes) bolt lift became so difficult that no more than two or three shots per minute could be fired. After seventy-five rounds or so it was almost impossible to get the bolt open, the writer became rather exhausted, and

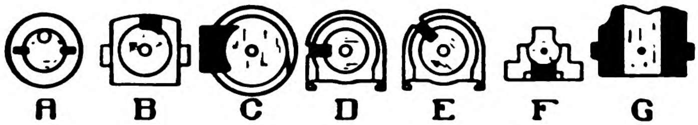

FIGURE 26. CARTRIDGE EXTRACTION SYSTEMS

The above series of bolt and breech faces will give an idea of a few of the methods by which the fired case is withdrawn from the chamber, or "extracted," after which it is kicked out of the action, generally by means of another trick gadget called the "ejector."

A—Shows double extractors as seen on some .22 rim fire rifles. **B**—top extractor, as seen in lever action Winchester rifle. **C**—extractor on right side of breech block, as in bolt action military rifle. **D**—extractor on right side, as in automatic shotgun where ejection is through port on right side of frame. **E**—extractor at 45 degrees up and to the right, as on automatic pistol. (**D** and **E** are standard Continental pistol practice.) **F**—bolt body of a 20 mm automatic gun, with extractor on bottom of bolt so ejection will be made through a port in bottom of receiver. **G**—is not a genuine *separate* extractor but is the simplest of all and also the most certain; this is the T-slot as found in the Browning machine gun through which the base of the case slides; the cartridge can't slip out until forced down to the bottom of the slot.

Note the size and width of the extraction claw in **C**. Bolt action rifles have exceedingly powerful cam extraction, and a large claw like this will extract cases that stick very tightly in the chamber without danger of the claw cutting through the extraction rim of the case. Next to **G** this is the most powerful and positive of all extractors. However, the extractor claw shown in **B** is probably heavy and wide enough to be quite positive in action with the lighter extraction pull that is applied with lever and slide action rifles, which rifles also are more freely chambered to assure easier extraction.

rapidity and efficiency of fire fell almost to zero. This is one of the ways in which a good semi-automatic breech action excels all other types. The soldier practically never experiences any extraction difficulties, and is not exhausted by his efforts to function his rifle.

The .280 Ross straight pull rifle was manufactured for a comparatively few years, and during that period the anneal of the cartridge case was apparently never brought to a satisfactory state.

The cartridge cases would stick very tightly in the chamber, and the mechanism lacked power to extract them. With the three rifles of this model with which the writer became thoroughly familiar, it was frequently necessary to place the butt of the rifle on the ground and stamp on the bolt handle with the heel of the shoe to open it, even though the rifle had not been fired often enough to overheat it. Considerable trouble was also experienced with primary extraction in the .303 Ross straight pull rifle with which Canadian troops were first armed in World War I. To correct this, the chambers of many of these rifles were enlarged by running an oversized reamer in. This particular straight pull action simply did not have sufficient power to insert or extract in the presence of dirt, sand, or when firing rapidly for prolonged periods, and for this reason, and also because it was found desirable to have all troops of the British Commonwealth armed with the same rifle for reasons of supply and maintenance, the Ross rifle was abandoned. Similar difficulties would surely occur with any of our existing lever or pump actions, except perhaps pump action shotguns, were they used for military purposes.

Let us examine rifle breech actions with respect to their method of employing force to insert and extract cartridges. The lever actions employ a lever of the first class in which the fulcrum is placed at the bottom of the receiver between the acting (finger lever) and resisting (head of breech block) forces. If the end of the effort arm of this class of lever be placed at the same distance from the fulcrum as the end of the resisting arm, then any pressure or force on the effort end of the lever will result in an equal pressure transmitted to the resisting arm. As the length of the effort arm is increased with respect to the resisting arm, the force transmitted to the effort arm is increased in proportion. In existing lever actions the effort arm is never more than twice as long as the resisting arm, therefore the force is never more than doubled. In other words a down or up pressure of 25 pounds on the finger lever is never translated to more than 50 pounds extraction or insertion pressure on the head of the breech block or cartridge.

Compare this with the Mauser type of bolt action in which the primary extraction and insertion is performed by two cam surfaces operating together, one on the rear of the bolt, and one at the rear of the receiver well. Here we have the mechanical principle of the inclined plane or wedge with power applied by means of a lever (the bolt handle). The force arm (bolt handle) is about two to two and a half inches long with the fulcrum extremely close to the resisting arm (the cams). With a wedge or cam, to find the force required to lift a certain weight, multiply the weight by the greatest thickness of the wedge and divide by its length. The thickness of the cam on the Mauser (Springfield) bolt and receiver, measured from front to rear in the direction of the force, is approximately .50 inch, and its length is approximately .25-inch. Therefore any force applied to the cam is approximately doubled in moving the bolt forward or back, disregarding friction. Force is applied to this cam by the bolt handle lever, with distance from fulcrum to cam of about .35-inch, and from fulcrum to bolt knob about 2 inches. Pressure on the bolt handle knob will thus be increased about six times on the cam, where it is doubled. Thus, disregarding friction, 25 pounds pressure applied on the bolt knob will be translated to about 300 pounds on the head of the bolt or case.

Very roughly speaking, therefore, with a given force applied, the Mauser bolt will multiply it about twelve times and the lever action will about double it. If, however, we include friction, which is greater with a bolt than with a lever action, we still have the bolt action at least five or six times as powerful as the lever action in its insertion and extraction.

This must not be taken, however, as condemning lever and pump actions except for military purposes. These are purely sporting actions, and difficulties from dirt, defective cartridges, and heat will practically never occur. Reasonable care will eliminate rusting of the chamber. In practice the only difficulties that are liable to occur are from cartridge cases of very soft anneal or from oversized cartridges. In his study of many years the writer can remember two instances where sportsmen have stated that it would be well to operate all cartridges to be used on a hunting trip through the action, as they once found a cartridge which could not be so operated. In both cases the writers were discussing their lever action rifles. The fact that upwards of four million lever action rifles have been sold for sporting purposes in the United States, and that probably one million are still in yearly use, is clearly indicative of their entire suitability for sporting purposes.

When force is applied to extract a fired case or loaded cartridge, that force is transmitted from the head of the bolt or block to the rim of the case by means of the extractor hook. This hook, biting on the rim of the case, is approximately 1/16-inch wide in .22 caliber rim fire rifles, about 1/8-inch wide in center fire rifles of older design, but embraces about one-fourth of the circumference of the rim of the case in the Mauser type of action. See Figure 26. If too much force is applied to a narrow extractor claw on a case that sticks obstinately in the chamber, the claw may break off, or it may drag or cut through the rim of the brass case. However the narrow claws of .22 rim fire, and older center fire actions probably have ample strength and width for any force which may be applied by the mechanics of the particular action. With the Mauser type so much greater force can be applied that the broader extractor hook is clearly indicated.

So far we have concerned ourselves only with the primary extraction. After the cartridge or fired case has been primarily extracted about one-fourth inch it is practically free in the chamber, and it is only necessary to withdraw it sufficiently so that the bullet end of the cartridge or the mouth of the fired case clears the front end of the receiver opening, and then eject it from the receiver. How this is accomplished is readily seen by examining any successful breech action.

In what direction shall the fired case be ejected from the receiver? It is generally conceded that it should not be ejected straight up, for then it might fall down upon the shooter, or even fall back into the action. Most actions which have the breech opening on top of the receiver, such as the Winchester lever actions, eject up and to the right which is very satisfactory except that it precludes the use of a normally constructed telescope sight. It is also conceded that a rifle should not eject directly to the right, or to the right and slightly backward, because ejected cases might strike a soldier occupying a position on the firing line to the shooter's right, or with a left handed shooter the ejection would be in the shooter's face. To the right and forward is probably the best direction.

This is probably a good place to discuss interchangeability of parts. When any article composed of a number of metal parts is produced in very large quantities this is very necessary from the standpoints of economy of manufacture and repair. With military arms it becomes absolutely essential by reason of maintenance in field operations. Most small arms rendered unserviceable in military operations become so only by reason of breakage of one or two parts. If those parts can be replaced in the theatre of operations in a simple manner the arm can be returned to service immediately, and the great expense of replacing the entire arm, or of returning it to an arsenal at home is avoided. Orders for the manufacture of military arms therefore include also the manufacture of a vast number of component parts in order that all supply depots and repair shops may have a supply on hand.

With high power rifles it is not possible to construct barrels, receivers, and bolts with strict and perfect interchangeability. These three parts must be assembled at supply depots where facilities for correctly headspacing the assembly are available. So too in the case of commercial arms when changes of barrel, bolt, or receiver are necessary the weapon must be sent to the manufacturer, or at least to a gunmaker having headspace gages.

Interchangeability of parts of arms involves intricate gaging and inspection of every part, and a system of modern production which only a large and modern factory is able to undertake.

3. Indentation of Primers. Proper indentation of the rim of a rim fire cartridge, or of the primer of a center fire cartridge by the firing pin must be assured for sure fire, for freedom from accidents, and for accuracy. The weight, energy, and direction of the blow, and the area indented must be such that the priming mixture within the case or primer is crushed in such manner as to insure a normal explosion.

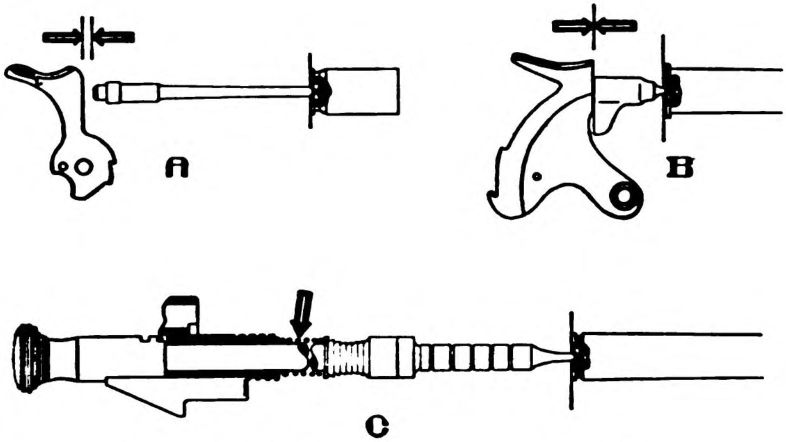

FIGURE 27. INERTIA AND SUPPORTED FIRING PINS

A—Illustrating the "inertia" firing pin method; the Model 1911 Colt Automatic, which is unsupported as it hits the primer.

B—Firing pin of the Winchester Single Shot rifle, which is supported by the hammer when it strikes.

C—The bolt action setup; the Model 1903 Springfield rifle, where firing pin is supported by the mainspring.

Primers, including primed rim-fire cases, are constructed within certain well defined limits of functioning.

A. They must not fire when struck by a firing pin falling with a definite minimum weight or energy. That is, they must not be so over-sensitive as to be dangerous to handle.

B. With a certain weight or energy of firing pin blow they must explode one hundred percent.

C. With a certain weight or energy of firing pin blow the rim of the rim-fire case, or the center fire primer cup must not puncture.

The mainspring or hammer, and the firing pin of the breech action of a small arm must be constructed so that they operate within the limits B-C above. But this is not quite all. Within these limits B-C will be found a still narrower limit in which more perfect ignition, insuring better accuracy will occur. This limit may differ slightly with primers of different makes and with different kinds of powder. If we take a rifle with a certain firing mechanism set to limit B and then gradually increase the weight or energy of blow while testing for accuracy on a machine rest we may find that

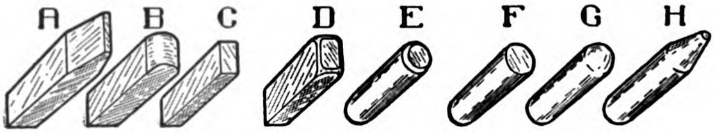

FIGURE 28. FIRING PIN POINTS

D and **E** show the best forms of point. Note the flat surfaces with very slightly bevelled edges. They crush the primer pellet over a wide area, and the bevelled edge prevents any cutting or shearing of the metal of the primer cup or the rim fire case.

B and **G** do not crush enough of the primer pellet and sometimes tend to give miss-fires. **C** and **F** often shear the sides of the indentation like a punch and give punctured primers. **A** and **H** are particularly bad in this respect. **H** is too much like a nail point and will give many punctures.

as the energy of blow is increased accuracy increases up to a certain point, and then decreases. Or it may increase up to the point C. For each design of firing mechanism the best average energy should be determined in this manner. Variations are made by varying the strength of the mainspring. A quick and light firing pin with short travel will require a stronger mainspring than one with longer travel or more weight.

Indeed there is a great deal more to the manufacturers' caution "Use our ammunition in our rifles" than the mere salesmanship of the sentence would indicate. A manufacturer who makes both arms and ammunition can be relied on to so adjust the firing mechanism of his guns so that they will give the very best possible ignition with the primers he places in his cartridges, and in other respects also, such as fit, his ammunition is likely to be most ideal for his arms.

The best shape of extreme point of the firing pin is slightly flattened, but with rounded edges on a radius so that it will crush the priming mixture over a considerable area, and yet not act as a punch to shear or pierce the primer as a flat pointed pin would do if it had sharp edges. See Figure 28. Many firing pins have hemispherical points, and this is the next best shape. Particularly the point should never be sharp.

The diameter of the firing pin or striker point for those rifles that use cartridges loaded with the large size primers (.211 inch) should be about .085 inch, while for those that use the small primers (.75 inch) it should be about .060 inch in diameter.

Firing pin *protrusion,* that is the distance that the firing pin projects out beyond the face of the breech block or bolt should be from .05 inch to .075 inch, tending towards the larger amount for large primers and the smaller dimension for small primers, but this differs slightly with different arms, and according to the tolerances allowable in the arm and cartridge. If the protrusion be too small misfires will occur, while if it be too large it is liable to puncture primers. In fact, with large primers a protrusion of over .080 inch usually tends towards pierced primers.

The firing pin hole in the face of the bolt or block should be a close but free fit for the pin, but there should be no danger whatever of the pin sticking in the hole. If it is too large the primer cup may extrude into the hole, between the hole and the firing pin,

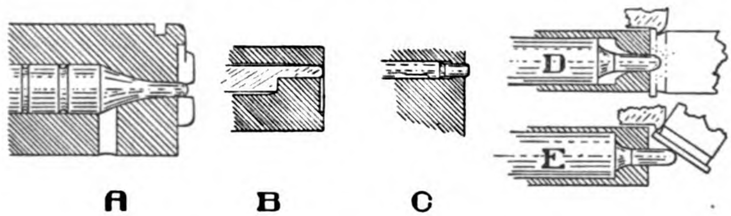

FIGURE 29. FIRING PIN PROTRUSION

A very small and very important detail on most firearms is the methods by which the protrusion of the firing pin is adjusted and controlled. This is most important in the case of the larger center fire cartridges, where excessive protrusion could cause the firing pin to pierce the primer and let gas back into the action. It is generally controlled by the shape of the shoulder of the striker, in back of the firing pin, as shown by **A**—the Model 1903 Springfield, where protrusion is closely adjusted and the firing pin face carefully polished into a smooth ball-shaped point—the *only* kind of a point used for center fire cartridges.

With the smaller rim-fire cartridges, protrusion is equally important; the firing pin "reach" must be controlled so that it will not strike or batter down the "anvil" formed by the breech face of the barrel and thus cause faulty ignition. **B** and **C** show the methods by which this is generally attained; in **B** protrusion is controlled by a shoulder on the firing pin and in **C** by a slotted arrangement with a retaining pin through breechblock.

D and **E** show a trick arrangement where the firing pin serves the dual purpose of firing the loaded cartridge and also acting as an ejector to expel the fired case. **D** illustrates such action in an Ortgies .32 automatic pistol at instant of firing, here protrusion is "controlled" by the action of the primer taking up the impact, which is possible in the case of such low-pressure cartridges. **E** illustrates same firing pin action as it ejects the fired case at the end of the recoil.

when the pressure is high, and cause trouble. Heavy grease should never be used on the firing pin or any of the ignition parts. It is usually best to just wipe off these parts with a slightly oiled rag or chamois. In very cold weather they should be wiped free of all oil.

Old breech actions made in the black powder period usually have very large firing pins with very rounded points, and the firing pin hole also is quite large, larger than it should be even for the large

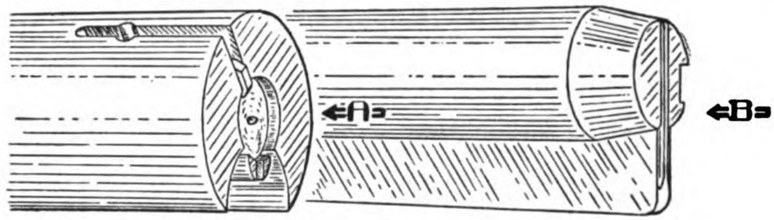

FIGURE 30. FIXED FIRING PINS

With the use of fully automatic firearms increasing, we find a new feature being introduced—the fixed firing pin, designed for guns which fire on an open bolt. The firing pin is an integral part of the bolt itself, arranged to seat and fire the cartridge as soon as it positions in the chamber.

A—Bolt with fixed firing pin for a central fire cartridge such as the .45 Colt or 9 mm Luger.

B—Bolt and fixed firing pin from a Marlin Model 50 .22 caliber rifle, a not-any-too-popular model placed on the market a few years back.

firing pin. If such an old action is used to build a rifle for a modern smokeless cartridge the firing pin should be made smaller, its point should be reshaped, and the face of the bolt or block should be bushed with a hole that is the proper fit for the altered pin. This is particularly necessary when Winchester, Sharps, or Remington-Hepburn single shot actions are used for such cartridges as the .22-3000 Donaldson 2R.

With rifles using rimless cartridges it is possible that the head-space of the rifle may be so large, or the corresponding dimension of the cartridge case so small, that the head of the case enters so deeply into the chamber that a firing pin with normal protrusion may not strike the primer a hard enough blow to fire it. Or, if the head of the cartridge sets back far enough the force of the firing pin may be expended in driving the cartridge deeper into the too long chamber, and again the primer will not be indented deep enough for sure fire. The depth of the indentation in the primer is a good indication of the action of the firing pin, but if the breech pressure be heavy the indentation may be set back with the pressure, and it may appear that the firing pin has not struck a hard enough blow, or that its protrusion has not been sufficient. Therefore when making a test with primers to see if the indentation is the proper depth it is best to use primed cases without any load in them.

4. **Trigger Pull.** The first basic principle of marksmanship is that unless the shooter has been trained to squeeze the trigger of his weapon properly accurate shooting will not result. Also unless the character and weight of the trigger pull be within certain limits the marksman cannot be easily taught to squeeze the trigger properly. The character and weight of the pull should therefore fall within these limits.

The limit as to weight may be said to fall between three and six pounds. That is, with the barrel of the weapon held vertically, and the weapon cocked, and weight applied to the trigger, the firing pin should not fall on an applied weight of 2 pounds 15 ounces, and should not fail to fall on an applied weight of 5 pounds 15 ounces. Most marksmen consider that the ideal weight is about 3 pounds 4 ounces. Most rifle coaches of very long experience would consider any weight between three and five pounds as entirely satisfactory.

Two types of trigger pull are seen on our best American breech actions. With the slackless trigger the trigger does not move until sufficient weight has been applied to release the sear or firing pin. This type is seen on most single shot, lever, and pump action rifles, shotguns and revolvers. In the trigger with slack, upon the application of about 1½ to 2¼ pounds pressure the trigger moves to the rear about ⅛ to ⅜ inch, during which movement the contact between the sear and firing pin is reduced. After this slack has been taken up by carefully applied pressure with the marksman's finger, the trigger comes to a decided stop and has no further movement until a total pressure to release sear contact with the firing pin has been applied. This type of trigger is usually seen on bolt action and semi-automatic arms, although very recently inventions of slackless triggers for bolt actions have appeared. The slackless trigger is to be preferred, although any man can be trained to a high degree of marksmanship with either type.

With either type of trigger the weight of pull should not vary, and the final release should be sharp without any drag or creep, like the breaking of a thin glass rod. Any drag or creep whatever in the final pull is very objectionable, in fact more so than under or over weight. Total elimination of creep or drag is more difficult to accomplish than adherence to weight, and in manufacture the adjustment of the trigger and elimination of creep often has to be a hand operation.

With bolt action and automatic weapons, where the mechanism is operated hard and fast, and where there must be sufficient clearance between parts to insure satisfactory operation in the presence of a certain amount of sand or dirt, a sufficiently fine and closely limited contact between sear and firing pin that will allow the use of a slackless trigger without creep has not been possible until recently with the perfection of the trigger mechanism seen on the Winchester Model 70 rifle mechanism. Ordinarily the sear must stand high with considerable contact with the firing pin shoulder so that there is no danger of the firing pin over-riding the sear nose as the bolt is closed fast and hard. Taking up of the slack in the trigger reduces this contact to the point where the finally applied pressure will give a clean, snappy release.

Sometimes an effort is made to turn a trigger with slack into a slackless trigger by reducing the amount of slack, that is the amount of contact between sear and firing pin shoulder when the arm is cocked. This cannot be done completely (except with some such mechanism as seen on the Winchester Model 70 rifle) without some of the slack remaining to take the form of a most unsatisfactory and disconcerting creep or drag—a trigger pull that no good marksman could use satisfactorily.

This matter of perfection of trigger pull is most important. There is no question but that a breech mechanism must have a perfect trigger pull within the above limits if the United States is to retain its superiority in marksmanship. A well informed rifle, shotgun, or pistol shooter will not countenance a poor pull. He simply says "To Hell with such a gun" and throws the weapon back on the manufacturer. There is no reason why any breech action cannot be produced with an entirely satisfactory trigger pull as described above. But there is a tendency among certain manufacturers of sporting arms to disregard the niceties of trigger adjustment because ninety percent of their customers are sportsmen entirely untrained in marksmanship and unable to appreciate the necessity for a good pull.

In the case of the .22 caliber rim fire bolt action a slackless trigger mechanism can be satisfactorily accomplished in a simple manner as there is no appreciable recoil, the action is not operated fast or hard, nor is clearance between parts to operate in sand or dust essential. A shotgun should always have a slackless trigger as in wing shooting there is no time to take up a slack.

Some marksmen prefer a trigger without backlash—that is one that stops positively as soon as the sear has been released, and has no further backward movement. This has been accomplished in the case of the trigger on the Remington Model 37 bolt action match rifle, and with several trigger mechanisms of private manufacture. Some marksmen may derive considerable benefit from such a trigger, but it is not believed to be essential as evidenced with the very large number of perfect scores being turned in continually with the Winchester Model 52 match rifle, the trigger of which does have backlash.

It is considered that a trigger with a pull under three pounds is unsafe. With a lighter trigger even a highly trained marksman may have a premature discharge in firing rapidly, and a cocked rifle with lighter pull might be discharged by a fall or rough handling. Riflemen indulging in certain forms of target and varmint shooting sometimes prefer a set trigger. Such a trigger ordinarily performs in the usual manner, but when "set" the weight of pull is greatly reduced, even to an ounce or a mere touch. It is not used in rapid firing, and should not be set until the shooter is all ready to fire, so that the danger of discharge from a fall is reduced. With a double set mechanism there are two triggers. Ordinarily the front trigger operates the same as a regular trigger, but if the rear trigger be pulled back hard the front trigger is thereby "set" and the pull reduced to a very light one. A screw, usually appearing in the trigger guard between the two triggers, serves to regulate the weight of the pull. By screwing this screw in a pull may be secured that will cause discharge when merely touching the front trigger lightly. With another form of double set trigger the rear trigger is pushed forward to set the front trigger. With a single set trigger there is but one trigger, and it is set by pushing it forward.

The set trigger to some extent precludes the necessity for careful training in trigger squeeze, and the trigger can be pressed with minimum disturbance of the rifle so as to assure very fine shooting. On the other hand the user must be extremely careful to avoid premature discharges and accidents, and everyone acknowledges that it is an impossible trigger for rapid firing. In America such a trigger is now placed on a rifle or single shot pistol only to special order, and is usually custom built.

Lock time is the interval of time which elapses from the instant when the final pressure to release the trigger has been completed until the priming mixture has been crushed and explodes. It includes the time for the trigger and sear movement to release the firing pin, and for the latter to fly forward and indent the primer. Practically it depends upon the length of firing pin travel and strength of mainspring.

While the old fashioned hammer rifles and shotguns probably have a longer lock time than any others, for the purpose of this discussion the Springfield Model 1903 rifle action may be taken as one having a rather long lock time. The firing pin travel is rather long, and the lock time has been measured as being approximately .0057 second. The lock mechanism of the Winchester Model 52 rifle with its very short firing pin travel may also be regarded as a good example of short lock time, its time being approximately .0022 second. Recent study of expert rifle marksmanship has shown that for the finest results the lock time should be as short as possible, for with a slow lock a slight movement of the weapon can take place between the time the trigger was pressed (when presumably the aim was correct) and the instant the primer explodes. This time is more important in offhand shooting, and in shooting at moving targets, when rifle and target are more or less in motion while the trigger is being pressed and the lock is operating, than in rest shooting and shooting from the rifleman's standard prone position when the rifle is held approximately steady and the target does not move. But in most weapons of modern design effort has been made to reduce lock time. However, the firing pin travel should not be shortened or the mainspring strength altered to such extent as would decrease proper ignition as described above. When an amateur attempts to shorten lock time he frequently injures ignition to such an extent that accuracy is seriously impaired. A trigger mechanism should always be tested from machine rest, together with variations in weight of blow, movement of parts, and strength of mainspring to assure that decrease in time is not had at the expense of accuracy. Modern hammerless shotguns usually have a very satisfactorily short lock time.

5. **Easy and Fast Operation.** This has been one of the chief aims in all breech action design since metallic cartridges were invented. In America first the lever action repeater superseded the single shot, and the revolver superseded the single shot pistol. Then came the pump or slide action, which while it did not supplant the lever action, was faster in its operation. Now the semi-automatic action, the fastest of all, is rapidly supplanting all former types, although it will probably not do so completely—that is until game shooting and expert target shooting are sports of the past. In America the bolt action has been an intruder in this list. It is slower in operation even than the lever action, although not more difficult to function if properly adjusted. Its popularity as a sporting arm has been due to its accuracy and its adaptability to cartridges of higher power and flatter trajectory than other types. Its superiority for military purposes has already been discussed.

In the hands of a skilled operator the lever action can be fired unbelievably fast. In recent years its rapidity has been slightly increased by the adoption of modern stocks which make for less disturbance of the rifle in recoil, by the adoption of a pistol grip, and by slightly shortening the lever throw. The pump action is even faster than the lever, the fastest of all manually operated actions. Its rapidity has also been increased by modernization of stocks and by larger and longer sliding forearms. As a matter of fact both ac-

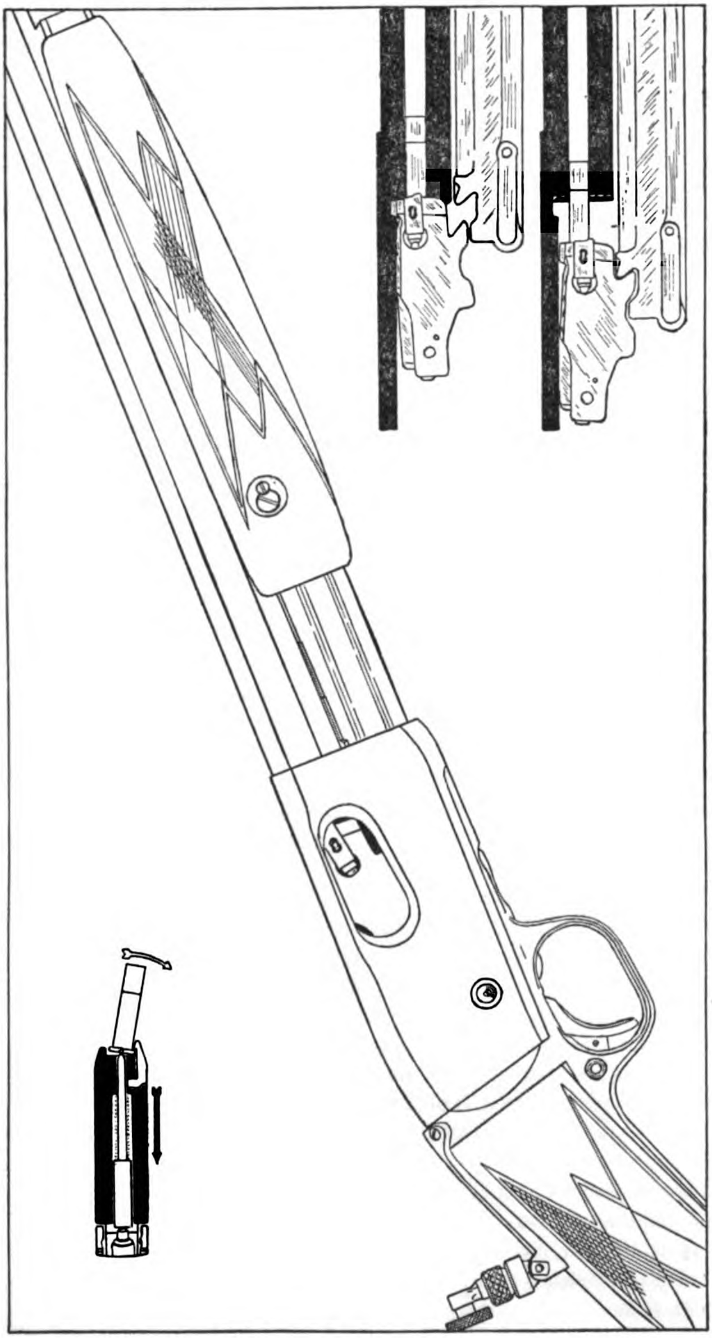

FIGURE 31. THE REMINGTON MODEL 12 RIFLE

A very popular and long-lived .22 slide action repeating rifle. Its action locks by a single lug placed close to the head of the cartridge, as shown. Its odd method of ejection "off the firing pin" is also illustrated in detail.

tions can be operated faster than the shooter can recover his equilibrium after recoil, and properly aim and squeeze succeeding shots. It is debatable, however, whether either of these actions is faster than a good bolt action when firing in the prone position, which position is not well adapted to the lever or pump, and does favor the bolt action rifle properly equipped with a shooting gunsling.

The magazine being filled with five cartridges, and an additional one loaded into the chamber, a skilled marksman has frequently fired six shots in twelve seconds and scored six hits on a man sized prone silhouette at 200 yards with the bolt action rifle;—experience of the Army Infantry Rifle Teams, 1903 to 1906. In recent years the fast operation of Mauser type actions has been facilitated by placing a rib on the bolt which prevents its being twisted slightly sideways when moving back and forth, and partly jamming in the well of the receiver, and also by properly locating the bolt handle. For quick operation the bolt handle should be on a plane with the trigger, and should be bent down as seen on the Springfield and Winchester Model 70 actions. The Mannlicher-Schoenauer bolt action, with its flat bolt handle located far forward is a very slow action to operate.

Certain types of bolt actions, notably the Lee-Enfield, the Enfield Model 1914, and the U.S. Model 1917 (the latter termed the "Enfield") are so arranged that the mainspring is compressed when the bolt is pushed forward, instead of being compressed by the first upturn of the bolt handle as in actions of the Mauser 1898 design. In operating these actions it is thus necessary to exert some force when pressing the bolt forward, while less force is exerted when first lifting the bolt handle to open the bolt. On the other hand, with the Mauser Model 1898 type the greater effort occurs when the bolt is first lifted, and much less effort is required to push the bolt forward after it has been completely opened.

British writers have contended that the first method, that of compressing the mainspring on the forward movement of the bolt, results in a mechanism that can be operated faster and easier to the extent of the full magazine of cartridges, than with actions constructed to compress the mainspring by the first upturn of the bolt handle. They have contended that the Lee-Enfield is the fastest and easiest to operate of all bolt action rifles. This statement has indeed been copied into American textbooks by writers who were not riflemen.

This contention is certainly not subscribed to by any experienced American riflemen who have had experience with both types of actions. It is their contention that when both types are properly adjusted, the one which compressed the mainspring with the upturn of the bolt handle is always slightly faster than the other because it requires less effort and in operation there is no tendency to move the butt plate of the rifle slightly away from the shoulder. Furthermore, any of our older military riflemen who have had extended experience in rapid fire shooting from the period 1902-1903 to date feel positively that the fastest and easiest of all bolt action rifles to operate is the U.S. Magazine Rifle, Caliber .30, Model 1898, otherwise known as the Krag Jorgensen.

Rapidity and ease of operation also depends on good lubrication of all working parts, and on the polish of the parts. If one will take the trouble of dismounting the lock of a very high grade British shotgun he will be amazed with the fine polish of the parts. Each shines like a mirror. If the parts of American lever, pump, and bolt actions were similarly polished operation would be very much easier and faster, but of course this would considerably increase the cost of production. The writer has done this with several Springfield bolt actions with very marked improvement in ease of operation. But it must not be done to such an extent that the proper clearances and dimensions for safety are thereby destroyed.

In the matter of rapidity of fire we must also consider how quickly a first shot can be delivered, starting with the weapon loaded and locked. If we assume that all types have equally excellent stocks, sights, and trigger pulls, this resolves itself into how easily and rapidly the safety lock can be thrown off.

It is debatable whether the shotgun safety on top of the upper tang, or a hammer as seen on Winchester Models 1886 and 1894 lever action rifles is the fastest. With familiarity with either the safety can be pushed forward or the hammer brought to full cock sub-consciously while the weapon is being thrown to the shoulder and no time consumed.

Then in the order of rapidity would probably come the safety in front of the trigger guard on the Garand rifle, the trigger guard safety on hammerless pump action arms, the pull-back and push forward safety at the finger lever of the Savage Model 1899 rifle, the safeties on the upper right of the receivers of some bolt action arms, the safety on top of the bolt sleeve of the Winchester Model 70 rifles, and lastly and slowest of all, the completely turn-over safety on the rear of the bolt of the earlier Mauser type rifles. In hand arms a revolver can be cocked and fired, even without using the double action, faster than can the safety be functioned on an automatic pistol.

Quite as important is that the safety shall be easily adaptable to operation without making any noise whatever, so that the weapon can be made ready instantly without disturbing either game or an enemy, and without making them aware of one's presence. A shooter learns to do this with all hammer guns by holding back on the trigger with the forefinger while he brings the hammer to full cock with his thumb, and then carefully releasing the pressure on the trigger. But with some safeties it is impossible to move them on and off without an audible "click." Such a clicking safety absolutely disqualifies an arm for either hunting or warfare.

6. Design Adaptable to Modern Marksmanship Methods. Prince Hohenlohe in his "Letters on Artillery," the "Bible" of artillery officers of forty years ago, stated that the first duty of the Artillery was to hit, and the second duty was to Hit, and the third duty was to HIT! The same may be said of the user of a small arm. American marksmen have attained a very enviable reputation as to hitting. They are the best shots in the world. But they can hit reliably only with a weapon of such design that it lends itself to shooting in the particular manner which these marksmen have found to be the only manner in which anyone can shoot surpassingly well. A small arms breech action should be so designed that it will lend itself to incorporation into a complete assembly of arm which will be suitable for this manner of shooting.

For example—To aim a shoulder arm accurately and steadily in all firing positions the shooter's face must be laid down in a natural and relaxed manner so that the cheek rests firmly on the left side of the comb of the stock. When the head and cheek are so rested the right eye is then held steady with respect to the weapon, as though it was a part thereof. The dimensions and shapes of parts, stock, receiver, and sights—must then be such that the pupil of the eye comes naturally and without effort into the line of aim through the sights. If a receiver were so designed that its high rear portion extended way back over what is called the "small of the stock" the head would have to be held way back in an uncomfortable, constrained, and unsteady position to prevent the recoil driving that portion of the receiver back into the eye, and accurate shooting would be an impossibility. Many semi-automatic weapons have been designed with just such a receiver, but of course in America they have not even got to first base.

It is well known that, other things being equal, the heavier the barrel of a rifle the more accurately will it shoot. A very light barrel, that is, light with respect to the power of the cartridge it shoots, is notorious for inconsistent shooting. The breech action design must be such as will permit the use of a barrel heavy enough for good accuracy.

Rear sights for modern rifles are of the peep variety and must be located within three or four inches of the eye when the rifle is in normal firing positions. The breech action must lend itself to proper location of suitable sights of this type.

The advantages of the telescope sight are such that many, almost a majority of sporting and target rifles will be equipped with such a sight in the future. A telescope sight of normal design must be located centrally over the top of the breech action and barrel, and it is desirable that it also be located as low down as possible, almost touching barrel and receiver. A modern breech action for a rifle should be designed with respect to receiver, loading, direction of ejection and safety lock so as to permit such location of a telescope sight.

For effective rapid fire the round bolt handle knob of a bolt action rifle should be located on the right side of the receiver, and to the rear in a plane even with the trigger. The handle should be turned down close to the side of the receiver or stock so that it is just possible to get the right fore-finger under it easily to raise it. If a fired case sticks in such an action the easiest and the quickest way to free it is to strike the bolt handle knob with the palm of the right hand. To permit striking a heavy blow without injuring the hand the knob should be round, not flat as seen on some rifles, particularly the Mannlicher-Schoenauer.

There are three types of shoulder arm stocks which in their outline, shape, and dimensions have proved to be very satisfactory for the American marksman and his method of shooting. The best examples of these are the hunting rifle stocks as seen on the Winchester Model 70 Standard Rifle, and the Winchester Model 71 Rifle; the prone target rifle stock or "Marksman" stock as seen on the Winchester Model 52 and 70 Target Rifles, and finally the shotgun stock as seen on most of the higher grades of American and English double barrelled shotguns. Shoulder arm breech actions should be such that they will permit of fitting these types of stocks which alone, generally speaking, lend themselves to the steadiest holding and quick catching of aim in the various normal firing positions, on both level and sloping ground. The stock on the U.S. Rifle, Caliber .30, M1 (Garand) should not be taken as an ideal military stock. It is a fair stock, but it had to be slightly modified from the ideal dimensions in order to utilize many millions of sawed walnut stock blanks already on hand when it was designed. It is a little too low at the comb and heel, and not quite long enough.

The best form of hand-gun grip is perhaps that used on the Hi-Standard Model D semi-automatic pistol. Many completely trained master hand-gun shooters prefer grips specially made to fit their hand exactly, but it is thought that a frame similar to the above Hi-Standard pistol will generally adapt itself to the form and shape of grip that the master pistol shot will usually design for himself.

Safety locks as at present made seem to offer a field for redesign to make them more convenient and easier and quicker in operation.

This is particularly true of bolt action rifle and automatic pistol safeties.

The desired weight of the completed arm should be taken into consideration in designing a new breech action. Our present thought is that the weight of the complete arm, but not including telescope sight, gunsling, or cartridges loaded into the arm should be approximately as follows:

For a very young boy's first rifle—4½ to 5 pounds.

For 10 to 14 years old boys and girls rifles and shotguns—about 6 pounds.

For upland and light waterfowl shotguns—6¼ to 7 pounds.

For heavy duck shotguns—7¾ to 8½ pounds.

For general hunting rifles—7¾ to 8½ pounds.

For Infantry rifles—9 to 9½ pounds.

For long range game rifles, varmint rifles, and sniper rifles—10½ to 11½ pounds.

For match rifles for highly competitive rifle shooting—11 to 13 pounds.

For hand guns for target and military use—35 to 40 ounces.

The balance of the arm should also be taken into consideration, although this is dependent rather upon barrel and stock than on breech action. However, a breech action may make the completed arm either too breech light or breech heavy.

Custom Built Rifle Actions

The building of a rifle action of special design for one's own use or for a customer is a very tedious and expensive undertaking because every part has to be machined separately from the steel. Only a very skilled machinist or a tool-maker can successfully undertake such a job even after the design has been laid down on the drawing board, and he must have access to a fully equipped machine shop including facilities for heat treatment. Similarly the manufacture of a few such actions for sale has to be undertaken in a similar manner and is too costly. Breech action manufacture commercially is really out of the question except in large quantities and in a modern factory. The fabrication of a single breech action by hand may run into months and cost thousands of dollars.

This is why shooters who wish to have special arms made for their own use have had to use existing breech actions which have been manufactured in quantity and can be had at moderate cost. To one of these they can then fit a special barrel, stock, and sights, and can even adapt the arm to a special cartridge for which the breech action is suitable. Thousands of such arms are being built in America annually, whereas the building of a breech action of special and new design is of rare occurrence. Of course before any

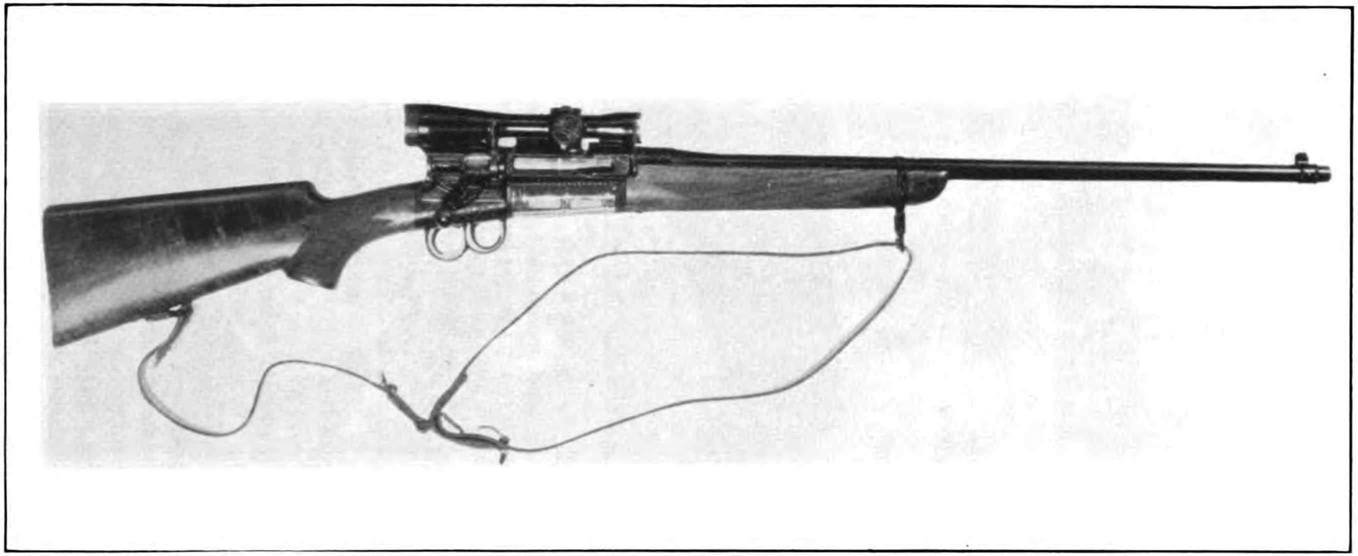

FIGURE 32. THE PACKARD 1938 RIFLE

The Ralph G. Packard 1938 rifle has a detachable revolving magazine somewhat like that of the Mannlicher-Schoenauer rifle, and loads and feeds only from the magazine. The front trigger is the magazine release. Bolt throw is very short—only the length of the cartridge. Receiver and scope tube were milled from a single block of steel. Rifle was designed entirely by Mr. Packard and built under his close supervision by two toolmakers in a small model shop in New York City. Heat treatment afterwards by the Remington Arms Company. This rifle, including the special optics by Dr. Kollmorgen, probably cost Mr. Packard upwards of $10,000. The writer has often shot this rifle, and it is an entirely practical and very efficient weapon. A fine wilderness hunting rifle, which was what Mr. Packard designed it for.

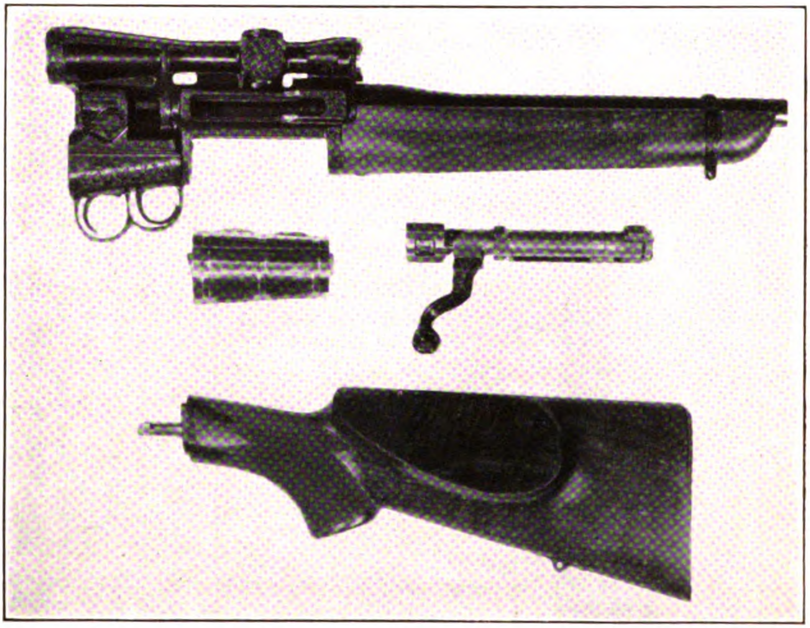

FIGURE 33. THE PACKARD 1938 RIFLE, TAKEN DOWN

The Packard rifle is entirely hand demountable without tools. The bolt handle acts as a spanner wrench to remove the butt-stock by loosening the stock bolt nut in the butt-plate. A number of extra magazines are provided, also extra optical assemblies which can be inserted and removed in optical adjustments by merely unscrewing the waterproof lens flanges at either end of the scope tube.

new breech action can be put into quantity production a "pilot model" has to be constructed and this is also a hand and tool-room job.

Some few breech actions of new and unique design have thus been made by hand from time to time, and have had considerable merit, but cost has prevented their ever getting beyond the "pilot" stage. Notably the writer can recall very fine rifle actions designed and built by Mr. A. O. Niedner and Mr. Conn V. Schmitt.

Perhaps the outstanding special rifle action made in America by an inventor for his own use is that designed by Mr. Ralph G. Packard. Mr. Packard has designed a number of very unique actions, the one referred to being completed in 1938. The two main objects that Mr. Packard endeavored to accomplish in this design were: First, to get a telescope sight in the best position for the eye, and for supporting the head on the stock, also the scope to be absolutely rigid with no chance of its ever getting out of adjustment, and of such rigid construction that it would stand ordinary usage on a hard hunting trip, that the whole outfit could be carried in a scabbard on horseback and require no more care than the ordinary old fashioned rifle with open sights. Second, to shorten the length of the bolt travel to not more than the length of the cartridge, and still retain the locking lugs at the forward end of the bolt.

Mr. Packard's action is illustrated in Figures 32 and 33. It is a bolt action for the .30-06 cartridge. The receiver and the telescope sight tube are milled from a solid piece of nickle steel. The revolving magazine is instantly detachable by pulling back the front trigger. Loading is exclusively from the magazine, and extra magazines are provided. The short 2½ power telescope sight has internal adjustments without backlash for both elevation and windage, with positive adjustments to half minutes, and the dials have dust and waterproof covers. The various optical elements are made easily removable from the tube. Every part of the rifle and scope, with the exception of the barrel and receiver, can be dismounted and assembled by hand without tools.

Under Mr. Packard's direction and close supervision this action was built in a small machine shop in New York City. The two toolmakers who did the work on it informed Mr. Packard on its completion that they had worked continuously on this and other firearm designs of his on and off for a total of nine years! Mr. Packard's wonderful collection of firearms, featuring chiefly the various types of ignition from the first hand cannon to modern weapons, and containing only very outstanding specimens, is now deposited with the Smithsonian Institution in Washington where it is available for study by inventors, designers, and collectors.

CHAPTER V

Semi-automatic Breech Actions

MODERN warfare demands a great volume of fire, particularly during the few seconds or minutes of the critical part of the fighting. In shoulder arms only the semi-automatic will give such volume with fair accuracy, and also this is the only type that will insure such volume when the weapon happens to be over-heated from much previous firing. This is therefore the preferred military action of the present war, and will almost certainly be the military action of the future. However, our present standard semi-automatics, the Garand rifle and the Winchester carbine, have proved so satisfactory in the present war, and such vast quantities of them have been manufactured, that the future designer will have to produce an action very decidedly superior to these to have it generally adopted for military service—a rather difficult task.

To train our youth up to a high degree of skill in semi-automatic marksmanship in an economical manner a similar training rifle, shooting the inexpensive .22 Long Rifle cartridge, will be desirable. Such a rifle should have the size, weight, dimensions, fit, feel, sights, and trigger of the service arm. No such rifle has yet been produced, and here there seems to be more chance for the designer.

Whether this type of action will ever become popular and widely used for the sport of hunting remains to be seen. There are certain elements of danger connected with its use by the average hunter, and it is thought that its use in hunting will be detrimental to game conservation, and for these two reasons the various States may legislate against its use for hunting. Also such a rifle has to be chambered rather freely to function positively, and it is likely that not all autoloaders can be made to give that very high degree of accuracy demanded by our mountain, plains, and varmint hunters.

The self loading shotgun, particularly the Remington-Browning type, is already a decided success, and the limiting of its shell capacity to three rounds, as required by Federal migratory bird legislation, has eliminated those objections to its use in hunting that pertain to the rifle.

The automatic pistol comes in another category. It is preferred over the revolver for military use chiefly because its parts are readily interchangeable and can be cleaned or replaced without the use of tools, thus making it a more serviceable weapon and one more easily repaired in the theatre of operations. Also the sport of pistol target shooting has increased by leaps and bounds in recent years and is now a very popular form of recreation. The courses of fire in pistol competitions have very fortunately followed the lines of the National Pistol Match which places equal emphasis on slow, timed, and rapid fire. Very intensive study of the finer points of hand gun marksmanship have shown that the uniformity of the grip of the hand on the weapon from shot to shot is most important from the standpoint of fine shooting—the kind of shooting that wins competitions. Since the revolver is a manually operated weapon, the grip of the hand is disturbed from shot to shot as it is manipulated, and in rapid and timed fire there is no time to resume the perfect grip between shots. With the automatic pistol the grip from shot to shot is not thus disturbed, and as a result our master pistol shooters using it have produced slightly higher scores than they have with the revolver. The more recent models of the Colt Woodsman and the Hi-Standard semi-automatic .22 caliber target pistols have proved highly satisfactory to our best shooters. It is thought that after the war there will be a decided demand for a similar pistol shooting a lead bullet, center-fire cartridge similar to the present .38 Smith & Wesson Special. It must be possible to reload the fired cases. Here is a chance for future designers.

But it is not alone for the designer that this work has been undertaken. Originally the writer started out to produce a book on small arms ballistics that would be understandable by and of practical use to the average shooter. He soon found that one could hardly be expected to understand ballistics unless he had some prior knowledge of the material with which he was working—that is design. And thus anyone who desires to gain a knowledge of ballistics as applied to semi-automatic weapons must have some knowledge of their design, manner of operation, and limitations.

The first outstandingly successful semi-automatic rifle action produced in America was the simple blow-back as seen in the Winchester Models of 1903, 1905, 1907, 1910 and 63. This type is decidedly limited in the breech pressure it will handle, and fairly straight cartridge cases are required. With a tubular magazine in the butt-stock it has been very successful with the .22 caliber rim fire cartridges, and for such ammunition this type will probably remain in demand for many years. It has become practically obsolete for center fire

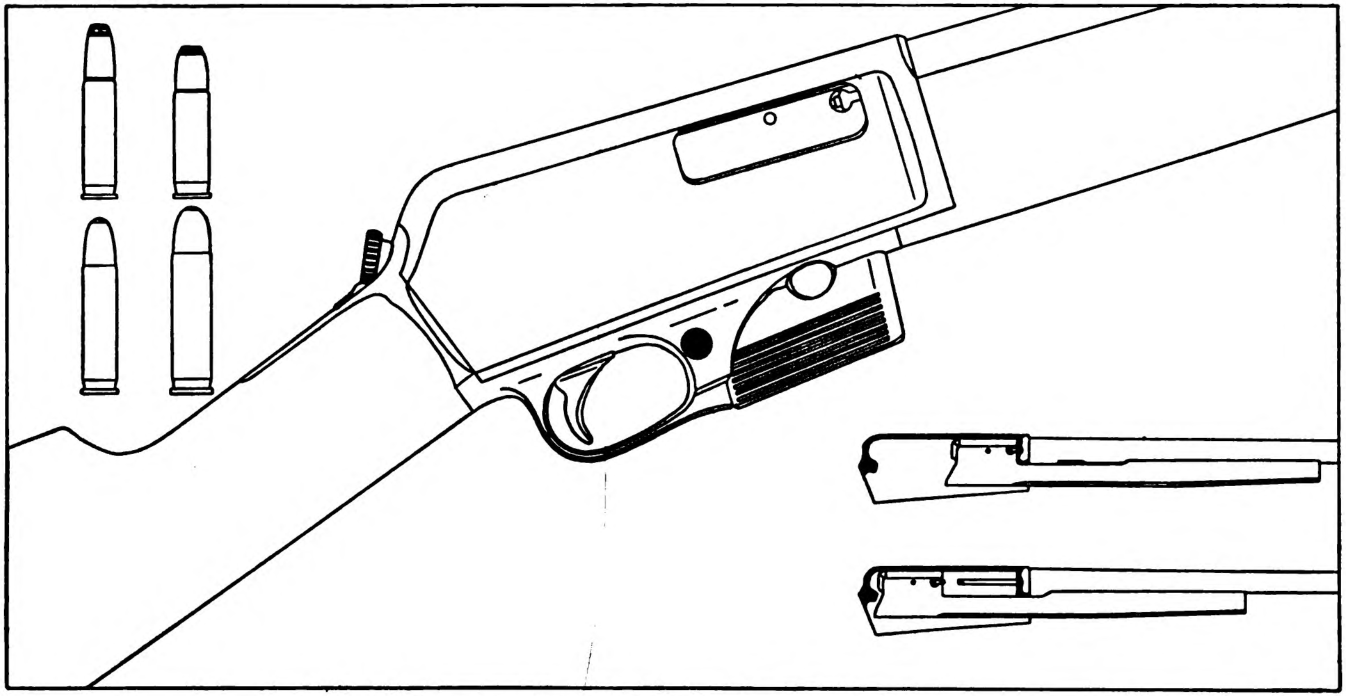

FIGURE 34. THE WINCHESTER AUTOLOADER RIFLE

The first outstandingly successful automatic rifle action produced in America was the above, furnished in practically the same general form but offered as the Models 1905, 1907 and 1910. It was a simple blow-back action which would only handle relatively low-powered ammunition. Details of action are shown and also the four different cartridges for which this rifle was chambered; the .32 W. S. L., the .35 W. S. L., the .351 W. S. L. and the .401 W. S. L.

cartridges because the limiting factors of permissible breech pressure and case design precluded the use of cartridges of modern high velocities.

The second outstanding semi-automatic action developed in America is the Browning recoil operated, as seen in the Browning and Remington automatic shotguns. It has been successful and popular for many years and, now that the patent has expired, it is being made by other manufacturers, perhaps because they have been unable to find another design which was quite so good. This action is so reliable for shotgun shells that it will probably remain in demand and manufacture for many years to come. It may be, however, that future designers may be able to produce a self loading shotgun action that is not so bulky and heavy.

While the design of a reliable and successful semi-automatic action for rim fire cartridges and shotgun shells was solved rather early in America, this was not true of a similar action to use high velocity, high pressure rifle cartridges. Here the problem proved much more difficult. When such cartridges are fired, the cases grip the chamber walls much tighter than do low pressure loads, and this tight gripping increases very materially as the barrel and chamber become heated from rapid firing. A very powerful primary extraction is required. The fired case has to be "torn" loose from the chamber with a powerful back motion of the bolt, combined with an effective and sure extractor hook. This violent rear motion of the breech bolt continues after primary extraction has been accomplished, and at the rear end of the bolt throw it must be cushioned or stopped by some form of buffer. The operation is thus quite violent. A semi-automatic action for high power cartridges is usually designed with the thought of possible military use, and other details become important such as operation in all positions and temperatures, and in the presence of dust, dirt, sand, and mud. Also the various parts should be interchangeable, dismountable by hand, and readily replaceable.

With the introduction of semi-automatic arms the Army has had to concede one thing to the inventor. They concede that the soldier will be fairly well instructed in the use, care, and maintenance of his weapon, and adequately supplied with proper cleaning and lubricating materials. In other words it is conceded that the user of such a weapon is operating a gas engine. He must understand it and care for it. If he does this fairly well the mechanism should prove reliable and dependable.

Until the development of the Garand rifle (U.S. Rifle, Caliber .30, M1) the United States had been unable to find any semi-automatic shoulder rifle suitable for its military service, although its Ordnance Department had thoroughly tested all promising inventions offered to it. Although the inventor, Mr. John C. Garand, was assisted by the extremely skilled personnel at Springfield Armory, where he was an ordnance engineer, it took him from 1918 to 1930 to develop and perfect his rifle, which is indicative of the difficulty of the problem. It was finally adapted as the standard Infantry rifle in 1939, and manufacture was started at Springfield Armory and by the Winchester Repeating Arms Company. It has now had three years of extensive use in war and has proved to be an entirely satisfactory weapon for its using services. It will probably remain the standard Infantry arm of the United States Army for many years to come.

The Garand is gas operated, the gas port being about an inch in rear of the muzzle, so that practically speaking the bullet has departed from the muzzle, during which time the breech is solidly locked, before the gas piston starts to operate. The bolt is symmetrically locked by two lugs at its front end, in basically the same manner as seen in the Mauser 1898 mechanism. The double column box magazine within the receiver is charged with a clip of eight rounds of .30-06 cartridges, the entire clip being inserted in one motion. Upon firing the eighth round the empty clip is ejected automatically, and the breech remains open for the insertion of a new clip. The mechanism is such as to provide a very excellent trigger pull, and the rifle is completely dismountable by hand and with the aid of a cartridge. An expert shot can fire from twenty-four to thirty-two well aimed and squeezed shots per minute.

About 1939 the design section of the Winchester Repeating Arms Company developed a semi-automatic rifle action based on an extremely short throw of gas piston. The extremely short but vigorous throw of the piston gives impetus to the operating rod which completes the unlocking and retraction of the bolt. Shortly thereafter the using services of the United States Army expressed a wish for a light, semi-automatic carbine which would weigh only about five pounds, would shoot a light and small caliber .30 cartridge with a 100 grain bullet at M.V. 2,000 f.s., effective to 300 yards. It was proposed to arm all men not equipped with the Infantry rifle (Garand) with this carbine, and to almost obsolete the pistol for military service. The type was selected by competition among many inventors, and the above Winchester gas cylinder design combined with a breech mechanism similar in design (although not in size) to that of the Garand proved to be the best, the military arm resulting becoming known as the U.S. Carbine, Caliber .30, M1. This weapon has now been manufactured in enormous quantities, and has met with universal approval.

Both the Garand and the original Winchester actions have been designed specifically for incorporation into an Infantry shoulder rifle of a total weight of not more than ten pounds which would lend itself perfectly to the type of rifle marksmanship which has been developed in the United States Army and Navy. That is the general type of rifle, the shape and dimensions of stock, the type of sights, the relationship of receiver to line of aim, and the location and pull of the trigger were more or less fixed, and the breech action had to be suitable for such a weapon. Efficacy of fire in our armed services demanded this, and it is believed that the decision was eminently correct. In the past fifteen years other very satisfactory automatic breech actions have been designed and produced, notably the B.A.R. M1918A2, the Fallschirmjaeger (Gewehr 42) and the Czechoslovakian (Z.B. and Bren), but these are more suitable for a machine rifle or a light machine gun than for an infantry shoulder rifle to be carried and used by the individual soldier. Several other good semi-automatic shoulder rifles have appeared, among them the Johnson, the Brno Semiautomatic Carbine, and the Gewehr 41W. There must also be mentioned the submachine gun which has found its best use in a light, short, straight blowback "tommy-gun."

The four outstanding automatic pistol actions that have been developed are the Colt Model 1911, the Walther HP (P-38), the German Luger, and the German Military Mauser. Another type of pistol action, at present adapted only to the .22 caliber rim fire cartridge, examples of which are the Colt Woodsman and the Hi-Standard, has been very successful, and will probably have a long life for civilian use.

The above, as the writer reviews all the breech actions known to him, are the really outstanding semi-automatics. The list does not include all good actions, but he thinks it does include all, or nearly all, that have been proved superior enough to have had an outstandingly long period or quantity of manufacture, or that would seem to have a continuing future life of usefulness.

We must now concern ourselves with what makes a semi-automatic action function, that is reload itself automatically without our having to operate a lever, bolt, or sliding forearm, or pull the trigger or cock the hammer of a revolver.

There are many types of automatic arms. First let us dispose of the machine gun or full automatic weapon. With such weapons, so long as the trigger is held back, the mechanism continues to load and fire the cartridges as long as any remain in the feed system, and the bullets leave the muzzle at a rate of from about 300 to 1800 per minute, depending upon the design of the mechanism. But such a mechanism, except as applied to "tommyguns," would be manifestly impractical for a small arm to be held by the average shooter at the shoulder or in the hand, which alone we are discussing here, because of the effect of recoil often and quickly repeated. If held in hand the muzzle would recoil upward at every shot, and the shooter could not recover from the recoil of one shot before another was fired. Thus with every shot the muzzle would rise more and more until the weapon was firing straight upward, and finally it would tear itself loose from the shooter's hands.

The only types of automatic mechanisms which we will discuss here are those known as the semi-automatic, auto-loading, or self-loading, where the mechanism automatically extracts and ejects the fired case, and loads another cartridge from the magazine into the chamber, making the weapon instantly ready to fire another cartridge practically as soon as the preceding cartridge has been discharged—but does not fire it. To fire, the trigger must be released, then pulled and squeezed for each and every shot. Repeated shots may be fired as fast as the trigger can be pulled, possibly five times a second, but here too recoil would have its effect, and in practice the shooter has to recover from the disturbing effect of recoil and regain his aim before he can again fire an effective shot. So the rapidity of effective fire is limited to about one round every two seconds, of course to the extent of the capacity of the magazine. The magazines of existing semi-automatic small arms usually contain from two to twenty rounds, depending on the design. For long sustained rapid fire the speed with which the magazine can be recharged is also of importance from the military viewpoint.

The power to operate an automatic breech action must obviously be self contained within the weapon, and comes from either the push of the recoil or the expansion of the powder gases.

Finally, before we proceed to consider the various types of self-loading mechanisms we must state one principle which applies with all automatic arms which use powder as the propellant. As we have seen with manually operated arms in the preceding chapter, the breech block or bolt must be tightly locked on the head of the cartridge before the weapon is fired. This manifestly does not apply with automatic weapons. Instead we must apply the principle: *The breech bolt or block must never open beyond a point determined by the mechanism design until the chamber pressure from the load just fired has dropped to a safe limit.* Otherwise powder gas would rush back into the mechanism or into the shooter's face with disastrous results.

The Blowback Action. The simplest form of automatic mechanism is known as the "blowback." It has a sliding breech block without any locking means, but of a rather heavy weight, and held against the head of the cartridge by a strong spring known as the *counter recoil spring.*

Consider for a moment the pressure in the barrel when the cartridge is fired. At the start, when the bullet has just left the case, or when it is about an inch or two up the bore, the pressure is at its peak or highest point. As the bullet passes up the barrel the space in the bore in which the gas can expand increases progressively, and the pressure likewise decreases, so that when the bullet is just about to leave the muzzle the pressure throughout the bore and in the now empty case, and pressing against the interior of the head of the case, is roughly only about one-fourth of the peak or maximum pressure. When the bullet leaves the muzzle the pressure drops rapidly to zero, but for a very brief interval some pressure remains in the chamber, and is enough to surely push the bolt back and eject the fired case. The ordnance designer calls this the *residual pressure.*

When a simple blowback weapon is fired the bullet moves first because it weighs so much less than the breech block. The sliding breech block also moves to the rear, but it starts and moves much more slowly because the inertia due to its weight and the pressure of the counter recoil spring has to be overcome. Thus by the time the bullet has reached the muzzle the breech block and the case in the chamber have moved to the rear only a short distance, in some guns perhaps 1/8 to 1/4 inch. During this small movement the high pressure within the case is pressing the mouth of the case, and the thinner portion of its forward walls against the walls of the chamber, and preventing the gas, while at high pressure, from coming past the case and out of the breech into the mechanism. Then the bullet leaves the muzzle, and the rearward momentum which the sliding breech block has acquired, plus the impetus of the residual pressure, continues to force the block to the rear, compressing the counter recoil spring, until the block comes to rest at the stop or buffer at the back end of the receiver. As the block thus moves to the rear it extracts and ejects the fired case. When the bolt is all the way to the rear it has uncovered the top cartridge in the magazine, and this cartridge then rises slightly from the pressure of the magazine spring until it is stopped by the lips of the magazine. Also while the block is moving to the rear it cocks the hammer if the weapon in question is hammer-fired. Now the strongly compressed counter recoil spring moves the block forward again, and as it moves forward its forward lower edge comes up against the head of the top cartridge in the magazine, held in just the right position by the magazine lips, and forces this cartridge forward, out of the magazine into the chamber. The action is now closed, the cartridge is in the chamber, and the hammer is cocked, and everything is ready to fire again as soon as the trigger is pressed. This type of mechanism is "timed" so that all these movements occur at the proper pressure times, and so that the block will move only slightly to the rear while the pressure remains high and the bullet remains in the bore, by regulating the weight of the breech block and the strength of the counter recoil spring although the last is relatively unimportant.

There are several limiting and important details with a simple blowback action such as this. The breech pressure of the cartridge should not be too high; in fact it should be relatively low for this type of mechanism. For example the .30-06 cartridge has a very high breech pressure, and to provide sufficient inertia and timing for its pressure it has been calculated that the breech block of the simple blowback would have to weigh about 27 pounds. The case, if loaded to high pressure, must be almost straight in its outside form, hardly tapered and not bottle necked, so it will continue to form a gas dam as it moves to the rear, although some bottle-necked pistol cartridges (notably the 7.65 mm Parabellum, the 7.63 mm Mauser, and the 6.5 mm Bergmann) have been successfully used in blowback weapons. With large cartridges the case must be short and tough and thick at the head to slide easily back through the chamber while the pressure is still high, and to withstand the high pressure while not entirely supported by the block and the rear of the chamber walls. So far as known the heaviest rifle cartridge that has been successfully used in such a mechanism is the .401 Winchester automatic cartridge, which is a short, stubby one with a straight case, and firing a 200 grain bullet at M.V. 2,140 f.s. As might be supposed this rifle has a chunky, breech-heavy feel because of the heavy weight of the breechblock, the weight being added in the form of a heavy bar of steel inside the forearm.

This mechanism has been particularly successful with the .22 Long Rifle rim fire lubricated cartridge, the pressure of which is relatively very low. The .22 case is not strong, but the lubrication prevents its sticking in the chamber. That is why only lubricated .22 cartridges are recommended for use in an automatic arm.

Simple blowback actions are timed by regulating the weight of the breech block and the strength of the counter recoil spring, and this must be done within rather close limits for the cartridge to be used. When regulated or timed for a certain cartridge, if a lighter loading of that cartridge be used, or a reduced load, the action may fail to eject the fired case, and the breech block may have to be retracted by hand. Too much pressure, on the other hand, may expand the case so it clings so tightly to the chamber walls that there is a failure to extract. Generally speaking, fast burning powders are better in blowback actions than slow burning or progressive powders.

The simple blowback has proved to be a very suitable system for the .22 Long Rifle cartridge. We have a number of very reliable self loading .22's with this type of action, and they seldom give any trouble when kept clean and used only with cartridges having lubricated bullets. Some of them can be used equally well with either regular or high speed cartridges, and others are timed only for the high speed cartridge. The latter will also usually function perfectly with the regular velocity cartridge except perhaps in very cold weather. When there is any trouble with these .22 automatics it is likely to be with the magazine feed, particularly with detachable box magazines. For the .22 rim fire cartridges only, the tubular magazine appears to function more reliably than a box or vertical column magazine.

One precaution should be exercised in using a .22 self-loading rifle. Do not fire it so fast or so continuously that the barrel gets very hot, for the barrel is then liable to lead and perhaps one or more bullets may eventually stick in the bore, which is almost certain to ruin the barrel. Also, cleaning a leaded bore is a difficult and tedious operation. So, treat the little .22 automatic as a rifle and not as a bullet squirter.

Examples of simple blowback arms are the early Winchester self-loading arms (see Figure 34), and the Colt Woodsman pistol (see Figure 35). In the former rifle note the heavy steel bar inside the forearm and under the breech of the barrel which is part of the breechblock and provides the weight to give the inertia necessary for correct timing.

With some designs of blowback mechanism the .22 rim fire cartridge, particularly the .22 Short cartridge, does not give sufficient pressure to surely function the mechanism. Particularly it has been found desirable from a commercial point of view to provide an auto-loading rifle that would function dependably either with the .22 Long Rifle cartridge or the .22 Short cartridge used interchangeably. Additional power is provided when the .22 Short cartridge is fired by incorporating a "power piston" in an ingenious manner in the chamber. Figure 36 shows this power piston in the Remington Model 550 Autoloading rifle, and graphically illustrates how it operates.

The Retarded Blowback Action. The above simple blowback is really a retarded blowback, retarded by inertia. However this term is usually reserved for those mechanisms where the breech bolt or block is retarded by mechanical means. The effect desired is the same in either case—that the breech must not open until the bullet has moved a sufficient distance: usually until it has left the muzzle. Examples of this are the .276 Pedersen rifle, the Thompson rifle and submachine gun and the H. & R. Reising.

The Pedersen employs a breechblock in the form of a toggle.

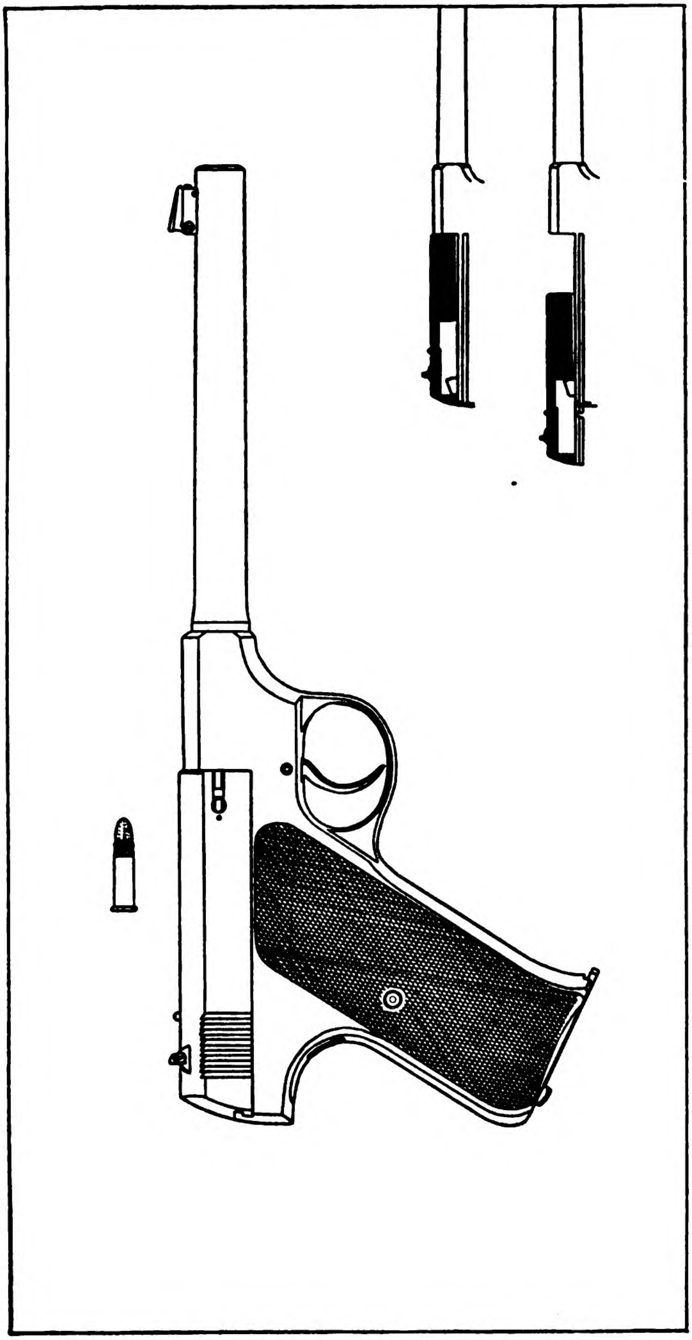

FIGURE 35. THE COLT "WOODSMAN" AUTOMATIC PISTOL

The most popular and satisfactory .22 caliber pistol on the American market at present. It fires the .22 long rifle cartridge and, in proper hands, is about as accurate and deadly a firearm as the average .22 sporting rifle. It is a straight blowback action, details of operation shown in small sketches.

When the two arms of the toggle are almost straight, and but very slightly off dead center, a very considerable pressure is required to start the arms to rise in the center, and thereby shorten the distance between the two ends. But as the center rises more and more it becomes easier for the two distant ends to be forced towards each other. The front end is the face of the breech block, and the rear end is the stop. Thus when the breech pressure is at its peak the toggle is offering much resistance, and its face is moving back very slowly, giving ample time for the bullet to leave the muzzle. Afterwards, the two arms having risen materially in the center to the easier operated position, the residual pressure and the momentum of the toggle arms complete the opening.

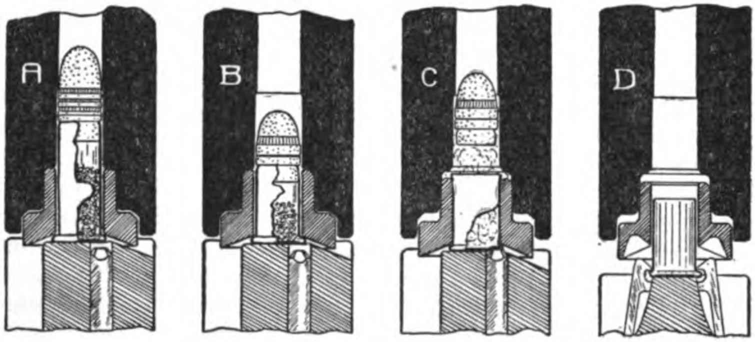

FIGURE 36. THE POWER PISTON

Illustrating the method of operation of the Remington Model 550 Autoloading .22 caliber rifle, a recent development in ballistic principle and operation. **A** shows seating of the .22 long rifle cartridge, where the aid of this "power piston" is not needed with either long or long rifle cartridges; therefore rifle chamber is so designed that either long or long rifle cases extend beyond the front of the piston, blocking off auxiliary gas pressure.

Sketch **B** shows the .22 short cartridge seated in chamber before firing. Note that the cartridge case extends only to the front end of the piston.

C—At the instant of firing of the .22 short cartridge, the gas pressure exerts its energy on front end of power piston as well as on head of cartridge case. This gas pressure acts upon a greater area, thus increasing energy, and operates the mechanism (Sketch **D**) which otherwise would function only with the .22 long or .22 long rifle cartridges. It is necessary to increase the operating energy of only the .22 short cartridge.

The rotary bolt of the Thompson .30-06 has locking lugs with surfaces ground on a slight slope like the threads of a screw. When high pressure is applied on the bolt face the lugs rotate or unscrew slowly, the timing being such that when the higher pressures have dropped the lugs will be fully rotated and unlocked. The residual pressure then carries the bolt back to the full extent of its travel. This is the so called "Blish" principle of retardation.

These mechanisms work well with cartridges of considerably greater pressure and with longer cases than will the simple blowback, but long cartridges of high pressure have to be lubricated, that is the body of the case must be greased so that the case will slide back easier through the chamber. If the case and chamber were dry the cases would stick so tightly as to interfere with free functioning, or the cases might rupture. As a lubricated cartridge would be very unsatisfactory for military use, this type of rifle mechanism has not found much favor in armies. The Schwarzlose machine gun had an automatic oil pump. The .30 caliber Thompson automatic rifle had oiled pads in the sides of the magazine to lubricate the cartridges, but these often accumulated dust and sand which increased friction in the chamber. The Pederson used cartridges coated with a special wax, hard at ordinary temperatures but softening to form a lubricant under the heat of the chamber. But this wax likewise softened in hot weather, and either rubbed off or accumulated dust and grit. Extraction is one of the principle problems with all automatic arms, particularly those employing the heavier cartridges. It gives the least trouble with short, straight cartridges like the .45 Colt Automatic which needs no lubrication.

The retarded blowback action must complete its unlocking movement in time to utilize the residual gas pressure in the chamber for retracting the breech block, ejecting the fired case, and compressing the counter recoil spring. That is, there must be enough of the residual pressure left to accomplish these functions after it has primarily extracted the case. It will be clear, therefore, that the mechanism must be timed for some one particular cartridge, it may not operate with a cartridge of much lighter or heavier pressure, and an entire re-design of the action would be necessary to adapt it to some other cartridge.

The pressure generated by the .30-06 cartridge has dropped to about 12,000 pounds by the instant the bullet leaves the muzzle, while the residual pressure when the bullet is several feet beyond the muzzle is about 5,000 pounds. The action should therefore be timed to complete its unlocking after the bullet has left the muzzle and yet in time to utilize the residual pressure (in addition to a certain amount of momentum) to complete the functioning.

With either the toggle or the Blish principle of retarded unlocking the bolt begins to move very slightly to the rear before the pressure has decreased materially. The case is still pressed tightly against the chamber walls. Unless the cartridge is lubricated, so it can slide back instead of sticking, it may split, separate, swell at the head, or the primer may blow out. The result is similar to that caused by excessive headspace in a tightly locked breech action. As a rule, brass cases under heavy pressures cannot stand more than about ten or fifteen thousandths of an inch stretch without rupturing. With conventional high power military cartridges no retarded blowback system can, in all likelihood, be designed without using lubricated cartridges. This system is seen at its best with the .45 Colt automatic cartridge (Thompson submachine or tommygun) and the Luger cartridges, both of which are short, do not stick tightly in the chamber, and require no lubrication.

The H. & R. Reising has an interesting delay mechanism. The bolt tips so that the rear of the bolt enters a locking recess, bearing against an inclined locking surface. When the gun is fired, the rear of the bolt must ride down this locking surface before the bolt can blow back.

Short Recoil-Operated Action. With this type of mechanism the breech bolt is locked tightly to the barrel, solidly supporting the head of the cartridge at the beginning of the operation. The barrel and bolt are arranged to slide backward together on firing, through a tube which encircles the barrel and a grooved well in the receiver, or along a track on the forearm and through a well in the receiver. Thus when the rifle is fired the barrel and bolt slide straight to the rear actuated by the recoil, during which movement the counter recoil spring is compressed. When the barrel has completed a certain short travel to the rear, and the bullet has left the muzzle, the barrel is stopped and at this point the breech bolt is unlocked from the barrel by cams in the receiver. In some designs a counter recoil spring is provided for the barrel and this spring then pushes it forward again to its normal position. But momentum and residual pressure continue to carry the bolt further back to the end of its travel in the receiver until it reaches the stop or buffer. The compressed counter recoil spring then moves the bolt forward, carrying the top cartridge from the magazine into the chamber, and the bolt locks itself to the barrel, ready to fire again. Examples of this mechanism are the .45 caliber Colt automatic pistol (see Figure 37)—a Browning patent—the Johnson rifles and L.M.Gs and the Luger, the P-38 Walther, and Mauser pistols. The Johnson semi-automatic rifle, designed by Captain Melvin M. Johnson, Jr. is probably the most efficient utilization of this system to date when it is to handle high power rifle cartridges.

The Johnson has a short recoil system, a rotary bolt locking with eight lugs and unlocking by the rearward movement of the sliding barrel. The bolt turns twenty degrees to unlock while the barrel is recoiling 3/8-inch. Unlocking is accomplished by cams on the bolt working in a cam chamber and channel in top of the receiver. It

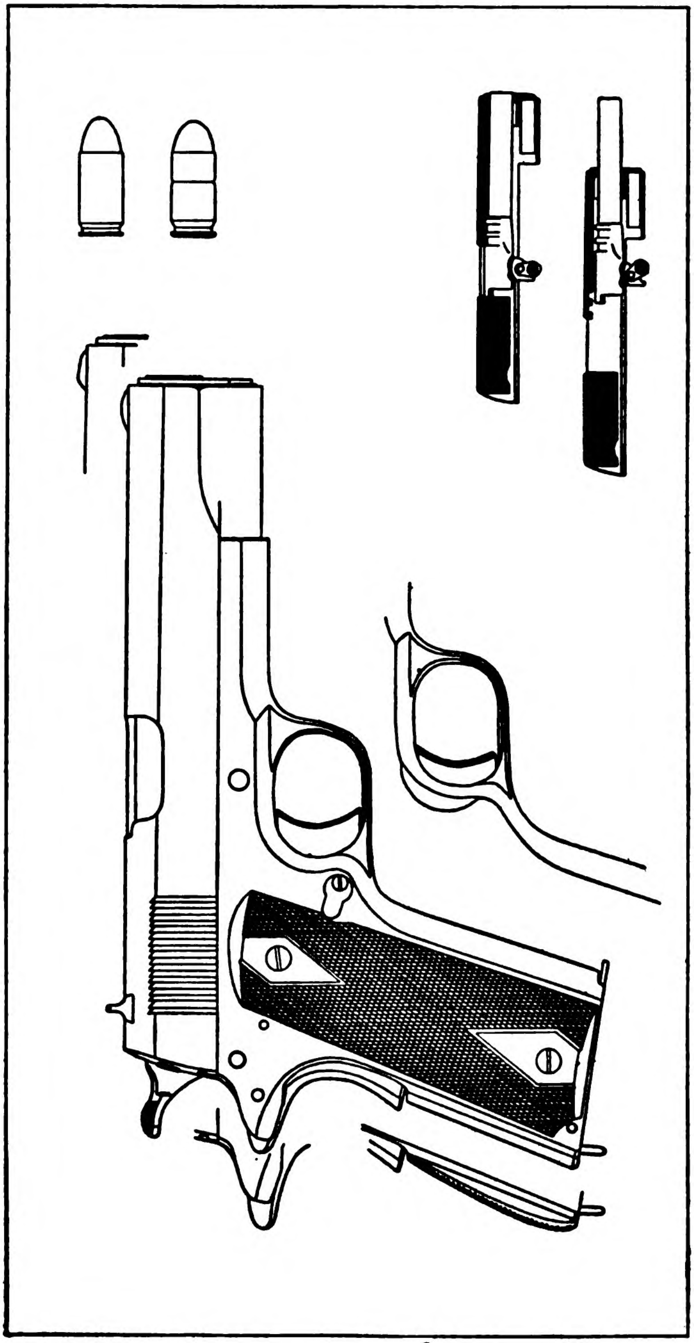

FIGURE 37. THE .45 AUTOMATIC COLT PISTOL

One of the most popular and dependable automatic pistols in the world. It is a recoil operated action which unlocks as shown above in the detail sketches. This, the service pistol of the U.S. forces, has been furnished in two different models, details of which are shown in the phantom sketches above.

has a rotary feed magazine holding ten cartridges in addition to another cartridge in the chamber. The magazine can be loaded with two standard Springfield type five-cartridge clips, or with loose cartridges, and can also be loaded whether the breech is open or closed. The rifle is 45½ inches long and weighs 9½ pounds. Some models of the Johnson light machine gun can be set to fire from either an open or from a closed bolt.

In the mechanism of the .45 Colt automatic pistol the slide is the breech block, and the barrel and slide remain locked together and move back together in recoil about ⅛ inch. Then the link pulls the barrel down at its rear end and disengages ribs on it from the slots in the slide by which the two are held together. The barrel stops, but the slide continues to the rear, being driven by its momentum and residual pressure. The counter recoil spring then pushes the slide forward again, and shoves the top cartridge out of the magazine into the chamber. This is the most reliable mechanism for an automatic pistol that has yet been invented but this locking system is not strong enough to stand the pressure of high power rifle cartridges.

The chief objections to the recoiling system are the sliding barrel and the excessive number of parts. The barrel requires a tube around it within which it recoils, and the tube retains heat excessively. The sights cannot well be fitted to the barrel, but must be secured to the tube and receiver. The barrel cannot be a perfect fit in its tube and slide, for if it were it would not operate in the presence of any amount of normal dust, and this necessary looseness, plus any that develops from friction, will cause variations in the line of aim. Two recoil springs are necessary, one for the barrel and one for the bolt. Usually a long and bulky receiver is necessary. It is a difficult weapon on which to fit a bayonet. All of these features add weight to the arm.

The recoiling action is timed by regulating the weights of the barrel and breechblock, and by the strength of their springs. If the barrel be too heavy it will have too much inertia, its recoiling speed will be slow, and ejection efficiency may be reduced. On the other hand a heavy breechblock tends towards better ejection, because it loses its momentum less than a light one after it has separated from the barrel.

The Luger pistol has a toggle-joint breech, which, unlike that of the Pedersen, is positively locked. Barrel and toggle recoil together with the breechblock held firmly against the base of the cartridge until a portion of the toggle strikes ramps on the frame. This pushes the toggle open, retracting the breechblock. A heavy spring in the rear of the grip then pulls the toggle closed and returns the moving parts to firing position.

The Walther and Mauser pistols are also positively locked. Both have separate locking blocks, that of the Walther being located between lugs on the bottom of the barrel and engaging grooves in the slide. The block of the Mauser rides in a slot in the barrel extension and engages grooves in the bolt.

The objections to this type of shoulder arm are that the receiver must be bulky and heavy, and it and the arrangement for the sliding barrel detract from the handiness and neat appearance of the weapon, and add to its weight. Also, with a rifle, both sights should be on the barrel, or else the barrel, particularly with wear, will not continue to line up absolutely with the line of aim. It has proven highly successful for pistols, however.

Long-Recoil Operated Actions. In this type of weapon, which is represented by the Remington Autoloading Shotguns and Rifles, barrel and bolt recoil all the way, solidly locked together. As they do so, they compress their respective return springs. When recoil is completed, the bolt is caught by a catch. As the barrel begins to move forward, it is unlocked from the bolt, which remains held to the rear and which in turn holds the empty case. In this type of weapon, extraction takes place as the chamber is "pulled off the case," rather than as the case is "pulled out of the chamber." When the barrel is almost fully forward, it trips the catch, releasing the bolt. In the shotgun, the carrier mechanism serves as part of the catch.

Other weapons of this type include the Frommer Pistol and the late unlamented Chauchat automatic gun.

Gas Operated Actions. In this type of self-loading rifle the expanding force of the powder gas is utilized in a different manner from any of the foregoing to operate the mechanism. A small hole is drilled through the lower wall of the barrel into the bore, and as the bullet passes this hole a portion of the gas rushes into the hole and down into a gas piston below the barrel. The rod of this piston pushes back an operating rod which is connected with the breech bolt and a counter recoil spring. The operating rod first operates a cam to rotate the bolt and unlock its lugs by which it was tightly locked to the barrel, and then pushes the bolt back to its stop, extracting and ejecting the fired case, compressing the mainspring, and cocking the firing pin. The counter recoil spring then pulls the bolt, operating rod, and gas piston forward. As the bolt moves forward it pushes the topmost cartridge from the magazine into the chamber, and firmly locks itself to the barrel ready to fire again. too

If the gas port in the barrel be close to the chamber, the gas at that point will be up towards the peak of its pressure, and will drive the piston violently to the rear, giving a harsh action and tending to tear the extractor through the rim of the case, or tear the head off the case. With the Garand rifle this gas port is located only about an inch in rear of the muzzle, at which point the gas pressure is very much less, the piston blow and movement is not so violent, the action is smoother, and yet there is sufficient power to extract a fired case, even if it be not lubricated, particularly from a chamber that is very slightly freed. Moreover the bullet has surely left the muzzle before the piston starts to the rear and before the bolt starts to unlock, the push to the rear being continued by the residual pressure. Locating the gas port and piston close to the muzzle, however, necessitates a long forearm of military type to encase the piston and the long operating rod.

The mechanism of the new Winchester short piston throw action is slightly different. The gas port is only slightly forward of the chamber, and the piston rod moves to the rear only about 1/10 inch when the gas enters the cylinder. The operating rod, held against the piston rod by the counter recoil spring, receives a quick, severe blow from the piston rod, and under the impetus of this blow moves to the rear and operates the mechanism as above. The action is like that seen in the lawn game of croquet where the two balls are placed touching each other. The foot is pressed hard on one ball (the piston rod) and that ball is struck a blow by the mallet (the gas). That ball does not move, or moves only a very slight amount, but the other ball (the operating rod) flies across the lawn. This is the type of mechanism used in the new Winchester carbine (U.S. Carbine, Caliber .30, M1). With it, it is not necessary to use a long forearm to house the piston and operating rod, and this lends itself to the design of a neater and lighter sporting arm.

In the early days of the gas operated mechanism, which were also the days of the chlorate primer, considerable trouble was experienced from the rusting and carboning (fouling) of the gas port and piston. Lately, however, with the introduction of the noncorrosive primer, and of powders giving less fouling, most of this trouble has disappeared, and it is now almost unnecessary to clean the gas port and piston through the entire accuracy life of the barrel. Unfortunately, however, some cleaning must still be done. Any armorer who has just cleaned the gas cylinder piston and piston plug of the Army carbine will assure you that the millennium is not yet here. Both gas port and piston receive sufficient lubrication when the bore of the rifle is cleaned with oil. These two systems of gas operation appear to be much better adapted for military and sporting shoulder rifles than any of the other mechanisms previously described.

Primary extraction of the case is always a difficulty with the gas operated automatic. With the blowbacks, extraction is helped by the residual pressure within the case, which presses back and assists the extractor to start the withdrawal of the case. With the recoil operated system, the cams on the bolt or receiver which unlock the bolt from the barrel assist in the primary extraction. But with the gas operated system, particularly with high power rifle cartridges, the gas is admitted to the gas piston when the bullet is proceeding with a velocity of, say, 2700 f.s.—that is, the gas rushes into the piston at a very high velocity. At this instant the case is quite tightly frozen in the chamber by pressure of its walls. The piston and connecting rod, starting back at very high speed, cause the breechblock to start back with similar speed, which gives a tremendous yank or jerk to both the extractor hook and the rim of the case. The nearer the gas port is to the breech, the greater the pressure within the piston and the more powerful the jerk. The extractor may break, or its claw may pull through the rim of the tightly sticking case. The extractor claw must be broad and sturdy, and its spring temper must be of the best. Even so, extractors may break—they often do. An automatic weapon is not worth its salt unless the extractor is easily replaceable without tools.

Practically all existing cartridge cases were designed for solidly locked weapons and have rims that are too thin so that it is relatively easy for the extractor hook to pull through them. Also the extractor groove of the case is not wide enough to permit designing an extractor with a heavy and strong claw. It would be fine if the designer of the action could also design the case, but unfortunately this is seldom possible because Governments demand a weapon to use a certain existing cartridge of which they usually have on hand a war reserve supply of billions of rounds representing an investment of millions of dollars.

Longitudinal flutes in the body and rear of the barrel chamber have been tried in an effort to reduce the friction accompanying extraction, but they tend towards gas leakage and split cases. The logical remedy seems to be to have a very perfectly cut and highly polished chamber that is relieved just slightly at its rear, as compared with the chamber usually seen on a fixed breech bolt action rifle, and to locate the gas port close to the muzzle. Reducing the pressure also helps extraction greatly. With lightly charged cartridges, for which the action must be designed and timed, extraction difficulties diminish. New progressive burning powders and a lighter bullet have operated to reduce the pressure of our service cartridge (Ball Cartridge, Caliber .30, M2) to about 38,000 pounds, as compared with the former pressure of 48,000 pounds in the M1 cartridge, and this has greatly improved the extraction and functioning of the Garand rifle.

All the power of the piston must not be expended in extraction.

There must be enough remaining to retract the bolt, compress the counter recoil spring, and eject the fired case. In this, the piston is assisted by the momentum of the bolt and connecting rod which it has put in motion. Momentum may be obtained either by a high initial speed given to a light mass, or by a slower speed given to a heavier mass. The machine gun, and to some extent the machine rifle, can employ a very heavy breechblock which retains its momentum well, but the semi-automatic shoulder rifle cannot have such a heavy block, for that would increase the total weight of the weapon to a most undesirable extent. Therefore, the gas operated rifle must employ speed of extraction instead, and as we have seen, this gets us into extraction troubles.

Here again, we find the matter of pressure looming up as a governing factor in design. The timing must be predicated on the pressure of the cartridge and the velocity of its gases when they enter the gas port, and these can vary but little. Automatic arms are not well adapted to a series of loads with light and heavy bullets at varying velocities. However, very often when a cartridge will not operate the self-loading feature of the weapon it is possible to manually operate the breechblock, which practically turns the rifle into a straight pull bolt action arm.

All semi-automatic rifles and pistols appear to operate better when a hammer is used to drive the firing pin forward, rather than a coiled mainspring operating a firing pin rod as in bolt action solidly locked weapons. It will be noticed that most of the semi-automatics have a hammer which is usually inclosed within the receiver. A disconnector operates to keep the hammer at full cock when the breechblock closes and thus prevents full automatic operation, for the trigger finger has no time to release its pressure on the trigger before the breechblock has completed both its backward and forward movement. When the trigger is squeezed the weapon fires but one shot. The trigger is then released slightly by the finger, and a second squeeze fires the second shot, and so on. An examination of the lock of a semi-automatic weapon will show how the disconnector operates.

Mention must be made here of the Browning Automatic Rifle (B.A.R.) Model 1918, used in the United States Army. For its purpose, which is purely military, it is a most efficient arm. It is debatable whether it falls within the class of weapons treated in this work. It would seem to be much more of a machine rifle than a shoulder rifle for it weighs 16 to 22 pounds according to the particular type, is usually provided with a bipod, and can be made to operate either semi-automatically or full automatic. It is suitable for much longer bursts of sustained fire than can ordinarily be obtained with a semi-automatic shoulder rifle.

But the feature about the B.A.R. that we wish to call particular attention to is the termination of its cycle of operation when the trigger is squeezed in semi-automatic fire. Between shots the breech is open, and there is no cartridge in the chamber. When the trigger is pressed the breechblock first closes, forcing a cartridge from the magazine into the chamber. The rifle now being closed and loaded, the hammer falls, driving the firing pin forward and discharging the cartridge. Then the gas enters the gas port which is located about midway of the bore, and the gas pressure, operating through the piston and connecting rod on the breechblock, extracts and ejects the fired case, and retracts the breechblock, leaving the latter fully retracted to the rear.

Now, when the trigger is squeezed, the breechblock, which is quite heavy, closes with a "slam, thump" just before the rifle fires. This slam is disconcerting to the shooter, and interferes to a con-

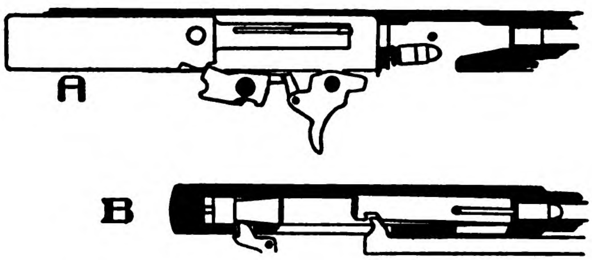

FIGURE 38. OPEN BOLT VS. CLOSED BOLT

Above drawings will illustrate the difference in the action of a fully automatic weapon which fires from an open bolt (sometimes termed a floating bolt, or a slam action) with one which fires in the conventional manner.

A—Shows action of the Thompson M1A1 submachine gun, which fires from an open bolt. As here shown, the gun is ready to fire by pressing the trigger, upon which the breechblock will sweep forward carrying the top cartridge into the chamber and firing it as soon as the breech locks, upon which breechblock recoils back to position shown, fired case is ejected and another cartridge rides up into position for loading. This completes one cycle of operation. Many full automatic weapons fire in this manner, and a few semi-automatic firearms have been so designed but have not been very successful in the sporting field . . . you just can't hit anything with them.

B—Here is the action of the Reising submachine gun. This fires same cartridge as the Thompson, but its action is entirely different although also fully automatic. With the Reising, the firing cycle rests with a cartridge seated in the chamber and the bolt closed and locked, as shown above. When the trigger is pressed only the "hammer" moves forward and much better aimed fire is possible from such a gun—better for the first shot, that is.

siderable extent with fine marksmanship. This makes little difference with this particular weapon because it is quite heavy (at least 16 pounds) and because its tactical use is more to deliver an intense and prolonged burst of fire on a certain position rather than to hit an individual enemy, although in the hands of a man skilled in its use the B.A.R. is fully capable of hitting an individual target up to 400 yards. But such an arrangement of the cycle of operation has no place on a medium weight semi-automatic shoulder rifle, due to its bad effect on the accuracy of fire. The marksman cannot surely hit small targets, because the slam of the closing breech interferes with a perfect trigger squeeze and hold through. One or two .22 caliber semi-automatic rifles have been made to operate in this manner but they have proved to be quite useless weapons from a practical standpoint.

But there is one very important advantage to this cycle of operation, particularly with a rifle intended to be fired in long sustained bursts where the barrel naturally gets very hot. With any clip-fed semi-automatic it is possible to fire it so rapidly for such a long time that the barrel will become so heated that if the firing be stopped abruptly with a cartridge in the chamber, the heat of the barrel will discharge that cartridge in two or more seconds without the trigger having been pulled. Thus the shooter may complete a fast and long-continued series of shots, finishing with a cartridge in the chamber, and he may even take the rifle down from his shoulder —and then in a few seconds—bang—off goes the rifle. Seemingly this is a very dangerous thing.

But this is abuse in a semi-automatic rifle, not legitimate use. In proper use it will never occur, not even in the most furious stages of an intense battle, for there will never be necessity or legitimate opportunity to fire fast and long enough to cause the heat necessary for such a discharge. Once again we remark that a rifle is not merely a machine for squirting a great mass of bullets quickly. It is a weapon to hit targets with.

Extremely fast and long bursts of fire are also detrimental to the barrel, causing fast erosion.

Quite often, in perfectly legitimate use, the barrel of a semi-automatic shoulder rifle may get quite hot from rapid and sustained firing. The heat of the barrel will then "cook" a cartridge left for long in the chamber, and while normal heating of this kind will not cause its discharge, yet it will considerably increase the breech pressure of that cartridge if it is fired while still very hot, and the bullet will probably strike high above the target. Therefore, it is best not to let a cartridge remain for any considerable length of time in a hot barrel, but extract it and leave the breech open to let the barrel cool.

This brings us to the matter of hand guards. Quick bursts of more than one magazine full, often necessary in war, but never in sport, will heat the barrel to such an extent that it would seriously burn the hands if touched. Therefore, semi-automatic shoulder rifles intended for military use are provided with wood hand guards over the top of the barrel to protect the hands from the hot barrel, both in ordinary operation and when using the bayonet. Such hand guards are objectionable in that they prevent free circulation of the air around the barrel to cool it, but they are necessary to prevent burning the hands. They also, to some extent, prevent the cloud of mirage or heated air that arises from a very hot barrel from obscuring the target when aiming.

The question is often asked: "Does an automatic arm shoot as hard (with the same velocity) as a manually operated arm with solidly locked breech?" Automatic rifles using residual pressure for retraction, and those in the recoiling barrel class show no loss in velocity. With the gas operated weapons a small amount of gas pressure is used for the operating force and taken from the propelling force, with a corresponding very slight loss in velocity. However, in the case of the Garand rifle the gas port is so close to the muzzle that the bullet has practically attained its maximum velocity by the time it has passed the port, and there is no loss in velocity. Also with the Winchester carbine the writer would not expect any loss because both the port and the piston are so very small, and there is practically no expansion within the piston. Of course in the comparison the cartridge and the barrel length must be the same.

What about the recoil? As some of the force which ordinarily causes recoil is absorbed in the operation of the mechanism, the automatic arm usually has less recoil than that with the solidly locked breech. The recoil of the Garand rifle is much less than that of the corresponding Springfield. However, with those mechanisms having recoiling barrels, if the barrel is allowed to move too freely, even a very small part of an inch, there will be a disagreeable jab. But it is not possible to compare appreciable recoil without considering the weight and balance of the arms, and what is just at important, the shape and dimensions of the stocks.

We have said that, as a rule, semi-automatic shoulder rifles are not quite as accurate as bolt action rifles. This is usually because the semi-automatic ordinarily has a chamber slightly freed to assist extraction, and because its barrel is slightly lighter than that of the usual bolt action weapon, to keep the rifle within the prescribed weight limit. But this brief statement should be clarified further.

The most accurate rifles we have known to date are the high grade, heavy barrelled bolt action rifles using a few cartridges noted for accuracy. Nearly equal to them are similar rifles with medium weight barrels. Next to these come the National Match Springfield, the Winchester Model 70, and the Remington Models 30-S and 720 in .30-06 caliber, using loadings equal to National Match ammunition.

The only semi-automatics we have had, so far, to compare with the above are what might be termed "service" automatics, and such a comparison is manifestly unfair. We do not know what the accuracy of the best semi-automatic rifles will be until we have been able to study their accuracy adjustments more fully, and have built such rifles with all the attention to small details that have been given to the above very specialized weapons.

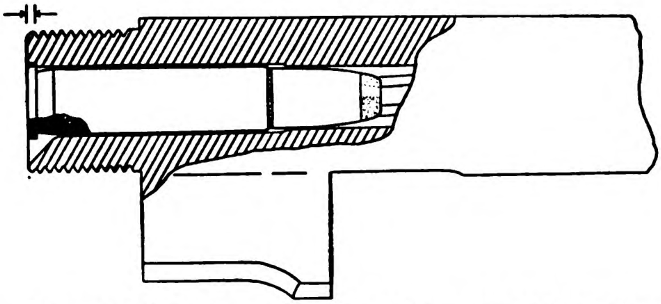

FIGURE 39. THE CHAMBERING OF A SEMI-RIMLESS CARTRIDGE

This illustrates the seating of a semi-rimless cartridge which, actually, is in reality a rimmed case and positions against its rim like any rimmed cartridge. Headspace in such ammunition is determined by the thickness of the case rim.

The above drawing also illustrates a general principle in the chambering of rifles operating automatically. This shows the .32 Winchester Self Loading cartridge in position for firing. Note the extreme tolerances given this rifle chamber and particularly note the great tolerance allowed at end of the chamber. This loose fit of all chamber dimensions is made to assist easy and certain chambering of the cartridge under all conditions of operation and use.

Rather it seems to us that the only proper comparison is between the Springfield 1903 Service Rifle and the Garand Service Rifle. Both have been made in the same arsenal, and both are as well made as is consistent with large quantity production. They should be compared when using service ammunition. From such a comparison the Garand does not suffer at all. In shootings by individual riflemen the scores obtained with it have been quite the equal of those averaged with the Springfield. The Garand has repeatedly shot possible scores at 600 yards. The Garand rifle of today is a better arm than as at first produced in 1939, as a result of the experiences of early production.

We have based our former statements that the semi-automatic rifle was not quite as accurate as the bolt action on the present necessity of chambering the former a little more freely, and because within an equal weight limit the barrel of the semi-automatic must of necessity be lighter because of its heavier breech action. The Garand probably makes up for these drawbacks by having metal parts designed to bed better in the stock, and particularly the recoil shoulder of its receiver is much larger and located more centrally behind the back-thrust motion than on the Springfield. It is often possible to remove the Garand from its stock, and then replace it without the least disturbance of its elevation and zero adjustments, a detail that very rarely obtains with the Springfield.

CHAPTER VI

Stocks and Sights

GIVEN a well made weapon for an accurate cartridge, then the degree of skill with which an accomplished marksman can shoot it depends, in the case of a rifle, on trigger pull, stock, sights, and method of sight adjustment. With a shotgun it depends on trigger pull, stock, and to some extent on visibility of front sight. With a revolver or pistol it depends upon trigger pull, sights, method of sight adjustment, and stock (grip).

Trigger pull has already been covered. It is proposed here to discuss stocks and sights; particularly their type and design. The use of stocks and sights comes properly in a work on marksmanship, and will be mentioned here only to the extent of showing the reasons for design.

Rifle Stocks

Original American Design. Prior to about 1903 the design of the majority of stocks seen on American sporting and target rifles was based on that adopted for the Pennsylvania rifle, usually erroneously called the "Kentucky" rifle, dating from about 1730. Such stocks were light in weight, small in dimensions, had considerable drop at comb and particularly at heel, and were fitted with a crescent shaped butt-plate. Consider the conditions under which these rifles were used. Hunting country and the theatres of Indian warfare were almost invariably heavily wooded with considerable underbrush, and usually it was impossible to see to shoot except from the standing position. The country was largely flat or slightly rolling, and game was found chiefly in the level and well watered valleys. The weapons were muzzle loaders and single shots. Therefore the design of stock was exactly what we would expect—most suitable for firing from the standing position at a target on about the same level as the shooter, and for single shot fire, that is slow fire only.

Development of Marksmanship. Prior to about 1875 there was no well conceived system of marksmanship in America, no worth while work had been published on the subject, and there were so few real marksmen in America that everyone knew most of them by name. There were, of course, many backwoodsmen who were good offhand shots at very short ranges, but that qualification does not by any means make a marksman. Between 1875 and 1903 a few magazine articles appeared showing that some individuals were making a study of the subject. Marksmanship among small groups in the National Guard of Eastern States and in the Regular Army began to show considerable improvement, and the first indication of a system of shooting can be seen. During this period those who shot well at long ranges and in rapid fire (skirmish) did so with military rifles which had stocks with more or less flat butt-plates and with very much less drop at the heel than the usual sporting and target stock of the day.

With the advent of the National Matches in 1903 real rifle marksmanship began in America, and real thought began to be devoted to the subject. That year many marksmen returned to their homes from these matches with new and sound ideas as to marksmanship. In 1901 Captain William DeV. Foulke had published his pamphlet "The School of the Krag," in 1903 Dr. Walter G. Hudson published his book "Modern Rifle Shooting from the American Standpoint," and in December of that year the writer's work "Suggestions to Military Riflemen" also was published. But the great impetus was the National Matches, which caused a remarkable increase in interest in the subject.

About 1920 all marksmanship studies were reviewed by the Regular Army, which then published the first really comprehensive manual on the subject, setting forth the American system of rifle shooting, which system has since been used at the School of Instruction at the National Matches. Now all of our competent rifle instructors and coaches use this system, all really good rifle shots have adopted it, and all are a unit in expressing the thought that it is almost hopeless to attempt to teach men to shoot under any other system or lack of system.

Influence on Design. As might be expected, all this study, and the development of this system had a profound effect on rifle design. Specifically the American system of rifle instruction lays emphasis on trigger squeeze as being the whole soul of good rifle shooting. But proper trigger squeeze cannot be taught until the marksman can aim properly and hold steadily. Aiming is easily taught, but holding is more difficult. The bone and muscular makeup of man is such that a rifle can be held steadiest in certain fairly closely prescribed positions—prone, sitting, kneeling, and standing. In the first three of these positions a properly designed gunsling, used in a certain manner, is a very great aid to steady holding. And finally that a beginner can be taught to hold with great steadiness in the prone position with the gunsling in about a week's time.

Therefore the beginner is first taught how to aim, and how to hold the rifle steadily in the prone position. Ability in these having been acquired, he is then taught the principle of correct trigger squeeze, and he then proceeds to learn to co-ordinate his aim, hold, and squeeze by shooting in the prone position. In a very short time he becomes skilled in this form of shooting, *and correct trigger squeeze becomes a fixed habit.* He is then taught in turn to shoot sitting, kneeling, and standing, and finally to shoot rapidly and at moving objects and natural targets at both known and estimated distances.

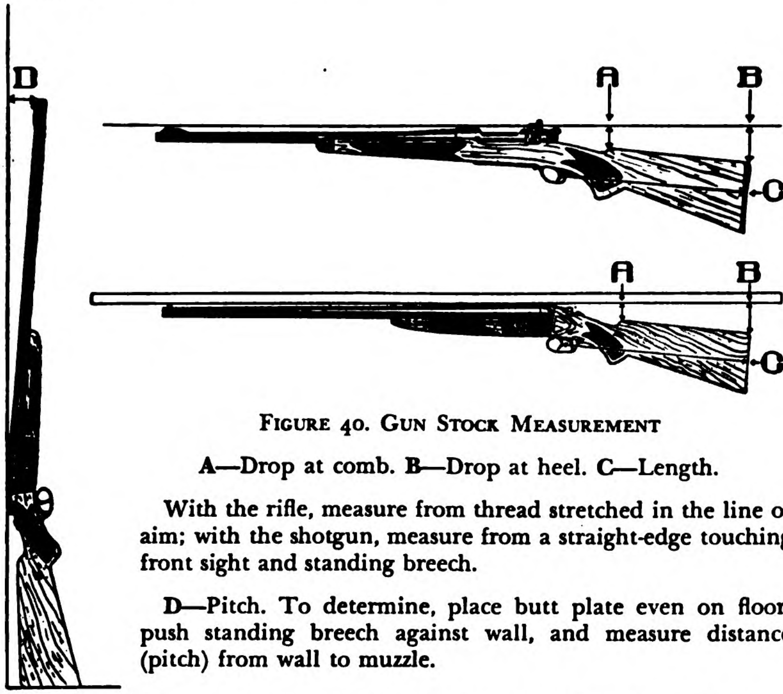

Figure 40. Gun Stock Measurement

A—Drop at comb. B—Drop at heel. C—Length.

With the rifle, measure from thread stretched in the line of aim; with the shotgun, measure from a straight-edge touching front sight and standing breech.

D—Pitch. To determine, place butt plate even on floor, push standing breech against wall, and measure distance (pitch) from wall to muzzle.

To make the rifle better suited to this form of shooting it became necessary to very considerably modify the stock from the usual American design of great drop and crescent butt-plate. In fact the old design was exceedingly uncomfortable and really impossible to use in any of the new firing positions except possibly when shooting in the standing position at targets on about the same level as the shooter and in slow fire. New stocks were designed with flat and larger butt-plates, with less drop at comb and heel, of greater weight (thickness), with pistol grip, and with an enlarged forearm, and fitted with a gunsling designed for use as an aid to steady holding as well as for carrying the rifle.

Modern Stock Design. Gradually these newer stocks have tended to a certain design, and to certain dimensions, and in these respects have now become fairly well fixed, so that we now have a design that has proved itself on a thousand ranges and in the hands of hundreds of thousands of marksmen, as well as in the hunting fields of the world. This now appears to be the one best design for marksmen of average American stature and also for all beginners who are learning to shoot. This design is well adapted to shooting in all four positions, up and down hill as well as on a level, and in rapid as well as slow fire. The gunsling which is an important adjunct, is also adapted to all such use.

Actually two designs have been developed, differing only slightly. The first has been found to be best for military use, for hunting, and for quick firing of the first shot (snap shooting). The second is preferred for the sport of target shooting, particularly for shooting in the prone position, and to some extent for use with telescope sights of present design. These stocks are perhaps seen at their best on certain rifles now being produced.

The Military and Sporting Stock is believed by the writer to have attained its best perfection to date in the stocks seen on the Winchester Model 70 Standard bolt action rifle, and on the Winchester Model 71 lever action sporting rifle. See Figures 41 and 42. A strictly military stock should be heavier and thicker than these to give strength, but of the same dimensions.

The butt-stock on these two rifles has a drop from line of aim, sights set at 100 yards, of 1⅝ inches at the comb and 2⅝ inches at the heel. The length from middle of trigger to center of butt-plate is 13½ inches on the Model 70 and 13³⁄₁₆ inches on the Model 71. The stock of a lever action rifle should be slightly shorter than on a bolt action as this facilitates operating the lever while the rifle is held at the shoulder. The checkered steel butt-plate is 5 inches long by 1⁹⁄₁₆ inches wide at its widest part, and is very slightly dish shaped—almost flat. It is set on the stock with a 3-inch down pitch. The front edge of the pistol grip cap on the Model 70 rifle is located horizontally 2⅞ inches in rear of the center of the trigger, and vertically 1⅞ inches below the center of the trigger, when the barrel is held level. The smallest portion of the grip is 5 inches in circumference. The front sling swivel on the Model 70 is 16¼ inches in front of the center of the trigger. On the Model 71 it is attached to the metal forearm tip. The rear sling swivel is located 2½ inches in front of the toe of the stock on both models. The forearm on the Model 70 is 1½ inches wide at a point 6 inches in rear of its tip, and its bottom is 1¼ inches below the center of the

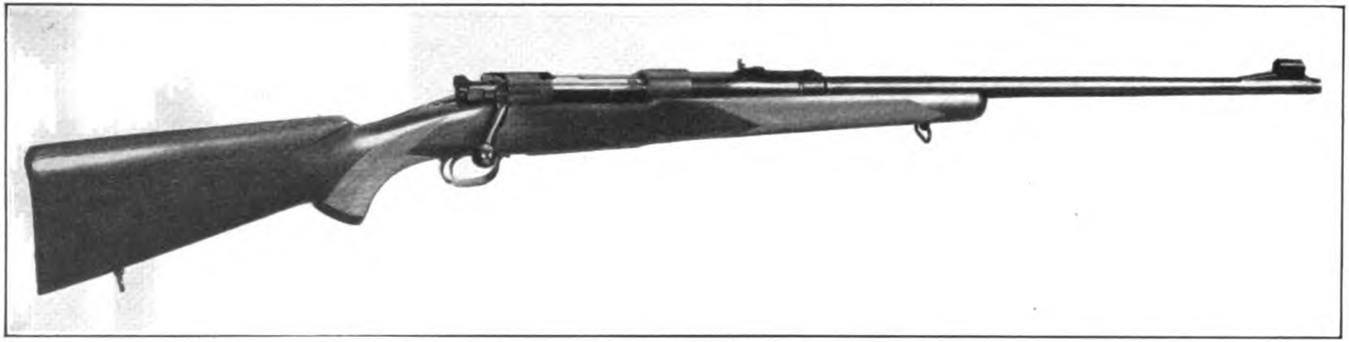

FIGURE 41

The dimensions and shape of the stock of the Winchester Model 70 *Standard* Rifle have proved to date to be the best for shooting in all firing positions by a great majority of American rifle shooters. Except that this stock is a little light, it also shows the best dimensions and shape for a military rifle stock. The "Marksman" stock shown in Figure 43 is generally considered to be better for firing exclusively in the prone position, but this "Standard" stock is by no means poor for prone shooting.

Do not pay too much attention to the sights shown in the above illustration. They are the poorest of crude open sights, inadequate for any serious ballistic work, and suited only for shooting at the largest targets like a deer at comparatively short distances.

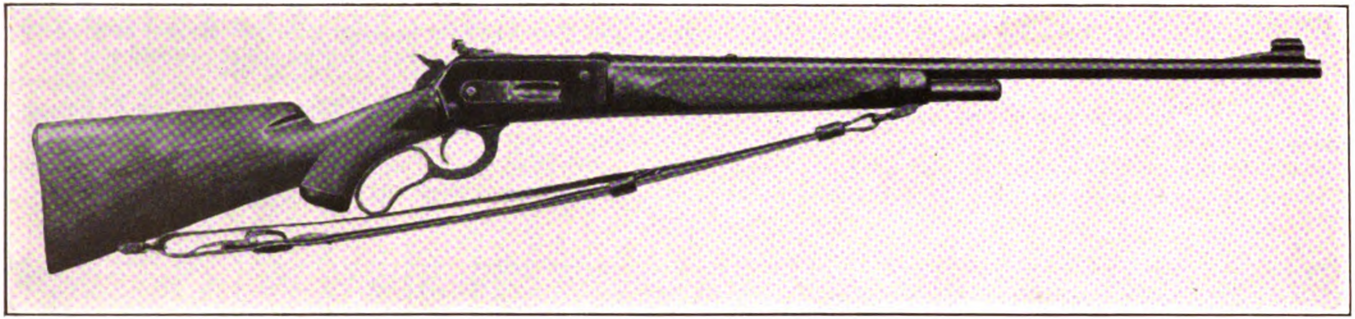

FIGURE 42

The ideal stock for a lever action rifle, shown on the Winchester Model 71 rifle. A similar stock is adapted to the Winchester Models 64 and 65 rifles. Suitable for all firing positions, and a splendid stock for snap shooting and rapid fire. Its use considerably decreases the appreciable recoil as compared to previous stocks fitted to lever action rifles. The entire make-up of this fine rifle—stock, sights, sling, and breech action—has the almost universal approval of all older American sportsmen.

Figure 43

The "Marksman" stock as fitted to Winchester Model 70 rifles of "National Match," "Target," and "Bull Gun" types, and also to the Winchester Model 52 small bore match rifle. Intended exclusively for target shooting in the prone position, for which it has proved supreme. Not a good stock for offhand or snap shooting. Is a straight stock with little drop at comb and heel, and very wide beaver-tail forearm, and the entire stock is thick and heavy throughout with a close and long pistol grip. The adjustable hand-stop in rear of the front sling swivel permits shooting of a long series of shots without cramping or pinching the left hand, and contributes to high scores.

This is a very good stock for use with telescope sights which are mounted high above the bore with target mounts.

bore. On the Model 71 the forearm is a modified beavertail in shape, and covers the tubular magazine.

These are excellent all-purpose stocks, and they are particularly good for snap shooting, and rapid fire in all the firing positions. If a telescope sight is used on the Model 70 rifle then the comb will usually be found a little low because the line of aim through the scope is higher than through the iron sights, and the comb should be a little higher. The comb on a standard stock can be raised the required amount for a scope by lacing a leather cheek pad on the stock.

The Marksman Stock for target shooting is believed by the writer to have obtained its best development in the stocks seen on the Winchester Model 70 Target Rifle, and the Winchester Model 52 Heavy Barrel Match Rifle. See Figure 43. These stocks have a drop from line of aim to comb of 1 9/16 inches, and to heel of 1 7/8 inches. The length from center of trigger to center of butt-plate is 13 1/4 inches. The flat checkered steel butt-plate is 5 3/16 inches long and 1 3/4 inches wide at its widest part, and is set on the stock with a 3 inch down-pitch. The grip at the small of the stock is 5 5/16 inches in circumference. The front edge of the pistol grip cap is located horizontally 2 1/2 inches in rear of the center of the trigger, and vertically 2 inches below the center of the trigger when the barrel is held level. The distance from the center of the trigger to the rear surface of the front sling swivel finger stop is 15 3/4 inches when the stop is at its most forward position, and 13 3/4 inches when in its rearmost position. The finger stop, just in rear of the front sling swivel (see Fig. 43) is intended to prevent cramping of the left hand from a tight gunsling during a long series of shots, and to provide a solid stop to run the knuckle of the left forefinger up against when firing prone. It is adjustable back and front 2 inches for men with long and short arms. The forearm has a very wide beavertail cross section, 2 1/2 inches wide at its widest part, and is quite flat on its bottom surface.

The Marksman stock is so straight, with so little drop at heel and comb, that it is not very satisfactory in most men's hands for snap or rapid shooting in the standing position, but it is ideal for prone shooting, and its bulk and thickness give stiffness which makes for the finest accuracy. It is also excellent for use with a telescope sight, and is usually used with iron sights set on the rifle higher than usual so that both iron and telescope sights are of equal height above the center of the bore. The forearm on the Model 70 rifle is not attached to the barrel in any way, the barrel groove in the forearm being merely a snug fit on the barrel—almost a floating barrel. On the Model 52 rifle the forearm is secured to the barrel by a barrel band which is adjustable for tension, and the barrel and receiver, instead of being in close contact with the wood, contact a number of small synthetic rubber washers which are located at critical contact points in the barrel and receiver grooves in the stock, the washers being seated in circular depressions in the wood, and their surface only very slightly above the wood surface. The barrel and receiver are drawn down to tight contact with these washers by the guard screws and the forearm band. The barrel and receiver are thus bedded tightly on rubber washers instead of on wood. A type of synthetic rubber is used that will not deteriorate in the presence of grease and oil. It is believed that this method of bedding merits serious consideration and investigation, as it seems to have very considerable merit on the Winchester Model 52 rifle, the only rifle, so far as the writer knows on which it has been tried extensively.

These are the dimensions and shapes of rifle stocks which have proved best for the vast majority of marksmen, and it is believed that when a rifle stock is to be produced in quantity it should adhere closely to these specifications. Also that stocks for "tommy guns" and young boys' rifles, while they must differ considerably in shape and dimensions, should be designed with as close adherence to the principles which led up to the development of these "standard size" stocks as possible.

Occasionally we find a man who is not well fitted with these standard stocks. A short, "chunky" man with short and muscular arms will require a shorter stock, perhaps one as short as 12½ inches. A very tall man, over 6′ 4″, particularly if he has long arms, may require a longer stock, even as long as 14¼ inches. If he also has a very long neck and sloping shoulders he may require more drop at the heel, perhaps as much as 3¼ inches. For special comb dimensions see below. Generally speaking, however, it is almost always a mistake to alter a stock from the above standards, or to have a stock built of special dimensions until a shooter has had a great deal of experience in target shooting and has been thoroughly trained to assume the normal firing positions. He can then prescribe for himself the alterations which will surely be of benefit to him. No one else can do it for him. It is also a bad mistake to take the dimensions of a well fitting shotgun stock as any indication of what the dimensions of a rifle stock should be. Almost invariably the shotgun shooter who is perfectly fitted with a shotgun stock measuring 14¼ x 1½ x 2¼ inches will be well fitted with the standard stock above for his rifle.

Stocks for women should depart from the above standard dimensions only after most careful study and experiment, although often ladies, unless rather tall, will require a shorter stock than will a man. Short, light stocks with much drop always accentuate the recoil. Stocks for very young boys of small stature should of course be very much smaller than the above, but they will probably outgrow such small stocks in a year or two. Most boys of 13 years and older can use standard stocks.

An experienced stocker can make a special stock of any dimension desired, carving and inletting it from the walnut blank. If he is experienced, and skilled and honest enough to do the work as it should be done it will take him about a week's time to make such a stock, and such a man's time is easily worth ten dollars a day, so such stocks are expensive. If he is not experienced and honest he will almost surely make a poor job of the bedding, and the rifle will never shoot accurately and reliably in his stock.

Rifle Stock Construction

There are in general two types of rifle stocks. **The one piece stock** where the forearm and butt-stock are one continuous piece of wood, and the receiver and barrel are inletted down into the wood, and the trigger guard and magazine are inletted up into the wood. The stock is secured by two or more guard screws which fasten the receiver and guard together, and go through the wood of the stock, pinching all together, up against a recoil shoulder on the receiver which prevents the assembly from driving backward through the stock when it recoils, and sometimes by a forearm fastener or one or more barrel bands. Such stocks are usually seen on military and sporting bolt action rifles, and also on the Garand and Winchester (carbines) military rifles. Military rifles also usually have a *handguard*, a covering of wood over the top of the barrel to protect the shooter's hands from a barrel that has become very hot from repeated firing.

The two piece stock is usually seen on lever and pump action rifles and on the Browning automatic rifles. The stock is made of two pieces of wood. The forearm is in one piece and is secured to the barrel by a screw or band, and its rear end usually has a tenon which is inletted into the receiver. The butt-stock is also of one separate piece, and is usually secured to the receiver by one or two tangs, which are metal extensions to the rear of the receiver. These tangs are inletted into the grip of the butt-stock and are secured by a tang screw which passes through both tang and stock grip. The butt-stock is also sometimes secured to the receiver by a long through-bolt (stock bolt), passing through the stock from its butt-end, screwing into the rear end of the receiver, and thus clamping the butt-stock and the receiver tightly together. The steel receiver intervenes between the forearm and butt-stock portions of the wood stock.

We have mentioned before that for the greatest reliability and accuracy in shooting the rifle should be as stiff as possible from muzzle to butt. There should be no loose, or even very slightly loose joints. This is most important when we come to consider the type and construction of the stock and the way in which it is secured to the metal parts of the rifle, particularly the barrel and receiver.

The method of securing and bedding the metal parts in a one-piece stock usually results in a much stiffer junction than with a two-piece stock, and this is one of the reasons why bolt action rifles are as a rule more accurate than rifles with two-piece stocks. The receiver and barrel are secured to the stock by guard screws, or else

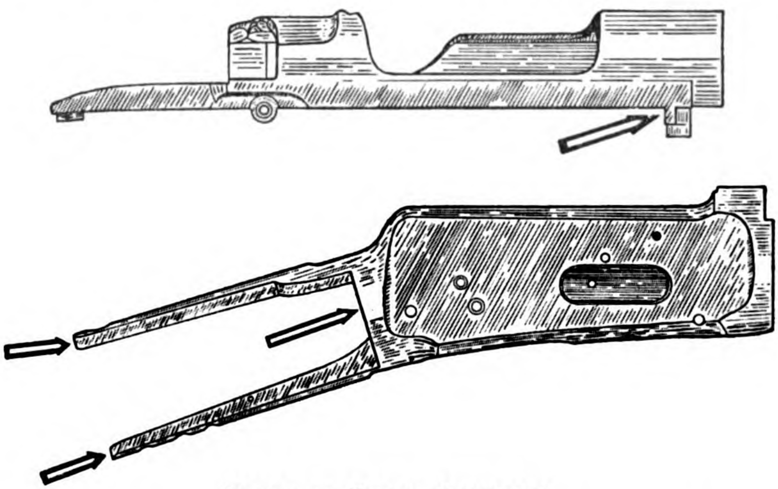

FIGURE 44. RECOIL SHOULDERS

Showing recoil shoulders on Mauser (top) and Winchester Model 1894 (bottom) receivers. These recoil shoulders, as shown by the arrows, must abutt squarely and hard against corresponding shoulders in the stock bed to prevent the barrel and receiver from driving back through the stock during recoil, and to insure a constant position of the metal parts in the stock.

If the forward recoil shoulders be not very solidly bedded, that is if the least little set-back occurs, the rear end of the tangs are liable to act as wedges and split the stock at the grip. In fact with modern bolt action rifles which usually take cartridges giving rather heavy recoil it is common practice not to bed the rear end of the tang tightly in the stock, but to have a slight clearance between rear of tang and wood to prevent splitting. The guard and tang screw holes must be accurately drilled in the stock so that these screws when tightened do not tend to back the recoil shoulder away from the stock shoulder, but rather to tighten up the contact. Guard and tang screws must be kept very tightly set up at all times or the shooting will be very poor.

a guard screw and a forearm fastening, that are always at least six inches apart and this of itself is much more secure than the fastening of the butt-stock of the two-piece stock where the distance involved in the clamping is very much less. In addition, in a well made stock of this type the under surface of the barrel and receiver are so perfectly bedded into the wood, that they are almost a part of the wood and there can be no rocking or movement of the metal parts in the stock either up or down, front or back, or sideways. The bedding of the recoil shoulder is also of extreme importance. Figure 44 shows the recoil shoulder on receivers of bolt action rifles of the Mauser type. The rear surface of this shoulder must abut firmly against a corresponding shoulder in the stock just in front of the magazine well. If this abutment is not solid and perfect holding the barrel and receiver, fore and aft, in exactly the right place, then when the rifle is fired these parts will recoil and move backward within the stock, which may loosen all the bedding, and also the wedge shaped rear end of the receiver recoiling backward, may split the grip of the stock lengthwise. Other things being equal, the shooting of a rifle, and incidentally its stiffness, depends upon how well the stock is bedded. A poorly bedded stock will make for poorer accuracy, no matter what its type. But the point is that with proper bedding the one-piece stock gives a much stiffer junction and hence more reliable accuracy.

With a two-piece stock the area of junction of butt-stock and forearm, when the tang method is used, is only the length of the tangs plus the abutments of the rear surface of the receiver (recoil surface) against the front end of the stock, the clamped area fore and aft being barely three inches. There is much more chance of looseness here, and moreover repeated recoil is almost certain to pound the receiver against the short contact in such a manner as is liable to introduce considerable looseness sooner or later. The through-bolt is a much stiffer method of attachment than the tang when it is properly done, with the stock screw practically a drive fit in its hole in the butt-stock. Then we have contact the whole length of the heavy screw, which is about 1/4 inch in diameter, as well as tight screw up contact of the grip end of the butt-stock with the rear end surface of the receiver. Of course in the last analysis the firmness of all these contacts and bedding depend upon the screws being set up very tightly and kept so.

Irrespective of the cartridge used, the finest accuracy has been obtained with bolt-action arms having one-piece stocks, and such accuracy has been approached only by heavy single shot rifles having two-piece stocks with the through-bolt method of attachment, and this only when these single-shot rifles are used with relatively light cartridges.

Except in extremely heavy rifles for very light cartridges, fine accuracy is always destroyed by poor bedding, no matter what the type of stock. Despite good bedding, fine accuracy may also be temporarily disturbed by the warping, swelling, or shrinking of the wood of the stock, due to change in its moisture content from climate or exposure. Some woods warp, swell, and shrink more than others, irrespective of the species of the wood. Some well seasoned walnut stocks give no trouble from this source when guarded against alternate exposure to rain and hot sun, and others do. Such changes in the wood will, of course, make a change in the tightness of bedding and clamping, and may also place pressure on one portion of the barrel and receiver, while relieving it on another part.

All this is not theoretical, for it has occurred again and again with every rifleman of long experience. The substitution of a well bedded one-piece stock for a poorly bedded one has very frequently changed a rifle capable of averaging only five inch groups at 100 yards into one that averaged one and one-quarter inch groups. Frequently, warping of a stock has changed a rifle from one that would place a small group in the center of the bullseye into one that would scatter its shots from the center of the bull way out to its outer edge in some particular direction.

Finally, no amount of good stock design and bedding will make a rifle which has been built with too light a barrel and receiver for the cartridge it shoots into a good shooting one.

The reader may gain the impression from the above that the obtaining of a really accurate and reliable rifle, and its maintenance in that condition is much a matter of luck. Luck does enter into it to a small extent because it is possible to utilize a piece of extremely well seasoned walnut for a stock which afterwards proved to be subject to periodical warping and shrinking, but such woods are rather rare. Aside from this the matter of luck, so far as the influence of the stock on accuracy and reliability is concerned, will be largely eliminated if the shooter selects a model of rifle where the stock is designed in accordance with the above principles and when the workmanship is as good as honest and careful inspection can make it, such as seen in the Winchester Model 52 and 70, and the Remington Model 30-2, 37, and T 20 rifles, and including also certain custom made bolt action rifles stocked by a workman who is both skilled and honest.

It is debatable whether it is best to bed the barrel snugly and firmly in the forearm, or to have the forearm free floating, that is not touching the barrel so that a slip of paper can be run between barrel and forearm channel when metal parts and stock are tightly assembled. Probably where the very finest accuracy is desired the latter procedure is the best because walnut is not a staple material as even when it is thoroughly seasoned it is liable to shrink, expand, or warp so that when snugly fitted originally it may not remain so at all times, and may put more or less pressure on the barrel thus causing a variation in the jump.*

It is also thought best not to secure the tip of the forearm to the barrel by a band or screw, because if the forearm warped this would exert more or less pressure on the barrel. Also if a band or screw be used then down-pull on the front sling swivel when shooting with a gunsling will be directly translated to the barrel, and by altering the jump will cause a considerable difference in the location of the center of impact from what it would be when shooting without a sling. However, the Winchester Repeating Arms Company uses an adjustable barrel band on their Model 52 (.22 caliber) match rifle, and seem to have improved the accuracy thereby. This band can be adjusted to clamp the forearm tight or loose to the barrel, and by experimental firing an adjustment can be found which will give the best accuracy. But, as previously described, this barrel band pulls the barrel down against rubber washers inletted in the barrel groove in the stock, and not against the wood of the stock itself, and these washers are probably the reason for the success of this type of barrel band.

The Comb. This subject is sandwiched in between discussions of rifle and shotgun stock design because it is of equal importance to both. A shoulder arm, either rifle or shotgun, is held, steadied, and aligned in firing position by: 1. The Shoulder. 2. The Left Hand. 3. The Right Hand, and 4. The Cheek. The latter is very important. The cheek presses against the left side and comb of the stock and helps considerably to steady the hold. With a rifle this resting of the cheek holds, or should hold the eye in the line of aim. If the eye be not held steady in the line of aim then neither accurate nor steady aim will result. Aim a rifle, and then move or tremble the eye and see what happens. A shotgun has no rear sight, but will be found to center its pattern on the desired spot only when the eye is so placed that it sees the front sight a certain distance above the standing breech or rib of the gun, and therefore the eye becomes the rear sight on a shotgun.

Whether rifle or shotgun, the comb of the stock must be of such height, and the stock below the comb where the cheek touches it must be of such thickness that when the cheek is rested down firmly and naturally on the stock the pupil of the eye comes exactly into the line of aim and is held steady there. The standard stocks as

* It is thought that the reader should pause here to read the chapter on "Jump" in Part II of this work, without which information it will be difficult to visualize the importance of jump in securing the finest accuracy from a rifle.

described here usually accomplish this in a very satisfactory manner. But all men do not have the same thickness of face and jaw, and in a few instances the height and thickness of the standard comb can be altered with advantage, or a cheek piece can be added. But as with custom built stocks such alteration should not be undertaken until the shooter has had much experience and can prescribe the dimensions and shape of the comb himself. A gunsmith can hardly do this for an inexperienced shooter for he cannot tell just how the comb will feel, or how closely the eye will come into the line of aim for that shooter. The highest type of marksmanship: accurate slow and rapid fire with the rifle, and wing and trap shooting with the shotgun, cannot be acquired until the stock fits the face and properly locates the eye, but in the majority of cases the standard stocks as described above and below accomplish this.

Shotgun Stocks

Unlike rifle marksmanship, shotgun shooting the world over has been much the same for almost two centuries. The shotgun user shoots at flying birds, or at clay pigeons thrown to simulate the flight of birds, and he almost invariably shoots in the standing position. Therefore shotgun stocks became more or less fixed and established in design about a hundred and fifty years ago, and there has been comparatively little change since then. Recent intensive study of the subject has resulted only in very slightly increasing the length and decreasing the drop as compared with the usual stock of fifty or a hundred years ago. Volumes have been written about the fit of shotgun stocks, and what is really a very simple matter has been needlessly complicated.

To reiterate what has been said above, there is no rear sight on a shotgun. If a shotgun be aimed using the standing breech or rear of the rib as a rear sight, so that the front sight just shows in alignment, it will seldom be found to be correctly sighted; that is the pattern will not center on the point of aim. A shotgun is correctly sighted when at 40 yards (25 yards for .410 and 28 bores) it places the center of its pattern on the point of aim, or not more than eight inches above the point of aim. Some shooters prefer the gun to pattern a trifle high. Such patterning will usually result when the front sight is seen in alignment a little above the standing breech, possibly one-eighth or one-fourth inch above, so that a partial view of the entire rib is seen when aiming. The exact aim for any gun depends on how that gun's barrel throws its pattern, and can only be discovered by targeting the gun, that is shooting the gun at a paper target and finding just how much front sight and rib must be seen above the standing breech to have the pattern center as the shooter wishes, either on the point of aim or a trifle high. Then the "picture" of front sight, rib, and standing breech so aligned should be memorized.

The pupil of the eye is the rear sight, and it is correctly adjusted when it sees the front sight, rib, and standing breech aligned as determined above. Thus the comb of the stock must be of such height and thickness that when the individual shooter throws his gun to his shoulder, and cuddles his cheek to the stock, his eye or rear sight invariably comes into this position. With practice he subconsciously aligns the front sight or the muzzle of the gun on the mark. *The gun then hits where the shooter looks.* Other than the comb, the other dimensions of the stock need merely facilitate getting the gun quickly and comfortably to the correct firing position so that the cheek cuddles against the stock as it should. For ninety-five percent of our shooters this means a stock 14 inches long with a drop of 2½ inches at the heel and about a 2 inch down pitch of butt-plate. For ninety percent a drop of 1⅝ inches at the comb, with a thickness of comb as found on a majority of our American stocks will be about right. The butt-plate should be at least 5 inches long and about 1½ to 1⅝ inches wide at its widest part. Butt-plates smaller than this, often seen on American shotguns, but never on English, do not distribute recoil well, and are to be deplored. Whether the butt-plate be hard rubber, a soft rubber recoil pad, steel, skeleton steel, or merely checkered wood is purely individual preference. If the stock is on a double trigger gun it is thought best to have it with a straight grip, but for all single trigger guns a pistol grip is much preferred. This then constitutes what may be called the standard American shotgun stock. As with rifle stocks, certain few individuals who differ materially from average stature will benefit considerably by slight small variations from these dimensions which will usually necessitate a custom built stock. A shotgun stock is measured in drop from a line or straight edge which touches the top of the front sight and the top of the standing breech, and not from the determined correct line of aim.

For a double barrel shotgun a majority of skilled shooters prefer a moderately wide beavertail forend rather than the small forend usually seen on such guns. The shape of the forend on repeating and self-loading shotguns is more or less dictated by the tubular magazine which it incloses.

Stock Materials

The great majority of stocks on medium and high grade shoulder arms are made of walnut, and by preference well seasoned walnut of dense grain. Walnut is without doubt the one best all-around wood that has been found for gunstocks, and if it is well figured it can be polished to give an elegant and pleasing appearance. One advantage of walnut is that a skilled stock maker can construct a stock of it to the exact dimensions required at a price that is not prohibitive for most shooters. It and all other woods, however, will shrink, expand, and warp more or less from changes in humidity, and this cannot be entirely prevented.

Good stock walnut is getting scarce and expensive due to the demand for it in the present war. The writer predicts that many stocks of standard dimensions that are made in quantity in the future will be constructed of plastic. Plastic has much to recommend it for this use. It is light in weight, can be made stronger than walnut, and can be given a finish superior to all but the best walnut. It is cheaper to produce in quantity than moderately priced walnut stocks. As the plastic stock is moulded it can be produced precisely as the designer wishes, that is to exact dimensions, to bed correctly, with the finest checkering, and with all the delicate and artistic shaping which could be produced in walnut only at excessive cost. The only objections to it are that it is colder on the face and hands than a walnut stock, but not objectionably so, and it cannot well be altered in dimensions without more or less injuring its fine appearance. Some plastic stocks produced in the past would not stand excessive heat, but it is understood that this slight drawback in early plastic stocks has now been overcome.

As this work is going to press E. I. du Pont de Nemours and Company have announced a new treatment of soft woods, such as pine and spruce, whereby these woods are made almost as hard and strong as steel without greatly increasing their weight. The wood so treated can be given any color desired completely through the piece, and the wood no longer warps, shrinks, or swells. It may be that this process can be used successfully in the making of gunstocks.

Pistol Stocks

An intensive study of pistol shooting may be said to have started slightly after World War I. Certainly modern text books on pistol marksmanship now read very differently from what they did in the days of Winans and Himmelwright. Since then the skill in pistol marksmanship among our master and expert shots has increased many fold. In these newer studies the importance of the grip of the hand, and the uniformity in grip from shot to shot is stressed very strongly. And in this connection all master shots are agreed that the pistol should be balanced on the flesh above the third joint of the second finger.

Since this intensive study started there has been no change in the grip portion of the frame of any of our American revolvers despite the fact that these studies indicated that a change in a cer-

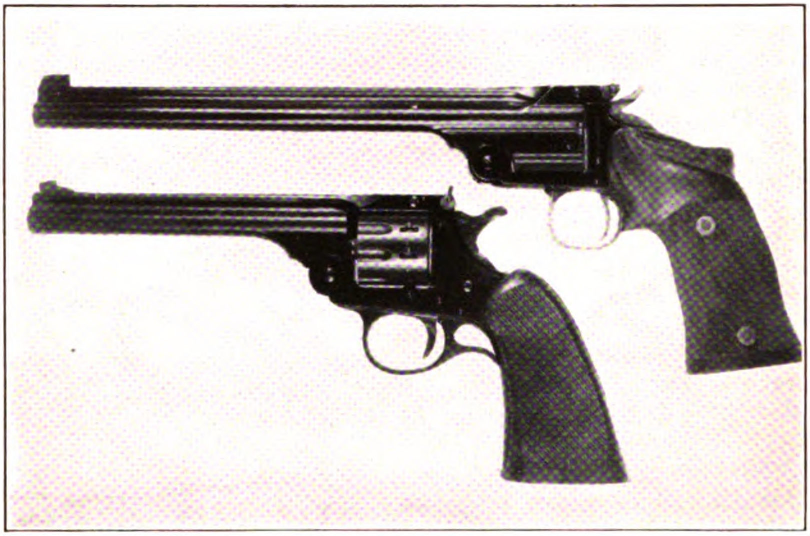

FIGURE 45

With the Harrington and Richardson Single Action Sportsman Revolver a spur has been added at the rear of the trigger guard to correctly position the second finger. The upper cut shows a special stock on the writer's Smith & Wesson single shot pistol, made to fit his individual hand, which has the space in rear of the trigger guard filled in to correctly position the second finger, and also a thumb rest.

tain direction was highly desirable. On all revolvers manufactured today, with but one exception, the frame which outlines the grip is very high in rear of the trigger guard where the second finger is positioned. This portion is as high as the top of the interior of the trigger guard. As a consequence when the frame is rested here on the above finger the grip on the stock is too high; so high that to reach the trigger the forefinger has to be bent or inclined down in an awkward and cramped manner, and cannot press straight back on the trigger as is required for a perfect squeeze. Moreover, when the second finger is held thus high to contact the high frame the revolver does not balance well.

The only exception to this is the frame of the Colt Single Action Army Revolver ("Frontier" model). The lower portion of the frame in rear of the trigger guard, much lower on this than on any other revolver, is largely responsible for its continued popularity notwithstanding that it dates from 1873. But even this grip is by no means as perfect as some writers would have us believe because, while it is very satisfactory for a single shot, the back portion of the grip and its taper are such that, when a shot is fired and the revolver recoils upward, the stock slides through the hand, and the grasp slides up to an entirely too high position on the stock, the uniformity of the grasp being lost. This frame and stock are very good for slow fire where the weapon can be regrasped after each shot, but very poor for rapid fire.

On their better grades of revolvers and single shot pistols the firm of Harrington and Richardson have made an effort to correct this defect by extending a spur of the trigger guard to fill the deep cut in the frame, and position the second finger properly, and have made the stock longer. The result has been a great improvement, but it is merely a makeshift that is rather ungainly. See Figure 45.

To correct this condition in all the other revolvers a majority of our well informed shooters fit hard rubber grip adapters to fill in this high gap in rear of the trigger guard (see Figure 46), but this also is merely a makeshift and is not satisfactory because it has the effect of shortening the stock so that the little finger no longer has contact, and the lower heel of the palm does not position as it should. Other more particular shooters, particularly those who have reached the master classification, have had custom stocks built of walnut to fill in this gap, to lengthen the stock, and to fit their hand precisely. See Figure 47. These custom built stocks provide a guide as to what the design of a stock should be on a modern revolver, and it is hoped that after the present war, when our manufacturers are considering new types for production they can see their way clear to at least modify existing frames so that they will be adapted to such forms of stocks.

It is also thought that manufacturers should provide, as an option to a finished stock, an inletted walnut stock blank made very large overall, and large enough so that if desired a thumb rest can be incorporated. Many shooters not only wish such a rest, but they prefer a stock that will fit all the contours of their hand perfectly, and with such a stock blank they can rasp and file it into a perfect individual fit, or their gunsmith can do so at a minimum cost. At present a custom built revolver stock to exact dimensions costs from ten dollars upwards.

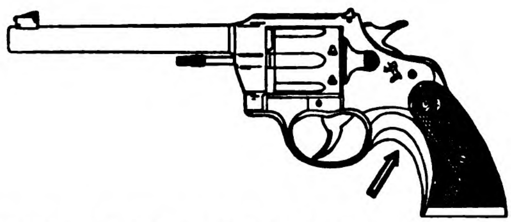

FIGURE 46. GRIP ADAPTER, TO FILL IN THE SPACE IN REAR OF TRIGGER GUARD

Most shooters find the frames on our automatic pistols very good, and the stocks also fairly satisfactory, particularly on the Colt .45 Service Pistol, the Colt Woodsman, and the Hi-Standard Models A, D, and E. These all provide a well located balance surface for the second finger. But here also it would be a great help if large inletted blanks could be furnished so that the individual could form his stock exactly as he desired, and particularly the left side stock should be large enough to be shaped with a thumb rest if desired. A thumb rest stock is optional on the Hi-Standard pistol.

Walnut continues to be the best material for pistol stocks, although any other hard and dense wood would serve as well. Hard rubber and plastic stocks, and also the pearl stocks sometimes seen are too slippery, particularly in warm weather. Ivory is better, but not as good as walnut and very expensive. Checkering is believed to be a decided advantage on a pistol stock.

Rifle Sights

Sights on small arms are used to align the barrel on the object that it is desired the bullet shall strike, and also should be capable of being adjusted so that the object can be struck at different distances and under various weather conditions when normal aim is taken. There are many types of sights, and their relative excellence from a ballistic point of view may be said to be measured by the accuracy with which they can be aligned and adjusted.

There are two general types of sights; *Iron Sights* or those which do not contain glass, and *Telescope Sights*. Each type is again di-

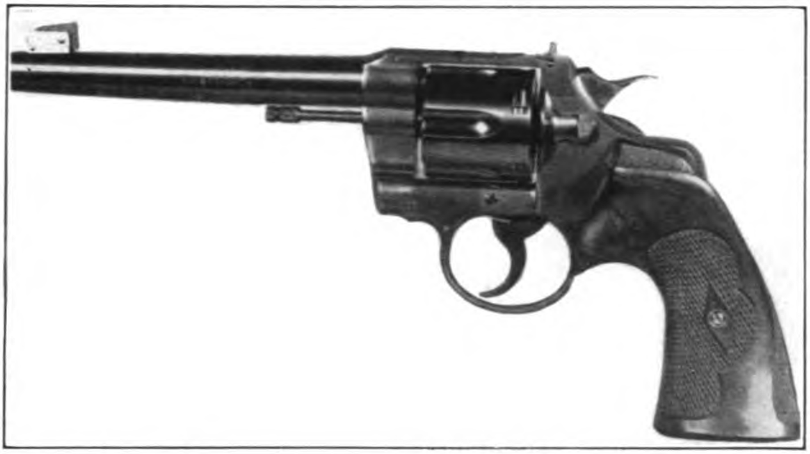

FIGURE 47

A special Roper stock on a Colt Officers Model Revolver, with space in rear of trigger guard filled, and a thumb rest which many shooters find very desirable and helpful. In post-war production it is thought that all hand guns should be furnished optionally with well inletted, large, blank stocks which the owner can rasp down to fit his individual hand and shape to his desires, including the filling in rear of the trigger guard and the thumb rest.

vided into many forms, but it will here serve our purpose to merely divide iron sights into *Open Sights* and *Peep Sights.*

The selection of sights for any particular purpose, the method of aligning them, and their use in war and sport belongs properly in a work on marksmanship. We are here chiefly concerned with their accuracy of alignment and adjustment for on these depend the value of the ballistic performance. In the realm of exterior ballistics if the alignment be crude the results will be crude and more or less worthless.

The acuteness of eyesight differs in individuals, but generally speaking it is assumed that the unaided eye cannot resolve an object smaller in diameter or thickness than one minute of angle. One minute subtends approximately one inch at 100 yards, or .003-inch at one foot. Thus with iron sights, where the eye is unaided in aiming, we will have errors of alignment up to one minute, and if rifle and ammunition will consistently group in one minute, or one inch for each hundred yards when no aim error is present, if the rifle be aimed with iron sights the groups resulting will average two minutes in spread, or two inches per hundred yards. Similarly if we do not use some mechanical aid such as a micrometer or vernier to adjust our sights, but instead use a simple scale, we cannot read that scale closer than one minute or .003-inch, and our error of adjustment will also at times be as large as one minute which equals one inch per hundred yards.

The resolving power of a telescope sight depends on its magnification, on the diameter of its object lens, and on its optical perfection; but generally speaking in a clear atmosphere it may be assumed that the resolving power is equal to one minute of angle divided by the magnification of the scope. Thus with a telescope sight of 2½ power the maximum error of aim would be about .4-minute, or with a 20 power instrument about .05 minute. Or when aiming with a 20 power telescope sight we would expect that our rifle and ammunition capable of grouping in one minute would average 1.05 inch groups at 100 yards when fired from a bench rest with all errors except the error of aim eliminated.

But this is not the whole story because accuracy of alignment of sights also depends upon the character of the target on which we aim, the light, the direction of light, the mechanical principle used in the alignment, and always on the acuteness of vision of the shooter. These can best be explained by referring to the sketches shown in Figure 48.

Sketch A shows the alignment of the common and crude open sights usually seen on commercial rifles. The accuracy of alignment in a series of shots depends upon how consistently the shooter can align the front sight in the exact center of the rear sight notch and with its top showing a precise amount above the bottom of the notch; on the perfection of each of his alignments on the bullseye, and on what change will occur in his efforts to do these things consistently if a change occurs in the intensity or direction of light (sunlight). Many years experience with such sights has shown that when aiming at the conventional bullseye target in consistent light the maximum error of aim is at least three minutes. When light changes during consecutive aims the combined error approaches six minutes. While such errors might not be prohibitive when the target is the body of a deer at a short distance, they are most unsatisfactory where any greater degree of accuracy is desired. Rifles are generally equipped with such sights because they are cheap, and they reduce the sales price of a rifle of one manufacturer to the point where it will compete with that of another manufacturer. Also the errors of aim are not so great as the errors of a shooter not trained in marksmanship. Or as one old rifleman put it many years ago; "It makes no difference what kind of a sight a gunmaker puts on a rifle. A good shot will knock it off and fit one to suit himself."

Sketch B shows a modern refinement of open sights. The front sight is a flat top post with parallel sides. The rear sight has a flat and level top, and the notch is large and "U" shaped or square. In shooting both sights are blackened by smoking them so they present a dead black silhouette against the white surface of the conventional target, and reflect less light back to the eye, with a minimum of glimmer. In aligning such sights the marksman endeavors to have the top of his front sight just touch the bottom of the black bullseye, and to see the front sight in the center of the notch with its top just even with the flat top of the rear sight. This he can do more consistently than with the sights shown in Sketch A, but in each of these efforts he is limited by the errors of the unaided eye, so that the average error is about 2 minutes in consistent light, and in varying light about 4 minutes.

Our army rifles (Krag and Springfield) used to be equipped with a rear sight which permitted the use of a sight combination similar to this and a peep sight as well. The writer can recall only one man who won a place on the Army Infantry Rifle Team after 1903 using the open sight, and this man discarded its use as soon as he learned the superiority of the peep sight. This form of sight (Patridge), however, still remains the most satisfactory known for a revolver or pistol where that weapon is held in the hand and aimed in the usual manner, for the reasons given below.

Sketch C shows a flat top post front sight used in connection with a peep rear sight. The construction of the peep sight is such that the edges of its aperture are in shadow and shaded from light rays that might illuminate one portion of the edge of its circumference more than others, so that centering the top of the front sight in the peep is not influenced by the direction and intensity of light. Also the human eye apparently has a natural aptitude for centering objects, and can center the front sight more accurately than it can determine if it is equidistant from both edges of an open rear sight notch. In addition a small peep hole has the orthoptic effect of making objects seen through it appear in better focus. Punch a pin-hole in a sheet of paper, hold the paper close to the eye, and see how much more clearly objects appear through the peep than when viewed normally. In practice the peep sight should be as close to the eye as practicable without danger of its recoiling into the eye when the rifle is fired from different positions.

There is thus very little error in aligning the top of a front sight in the center of a rear peep sight, but there still remains the error of trying to touch the top of the front sight to the bottom of the bullseye alike every time. Long experience has shown that the average aim error in consistent light with such sights is about 1¼ minutes, and that when the front sight is smoked black this error combined with the error introduced by changing light is not more than about 2½ minutes. This combination of front and rear sight is now used on our most modern military rifles (Garand M1 rifle and Winchester M1 carbine) and has proved very satisfactory in the military service.

Sketch D shows a rear peep sight used in conjunction with a hooded aperture front sight. Here we have the advantages of a peep sight applied to the front as well as the rear sight. The bullseye is centered in both sights, and the error is less than when we attempt to touch the top of an open front sight to the bottom of a bullseye. Both sights are shadowed from the effect of a varying light source. Under best conditions the error of aim is not more than about half a minute, the orthoptic effect operating to increase the acuteness of the eye. Using such sights and minute of angle rifles, hundreds of small bore riflemen have recorded ten shot possibles on the 2-inch ten ring of the 100 yard target. However, such sights can be used successfully only when aiming at the conventional black and white bullseye target where they are seen in clean cut silhouette against the white surface. Clear and distinct aim cannot be obtained on natural targets, but against bullseye targets they do give results accurate enough to be of value in ballistic experimental work.

Sketch E illustrates a 2½ power hunting telescope sight with a flat top post reticule. The flat top post of similar appearance as the iron front sight gives similar errors of aim, but here reduced by the magnification of the scope to about .4 minute.

Sketches F and G show aim with a high power target telescope sight with medium fine cross-hair reticule, aim being taken on spe-

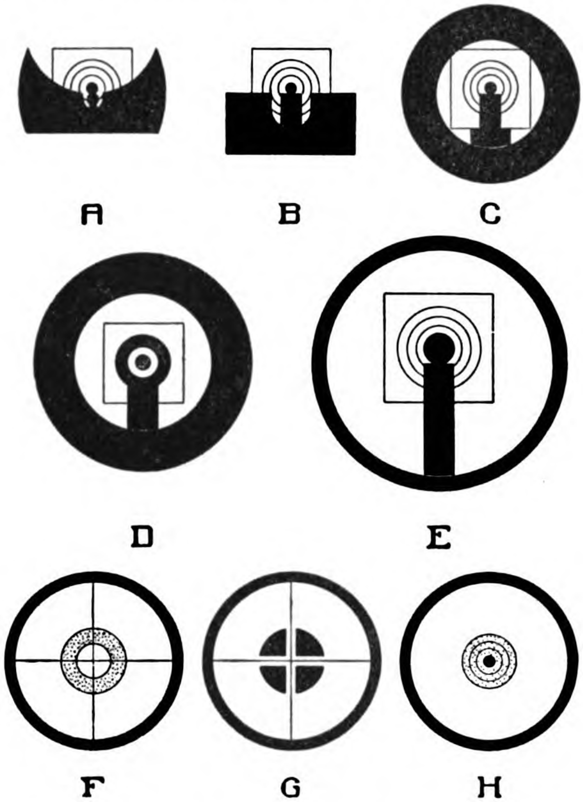

Figure 48. Rifle Sights and Sighting Principles

With special reference to accuracy of aim.

A—Regular bead front sight and open "Rocky Mountain" rear sight, commonly fitted to ordinary and inexpensive American sporting rifles. Crude adjustment for elevation only. No sure guide to accurate alignment which is much affected by sun shining on the sights from various directions. Large errors of aim are frequently present, particularly when aim is hurried. Good enough for a shot at a deer up to 75 yards or a squirrel to 25 yards, but hopelessly inadequate for really accurate shooting or ballistic experiments.

B—The best open sights. A wide flat top post front sight and a flat topped open rear sight. The top of the post is aligned level with the flat top of the rear sight and the post is in the center of the notch. A similar combination, with square instead of "U" shaped rear sight notch, called "Patridge" sights, is the best for revolvers and pistols. Alignment often influenced by sunlight from various directions, but this can be reduced by undercutting the rear surfaces of both sights, throwing them into deep shadow, and making all sighting surfaces and edges sharp.

cially prepared targets, F—a black bullseye with white center, and G—a black bullseye with white cross intersecting it. On both of these targets the eye can center the cross-hairs on the bullseye with considerable accuracy, and the errors of aim are reduced to about .10 to .05 minute, provided of course that the rifle can be held that steadily on the bench rest.

Sketch H is a target scope of high magnifying power fitted with a T. K. Lee center dot reticule, the dot centered on a gray or light blue bullseye. Keen eyes can also center it equally well on a black bullseye which is dull enough in color to appear a trifle gray. Accuracy of aim closely approaches the cross-hair reticule, probably with less eye strain.

C—The most practical rifle sighting system for service. A flat top post front sight in combination with an aperture rear sight close to the eye. The top of the post is aligned in the center of the aperture, and the top of the post just touches the bottom edge of the bull's-eye. The most practical iron sights for military service and hunting, but there is a rather unavoidable error of aim which may amount to as much as one minute, and this may be increased another minute by variations in light.

D—American target sights. An aperture front sight in combination with an aperture rear sight. Suitable for use on conventional bull's-eye targets only. The bull's-eye is aligned in the center of the front aperture, and the latter in the center of the rear aperture. The error of aim with keen sighted individuals is not more than 1/4-minute, and provided that the sights are dead black and shaded, alignment is little affected by light. When eyesight is keen such sights are suitable for ballistic experiments on bull's-eye targets.

E, F, G, and H show reticules of telescope sights.

E—A flat top post reticule very satisfactory for military service and big game shooting, particularly where the aim must be quick, on targets in poor lights, or against a dark background. The flat top post is aligned just touching the bottom of the bull's-eye. There is usually an error of aim of about 1/4-minute with this form of reticule using telescope sights of 2 1/2 to 4 diameters magnification.

F and G—Fine cross-hair reticule aligned on a bull's-eye having a white center, and on a bull's-eye quartered by broad white lines. These, together with H, are the most accurate aiming systems. Resolving power is dependent to a large extent on the magnification of the telescope, and on the size of the objective lens. A telescope sight of at least 12 power is desirable for the finest ballistic experiments, and 20 power is better and about ideal.

H—The Lee center dot reticule gives exceptionally accurate alignment on a bullseye which has visible scoring rings in which to center it. Very excellent for target shooting and experiment. For military service and hunting F and G (and H unless it subtends at least four minutes) are sometimes invisible against dark targets, targets in deep shadow, dark backgrounds, or in poor lights.

It should be understood that the estimate of aim errors given in the above instances are approximate only. The greatest varying factor is the keenness of eyesight. However, it is remarkable how close they approach the errors that our best riflemen obtain in practice with each type of sight.

Sight Adjustment. To utilize tables of angles of elevation and wind deflection for a known cartridge, or to determine such tables for an unknown cartridge by experimental firing it is necessary that the rear sight or telescope be adjustable in range and azimuth to minutes of angle. In competitive rifle shooting a still greater refinement of adjustment to quarter minutes of angle is very desirable so that the marksman can positively center his point of impact on the center of the bullseye and thus obtain the highest count for his score. To obtain such adjustment with positiveness and reliability, and to read and record the adjustments with the naked eye, the micrometer or vernier system of adjustment must be used. Very satisfactory iron rear sights, and telescope sight mountings employing such adjustments are now manufactured.

To sum up the above, if we employ the D, F, G, or H combinations of sights with quarter minute adjustment we practically eliminate errors of aim and sight adjustment. We can then determine reliably enough for all practical purposes the errors and capabilities of rifle and cartridge, the trajectory, and the wind deflection. In other words we can solve all the important ballistic problems. And if we use the rifle in competitive shooting we can obtain the highest score that the rifle, ammunition, and our skill are capable of.

The question will naturally arise "Why not use a machine or mechanical rest in connection with ballistic problems or accuracy tests?" A gun shoots very differently in a machine rest from what it does in a shooters' hands; that is, its jump and location of centre of impact are usually quite different. There are many ballistic problems in which we desire to determine what the results will be *in the shooter's hands* and the machine rest will not give us this answer. There is only one machine rest which will give absolutely reliable results in an accuracy test, free from human and mechanical errors. This is the Mann "V" rest used in connection with a heavy Mann barrel. It tells us what the ammunition will do in a very heavy and more or less perfect barrel, but not what a practical rifle will do, or what the ammunition will do in a practical rifle. There is one machine rest, the Woodworth Cradle, which will give quite reliable results with a high power rifle, but this cradle has been made only for the U.S. Rifle, Caliber .30, Model 1903, and so far as the writer knows, only four or five of these cradle rests are in existence. However, a number of machine rests have been made that are very satisfactory with .22 rim fire rifles, and the smaller low power rifles. Machine rests will be discussed in more detail in Volume II. Therefore, it is not practical to eliminate sights and man-held guns from many ballistic problems.

Sight Attachment. On the usual American rifles that are produced in quantity the common method of attaching the sights is by means of dovetail slots in barrel and receiver. The sight itself is constructed with a male dovetail base which is driven into a female dovetail slot in the rifle and held there by being a driving fit plus friction. This is a crude method, usually fairly satisfactory with sights of light weight and bulk, but always liable to be driven out of alignment by a blow or loosened by recoil. Certainly the common barrel dovetail slots should never be used as a basis for the attachment of telescope sight mounts.

The better front sights are made in the form of blades, and are driven into a longitudinal slot in a front sight ramp which is made integral with the barrel, and are then pinned there. A screw instead of a pin would facilitate interchanging front sights which is sometimes desirable. The best rear sights are screwed to the receiver, but usually the screws are not nearly as large or strong as they should be. The modern rear sight is quite heavy and has such inertia that the recoil strain is rather severe. As between securing such a sight with two small screws, and with a very large and wide dovetail, two methods which are used on the Winchester Model 52 Match Rifles, the latter is much preferred. Screws are liable to loosen from recoil and vibration, and their threads should be accurately cut and they should be kept set up very tight. If a telescope sight is rigidly mounted on a rifle with a dovetail base the base should be very long and wide, at least four inches long, and the male dovetail should be at least half an inch wide, and the female dovetail should clamp to the male by pinching in on its sides and clamping down, and not by pressing on the top and clamping up. There must be two clamps, as far apart on the base as possible, and the fixed base should be pinned and screwed very securely to the receiver. The original Niedner mount is an excellent example of what a bracket mount should be, except the base is not long enough or wide enough. This ideal bracket mount would not be popular with many shooters because of its size and weight, but nevertheless it is indicated for absolute reliability.

Of course the best method of attachment is to have the sight bases milled from the barrel and receiver metal, or firmly welded thereto, methods which are generally used on the best military rifles.

Shotgun Sights

Commonly there is but one sight affixed to a shotgun—the front sight. There are a few shotgun shooters who contend that a front sight is not necessary, that it is seldom seen in wing shooting, and that the muzzle of the barrel alone provides a sufficient sight to align with the eye and mark. But most of the deeper students of shotgun shooting believe that if the front sight be sufficiently visible and in evidence the subconscious mind will always use it in aiming, although the shooter may not be conscious of it, and that with such a sight the aim will be more accurate and the pattern better centered on the target than if no sight were used. The usual small brass stud front sight seen on most shotguns does not intrude itself on the subconscious mind, and is little better than no sight at all. It is therefore thought that a shotgun should have a large ivory or red bead front sight at least 1/8 inch in diameter, or else the still larger Nichols Bevel Block front sight.

The small Lyman sight on the rib half way up the barrel is probably not a disadvantage, and it may be an advantage to the shooter whose psychology is such that he thinks it is a help.

In recent years telescope sights without any magnification and consequently very large field, with large exit pupil, great latitude of relief, and a three minute center dot reticule (Weaver) have been employed to some extent on shotguns. From many experiences it must be conceded that many shooters can learn to use such a sight, and do first class wing shooting with it, although a longer period of practice is probably necessary than with the usual sight. Such telescopes certainly give a very clear and distinct aim. The old shooter is usually opposed to the telescope on general principles, but is really not competent to express an opinion on it until he has used it extensively. It would seem to be indicated particularly for those shooters who, by reason of certain defects of eyesight, have trouble in getting a distinct view of their targets.

Pistol Sights

A pistol or revolver has no stock, and there is no comb to hold the eye steady in the alignment of bullseye, front sight, and rear sight. Consequently there is a continuous tremor to the line of aim, depending in its extent on the ability of the shooter to hold steady. The successful pistol shooter by practice acquires ability to minimize this tremor. He may even arrive at the point where the diameter of his tremor does not exceed the diameter of the 10-ring on the target. Then, while the tremor is thus confined, he increases his squeeze on the trigger so that the weapon discharges unexpectedly. The result is that his group of shots is confined to a circle the diameter of his tremor plus the radius of the shot group that would be obtained were the weapon fired from a steady rest with errorless aim. This is the modern theory of accurate pistol shooting.

Peep sights cannot be successfully employed on a handgun because the tremor is continually blotting out the shooters view of front sight and bullseye. The shooter must see the tremor continuously in order to reduce it by steady holding, and he can only do this with open front and rear sights.

The experience of our master pistol shooters has pretty conclusively proved that the best handgun sights are a broad flat top post front sight and a flat top rear sight with a wide square notch, known as Patridge sights, and shown in Sketch B, Figure 48. The front sight should be very wide, perhaps as wide as 1/8 inch. The width of the notch in the rear sight depends on the length of the shooter's arm—that is on how far the sight is from the shooter's eye when aiming. Its width should be such that a "ribbon" of white target is visible on either side of the front sight, showing perfect centering of the front sight in the notch. The skilled shooter can use a much narrower notch than the beginner whose tremor will be larger, and who will have difficulty in the "ribbon" blotting out continually on one side or the other due to his larger tremors.

Sight Adjustment. With a pistol the location of the center of impact will always vary according to the load used (not so much from trajectory as from jump), and the tension with which the shooter holds the weapon. The line of aim will also vary slightly with different shooters. The correctness of sight adjustment for any individual shooter can never be determined with exactness until that shooter has become fairly skilled in steady aiming and holding, trigger squeeze, and uniformity of gripping the weapon.

For these reasons the sights on a handgun should always be adjustable. A very satisfactory and common method is to have the front sight adjustable for elevation by means of an inclined ramp or wedge, and a screw that forces it up and down on this wedge. The rear sight can then be made to adjust in azimuth or windage by means of a dovetail slot and screw. Both screws should be cut with such threads that one complete revolution of the screw head moves the line of aim ten minutes, or one inch over a ten yard range.

CHAPTER VII

Ammunition

Introductory

IT IS the ammunition that determines the "ballistics" or shooting properties of a small arm. The arm being suitable for the cartridge, it is the latter that gives the velocity, penetration, trajectory, wind deflection, and killing power. Thus it is not entirely proper to state that a certain small arm has such and such a velocity, range, or penetration, for these properties depend rather on the cartridge. Nor would we be safe in assigning certain attributes to the .22 cartridge or the .30-06 cartridge without being more specific, because there are dozens of different types of these cartridges varying greatly in their properties. Therefore it is thought that a study of ammunition design, as well as small arms design should precede the study of ballistics, as they are, in one way, the basis of that science. And in this study the first step is the terminology and nomenclature of the cartridge.

Modern ammunition for small arms consists of what is termed **fixed rounds,** that is cartridges or shells in which all the components —primer, powder, bullet or shot, and the inclosing case or shell— are assembled in one round which can be loaded in one motion into the weapon.

Small Arms ammunition is further divided into two classes; **metallic ammunition,** largely for rifles and pistols, where the case is made of brass, copper, or mild steel, and the projectile is a single metal bullet—that is both made of metal; and **shotgun shells** where the case is constructed partly of paper, and the projectile is one or many pellets of lead, called shot.

Caliber. The most common way of describing a cartridge or shell is to state its caliber, that is the diameter of its bullet, or the diameter of the bore of the arm in which it is used.

At the beginning of the nineteenth century the caliber or size of cannon was designated by the weight of the round individual cannon ball, in pounds. Thus cannon were called "12 Pounders," "50

Pounders," and so on. The caliber of small arms was likewise designated, according to how many round lead balls, which fitted the bore, would weigh a pound. Thus a 12-bore or 12 gauge small arm was one of such size of bore that twelve of the balls which just fitted that bore weighed a pound. These terms were originally used to designate the caliber and size of ball of shotguns, rifles, and pistols alike, and today this manner of designating the caliber by "bore" or "gauge" still persists in the case of shotguns and their shells, although it has fallen into complete disuse with respect to rifles, pistols, and their cartridges. The various bores or gauges, and their actual diameter in inches is as follows:

Modern Shotgun Gauges

4	bore or gauge	(4 ounce)	.935-inch
8	" "	(2 ounce)	.835 "
10	" "		.775 "
12	" "		.729 "
16	" "	(1 ounce)	.662 "
20	" "		.615 "
28	" "		.550 "
.410	"	(67½ gauge)	.410 "

Early Rifle Gauges *
(Round lead balls to the pound)

10—.790″	26—.575″	60—.437″	210—.288″
11—.760″	27—.572″	64—.416″	220—.284″
12—.748″	28—.559″	70—.400″	230—.282″
13—.727″	29—.549″	80—.388″	240—.280″
14—.708″	30—.533″	90—.383″	250—.278″
15—.695″	32—.530″	100—.364″	260—.274″
16—.682″	34—.519″	110—.350″	270—.2715″
17—.665″	36—.506″	120—.340″	280—.269″
18—.647″	38—.491″	130—.332″	
19—.637″	40—.485″	140—.324″	
20—.628″	42—.4805″	150—.318″	
21—.618″	44—.474″	160—.310″	
22—.609″	48—.463″	170—.305″	
23—.601″	50—.458″	180—.298″	
24—.588″	52—.453″	190—.292″	
25—.585″	56—.442″	200—.290″	

Shortly after the rather general adoption of conical bullets to replace round balls in rifles and rifled-pistols, the above method of designating caliber and bore was dropped and instead the caliber

* From "The Kentucky Rifle" by Captain John G. W. Dillin.

was designated in terms of diameter of bore. In the United States we quite generally designate the caliber by stating the diameter of the bore of the rifle or pistol, or the diameter of the bullet in hundredths of an inch, although in the past twenty-five years it has become quite common to express it in thousandths of an inch. Thus we have .22, .25, .270, .30, .35, .375, .38, or .45 caliber rifles, pistols, and cartridges.

In England calibers of rifles, pistols, and their cartridges are now almost always designated in thousandths of an inch, as .220, .303, .450, etc. The larger elephant rifles, however, continue to be designated on the gauge system, as 4 bore, 8 gauge, 10 bore, etc. On the continent of Europe the decimal system is used as, 6.5 mm, 7 mm, 7.62 mm, 9 mm, etc.

The question naturally arises; exactly what diameter is referred to in designating caliber—bore diameter of barrel, groove diameter of barrel, or diameter of bullet? Generally speaking the caliber figures refer to the bore diameter of the barrel. This is pretty generally true as regards English and German calibers, but there are many exceptions in the United States. Thus while we have in America many revolvers, pistols, and cartridges for them that are called ".38 caliber," there is not a single one which even closely approaches .38 caliber. All have a bore diameter of approximately .35-inch, and a groove and bullet diameter of approximately .357 to .358-inch with one single exception, the .38-40 W.C.F. cartridge and revolvers for it, the bore diameter being .394-inch, and the groove and bullet diameter .400-inch. The .44-40 W.C.F. rifle and cartridges for it have a groove and bullet diameter of .429-inch. Why these differences, no one now knows.

Metallic cartridges are divided into **Rim Fire** and **Center Fire.** For a detailed description of these two forms of ignition see the next chapter. The rim fires were the first successful metallic cartridges for rifles and revolvers, and were developed about the time of our Civil War. At first all the bullets were what are called **outside lubricated;** that is the case was almost a true cylinder from base to mouth, and the *bearing* of the bullet (that portion which the lands cut into) was approximately the same diameter as the outside of the mouth of the case. The bearing had shallow grooves, or **cannelures,** and was covered with a film of lubricating grease or wax. Then the bullet had a smaller diameter or *"heel"* at its base, to which the mouth of the case was crimped to make the bullet secure in the case. See Figure 49. The construction and assembly was exactly the same as we see in the .22 Long Rifle cartridge of today. Outside lubricated cartridges were unsatisfactory to carry in the pocket or belt as the grease became rubbed off, and also the grease picked up dirt, so it became the custom later to seat the bullet deeper in the mouth of the case so that the cannelures containing the lubricant were completely covered by the case mouth, and these were called **inside lubricated.**

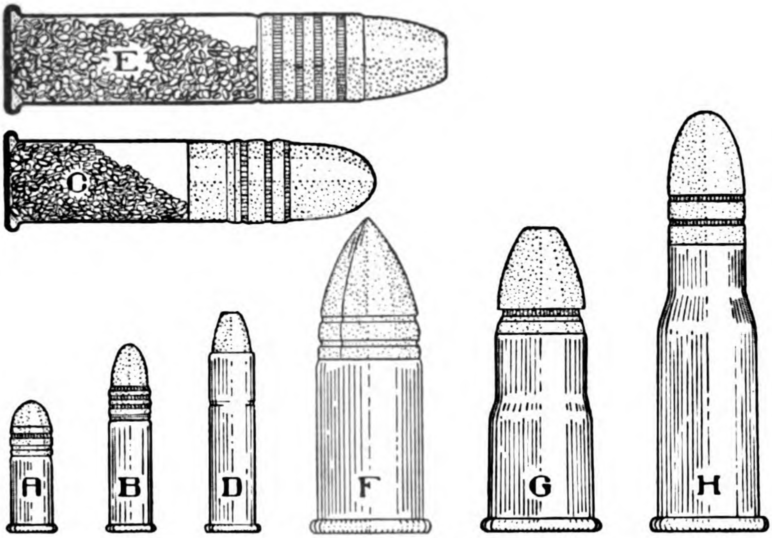

FIGURE 49. RIM FIRE CARTRIDGES

A—.22 Short. **B**—.22 Long Rifle. **C**—.22 Long Rifle, sectionalized, enlarged. **D**—.22 Winchester Rim Fire. **E**—.22 Winchester Rim Fire, sectionalized, enlarged. **F**—.56 Spencer. **G**—.56-46 Spencer, the first bottle necked cartridge. **H**—.41 Swiss, the heaviest rim fire cartridge.

Sketches **D** and **E** show inside lubrication. All the others are outside lubricated.

Stampings on the bases of rim fire cartridges are:—"U" for Remington, because the cartridge making branch of that firm was originally the Union Metallic Cartridge Company; "H" for Winchester, because that Company originally bought out the Henry Rifle Company; "P" for Peters; and a diamond for the Western Cartridge Company.

One of the first large-caliber rim fire cartridges was that for the Spencer repeating rifle used in our Civil War. This rifle was originally made in .56 caliber, and the .56 Spencer cartridge had an outside diameter of case and bullet of that caliber, with the case almost straight from base to mouth, and loaded with 45 grains of black powder and a 350 grain bullet. Then the manufacturers decided that they would produce the rifle also in smaller calibers, and in order to use the same breech action they retained the base diameter of the .56 case but necked the mouth of the case down to hold the smaller bullet, and thus was produced the first bottle necked cartridge. Thus there appeared the .56.52, .56.50, and .56.46 Spencer cartridges, all loaded with 45 grains of black powder, but with .52 .50, and .46 caliber bullets weighing respectively 386, 350, and 330 grains.

While rim fire cartridges were cheap to produce they had one serious limitation. The rim of the case had to be thin so as to contain the priming mixture, and also so as to be easily indented, and the priming mixture crushed by the blow of the firing pin. This made the case relatively weak, so that it would not withstand the high pressures given by large charges of powder and heavy bullets. The heaviest rim fire cartridge that was regularly manufactured was the .41 Swiss, adapted to the Vetterlin and other Swiss rifles. It was loaded with 55 grains of black powder and a lead, outside lubricated bullet of 310 grains, and had a bottle necked case. See Figure 49. In 1900 this .41 Swiss cartridge cost $3.00 a hundred rounds, and other rim fire cartridges were similarly low in price. Today the little .22 Long Rifle cartridge costs only seventy to ninety cents a hundred. Thus the advantage of the rim fires was low cost, and the disadvantage was that they could not be used for powerful loads.

The demand for more power and longer range in rifle cartridges led to the invention and adoption of the center fire cartridge about 1870. The primer or cap is made separate from the case, and is seated in a pocket in the center of the head of the case, and will stand very much higher pressures than will the rim fire case. Center fire cartridges are much more expensive to make than rim fires, costing from three to ten times as much.

When center fire cartridges were introduced, someone in America conceived the idea of designating them by three numbers, the first being the caliber, the second the number of grains of black powder, and the third the weight of the bullet in grains. Thus we have the .45-70-500 cartridge for the Springfield Rifle, Model of 1873, which rifle had a bore diameter of .45-inch, and a groove diameter of .457-inch. The bullet measured .457-inch, and the cartridge was loaded with 70 grains of black powder, and an inside lubricated lead bullet of 500 grains. See Figure 50. Other popular black powder rifle cartridges designated by the three numbers were the .25-20-86, .32-40-165, .38-55-255, .40-82-260, .44-40 W.C.F., .45-90-300, etc.

Soon there came a demand for different weights of bullets in certain cartridges. For example, the .45-70-500 cartridge came to be loaded with bullets weighing 300, 330, 350, and 405 grains, and therefore cartridges of this caliber gradually became to be known generally as .45-70 cartridges, and the numbers .45-70 were stamped in the head of the case, together with the initials of the factory making the cartridge, and the only way to tell the weight of the bullet that the cartridge was loaded with was to look on the paper carton in which the cartridges were packed, or, of course, to weigh

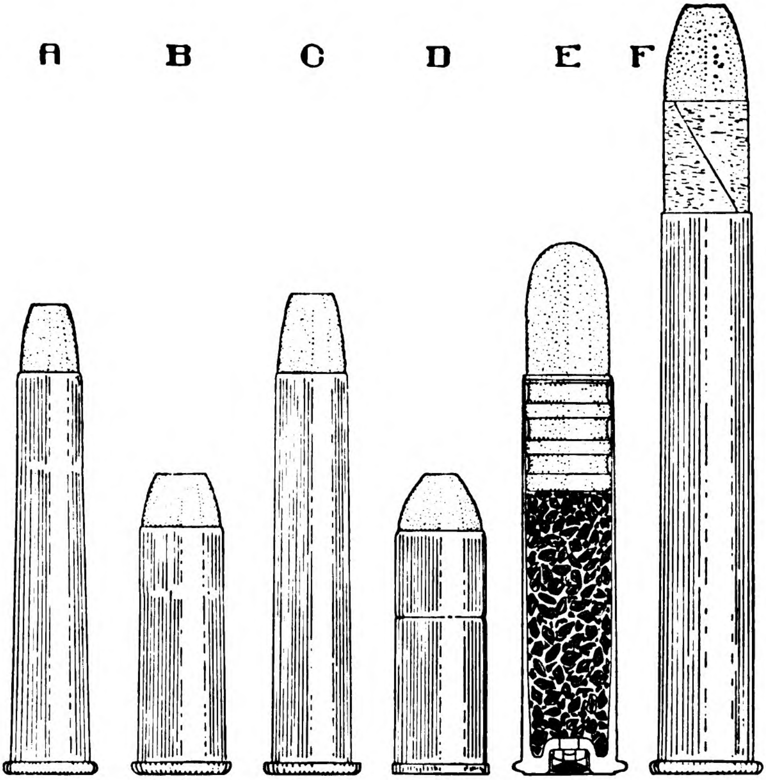

FIGURE 50. THE OLDER CENTER FIRE BLACK POWDER CARTRIDGES

A—The .32/40/165, a popular and famous target cartridge of the last century and one which made some outstanding accuracy records.

B—The .44/40 W. C. F., or .44 Winchester, one of the pioneer center fire cartridges, used in both rifles and revolvers.

C—The .38/55/255, a companion cartridge to the .32/40 very popular for both target and hunting in its day.

D—The .45 Colt, a revolver cartridge designed back in the '70s for use in the Colt single-action Army revolver. Note the rather inadequate rim to this case; the revolver for which this cartridge was originally designed ejected its fired cases one at a time by means of an ejector rod punching them out from the inside, the rim was merely for positioning the case in the cylinder, which they designed as compactly as possible. Yet to this day, the cartridge manufacturers have been unable to add much to the rim of this .45 Colt case, for fear such cartridges would not seat to capacity in these old single-action Colt revolvers, of which many thousands are still in use throughout the country. However, in 1909, when the U.S. Army purchased a supply of Colt double-action revolvers for use in the Phillipines they made up their own special .45 Colt cartridge with much wider the cartridge. All of these cartridges with various weights of bullets could be shot in rifles originally made for the .45-70-500 cartridge. There were a number of other cartridges which were similarly loaded with various weights of bullets, and indeed this practice has become quite common in recent times. About this time also, rifle and revolver manufacturers started to stamp the name of the cartridge that the rifle or revolver was chambered for on the barrel of the weapon, but usually they stamped only two numbers, as .38-55, instead of .38-55-255.

There were a few exceptions to this system of designating cartridges by three or two numbers. Thus early in the black powder period the Sharps Rifle Company brought out their .45 caliber long range rifles to use cartridges of varying lengths of cases, so they could be loaded with different charges of black powder. Thus there were various Sharps cartridges called by the length of the case, as .45 Sharps 2⁴⁄₁₀, .45 Sharps 3¼, etc. The Sharps Rifle Company usually stamped these numbers on the bottom of the barrels of their rifles just in front of the tip of the forearm to show what cartridge the rifle was chambered for, as ".45-3¼." But sometimes the manufacturer did not stamp the name of the cartridge on the rifle, and where this happens there is now liable to be a great deal of difficulty in telling just what cartridge that unmarked rifle takes. Perhaps the only sure way of telling is to make a sulphur cast of the chamber of the rifle, and compare this cast with samples of the older cartridges that appear to be about that size.

About 1885 British rifle and cartridge makers began to load some cartridges with relatively large charges of black powder and a relatively light bullet to give them higher velocity and a flatter trajectory, and they called these cartridges Express Train cartridges

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rim, known officially as the .45 Revolver Ball Cartridge, Model of 1909. These latter will not function in the old, single-action revolver unless loaded into alternate chambers.

E—.45/70/500 U.S. Gov't, sectionalized. Note that the charge of black powder completely fills the case, which is the rule with black powder cartridges. If the black powder does not entirely fill the powder space (that is, if any air space is left) the fouling deposited in the bore will be very excessive. With smokeless powder cartridges, however, the powder does not *usually* fill the powder space, for if it did the pressure would often be excessive.

F—The old .45-120-550 Sharps Straight cartridge with paper patched bullet. Loaded with black powder. Prior to 1900 this was our best cartridge for 1,000 yard match shooting. It was also much used by the latter day buffalo hunters, and was the cartridge used by Colonel Pickett, the famous Grizzly bear hunter. When used for target shooting the bore of the rifle was cleaned and wiped dry after every shot.

because of their greater speed. Formerly, black powder rifle cartridges loaded with regular charges of powder and heavy bullets did not give muzzle velocities much in excess of 1450 feet per second, but some of these Express Train cartridges were given velocities as high as 1900 f.s. In attaining these higher velocities the British makers were helped by their superior black powder. Their Curtis and Harvey No. 6 black powder was a very clean burning powder of such strength that 90 grains of it would give the same velocity to a bullet as 120 grains of the usual American FG black powder. Soon the term Express Train came to be abbreviated into "Ex-

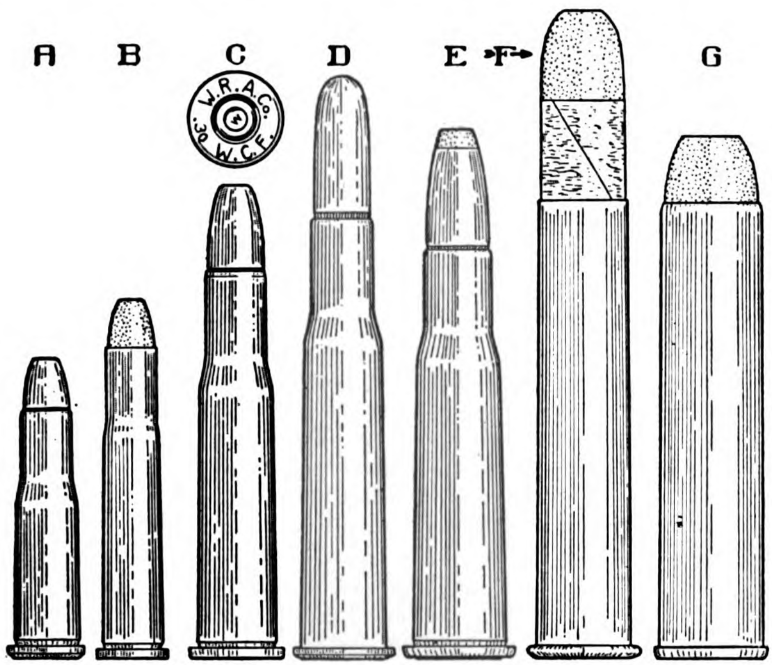

FIGURE 51. COMMON AMERICAN RIFLE CARTRIDGES WITH RIMMED CASES

A—The .25-20 Repeater cartridge, also called the .25-20 Winchester.

B—The old .25-20 Single Shot cartridge, the fore-runner of A. A was shortened so it could be made to operate through the Winchester Model 1892 breech action, and the body was increased in diameter and made more bottle-necked so it would contain more powder. Actually A has about three grains less powder capacity than B.

C—The famous ".30-30" cartridge originated by Winchester and called by them the ".30 Winchester Center Fire." A very popular cartridge for deer rifles. Not adapted to any military rifles.

D—The .30-40 Krag cartridge, officially called the "Ball Cartridge, Caliber .30, Model 1898." Our first high power smokeless cartridge adapted press." Thus in England the term Express meant merely high velocity, that is a higher velocity than had commonly been obtained in black powder arms. In America we also developed express cartridges in various calibers, but we could not attain quite the velocity of the English cartridges because of the limitations of our black powder. Our express cartridges were commonly loaded with light bullets, having a hollow or hole in the point to make them expand more readily on game, and give a more killing wound. Thus, with us, an express cartridge meant one loaded with a light, hollow point bullet, to give slightly more muzzle velocity than the ordinary cartridge loaded with a heavy bullet.

The disadvantage of black powder, besides the smoke which might obscure the game or the enemy after the first shot was fired, and give away the position of the firer, was the large amount of fouling that the black powder deposited in the bore of the rifle. Particularly in dry weather this fouling caked hard in the bore and offered an obstruction to the clean passage of the bullet, deforming the bullet as it passed up the bore, and to a great extent destroying the accuracy. With some black powder cartridges only five or ten rounds could be fired before the fouling began to destroy accuracy, then the bore of the rifle had to be cleaned to restore the accuracy.

Besides the cannelured, inside lubricated lead bullets, some black powder cartridges were loaded with **paper patched bullets** for fine target shooting. Such bullets were cast perfectly smooth without the grease cannelures, and were made of bore diameter. Then they had a patch of strong but thin paper wound around their bearing, and folded over their base, which increased their diameter to groove diameter. On firing, the rifling cut only into the paper, but there

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first to our Krag Jorgensen rifle, and then to Winchester single shot and Model 1895 rifles. 220 grain round nosed jacketed bullet with M.V. 1,960 f.s. in a 30 inch barrel. Very excellent and successful in its day. Rifles no longer made commercially for it.

E—The .33 Winchester Center Fire cartridge adapted to the Winchester Model 1886 rifle. Produced to give those who preferred the '86 breech action a cartridge equal in killing power to the .30-40 Krag cartridge. 200 grain bullet at M.V. 2,000 f.s., later increased to 2,200 f.s.

F—The .45 Sharps Special, 2⁴⁄₁₀" shell, loaded with 100 grains of black powder and a 500 grain paper patched bullet. A favorite long range cartridge in the 80's and 90's. These cartridges were also furnished in 2⁹⁄₁₀, 2⅞, and 3¼ inch shells, the latter loaded with 120 grains of black powder and 550 grain patched bullet. Rifles were chambered for only one length and would not handle all lengths of cases. For good results the bore had to be wiped clean and dry after each shot.

G—The .50-110 Winchester Express cartridge.

was sufficient friction between paper and bullet to cause the bullet to revolve with the rifling. The rifling did not engrave the lead bullet, and the paper patch left the bullet at the muzzle. Thus the projectile was a perfect, smooth, undeformed lead bullet which flew with better accuracy than the slightly deformed grooved or cannelured lubricated bullet which was marked on its surface, and slightly deformed by the lands. But black powder fouling cut these paper patches badly in the bore, and hence for fine accuracy the rifle bore had always to be cleaned after every shot. It was the practice of our older riflemen who used these paper patched bullets

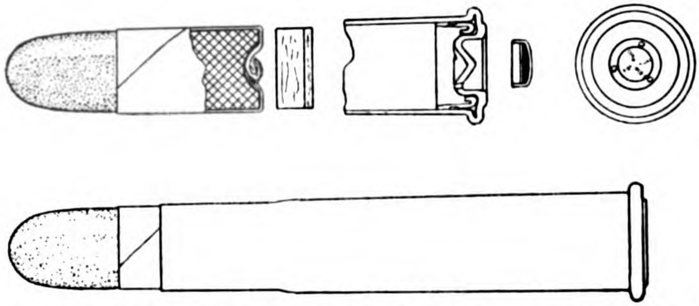

FIGURE 52. AN EARLY CARTRIDGE WITH PAPER PATCHED BULLET

An example of early heavy caliber target and hunting ammunition; the .44/90 Remington bottle necked rifle cartridge. This was one of the later buffalo cartridges, fired from the Sharps rifle, shooting a 520 grain lead bullet. Drawing above shows the details of this paper patched bullet, lubricating wad with cardboard wad underneath, original folded head case, and Berdan primer with primer pocket having three flash holes leading into the powder chamber.

to clean the bore of their rifles after every shot. Fired thus, cleaning after each shot, the long range Sharps rifles using patched bullets gave accuracy equal to anything which we can attain today. The Wimbledon Cup Match, calling for twenty shots at 1,000 yards, was won with such a rifle in 1900.

Entirely new forms of cartridges loaded with high pressure smokeless powder and bullets jacketed with copper or cupronickel, as well as rifles to use them, began to appear on the American market about 1895. Such cartridges had begun to be seen abroad several years earlier, and our Army had begun to experiment with such ammunition for the Krag Jorgensen rifle in 1892. The first American commercially-made rifle for these new high power smokeless cartridges to appear was the Winchester Single Shot rifle which was introduced for the .30-40 Krag Jorgensen cartridge on April 26, 1894. It was followed by the famous .30-30 cartridge (.30 W.C.F.)

adapted to the Winchester Repeating Rifle, Model 1894, on May 16, 1896. The Krag Jorgensen cartridge was a long, bottle necked cartridge shooting a .30 caliber cupronickel jacketed bullet weighing 220 grains. See Figure 51. The bullet had a diameter of .308-inch, the bore and groove diameters of the rifle barrel being .300 and .308-inch. The first charge of smokeless powder weighed 40 grains, and gave the bullet a muzzle velocity of 1,960 f.s. in the 30 inch barrel of the Krag Jorgensen rifle, a considerably higher velocity than it was possible to attain with black powder.

When these new cartridges were first introduced, the same three-number system of designating them that had become common with black powder cartridges was continued until about 1900. Thus the Krag Jorgensen cartridge was first called the .30-40-220, and the smaller .30 Winchester cartridge was called the .30-30-160. But as smokeless powder was gradually improved, quite a different weight of charge of newer powders were required to give the cartridges the standard velocity that was given by the first charges of 40 and 30 grains, and thus the weight of the powder charge came to have no real meaning, and was dropped. The Krag cartridge came to be known as the .30-40 Krag, or .30 Krag, or the .30 Army. The smaller Winchester cartridge has always officially been called the .30 Winchester Center Fire by Winchester, but popularly the name .30-30 has commonly been applied to it. .30-30 cartridges are now variously loaded with bullets varying in weight from 110 to 170 grains, the original weight of bullet being 160 grains.

Thus, about 1899, this three-number system of designating cartridges ceased, and since then there has really been no system at all, except that the first number is usually the bore diameter of the rifle in which the cartridge is to be used, and this number is followed by a name. The first exception to the old rule was the .303 Savage cartridge, which when first made for the Savage rifle was loaded with a 190 grain bullet measuring .311 inch for a rifle with a bore and groove diameter of .303 and .311 inch, and with sufficient smokeless powder to give a muzzle velocity of 1925 f.s. Next came the .32 Winchester Special cartridge, a cartridge quite similar to the .30-30, but with a .321 bullet weighing 165 grains. Later there appeared the .250-3000 Savage cartridge, so called because it was a .25 caliber which had the great muzzle velocity of 3,000 f.s. Other later cartridges have been named after their designer, as .257 Roberts, or have been given some catch trade name such as .22 Hornet, etc.

Today, perhaps the best way for a novice to become familiar with all the many cartridge names, and the weapons to which they are adapted, is to procure an illustrated cartridge catalog such as is issued from time to time by the Winchester, Remington, Western,

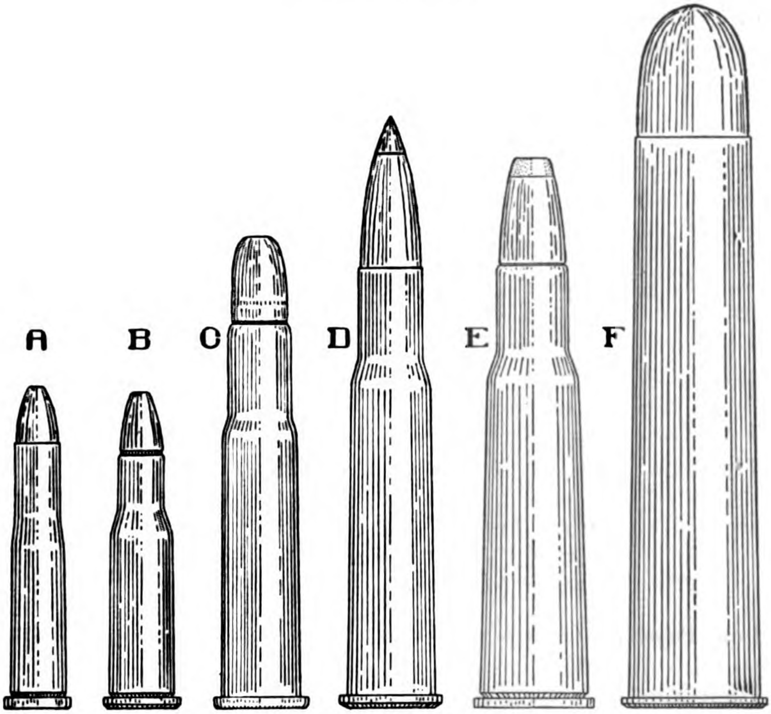

FIGURE 53. SMOKELESS RIFLE CARTRIDGES WITH RIMMED CASES

Showing a series of present-day rifle cartridges with the rimmed case. These cartridges position (or chamber) on the forward edge of the case rim and their use is indicated in the older types of actions such as tubular repeaters, falling block single shots, three-barrel guns, double-barrel rifles, etc. This type of case-rim gives positive positioning in the chamber together with ease of extraction by means of hook or wedge-type extractors. The cartridge is also completely enclosed in the rifle chamber and there is practically no chance of the case head blowing out from a defective cartridge case or poor brass.

A—The .22 Hornet. **B**—.218 Winchester Bee. **C**—The famous .30 Winchester Center Fire (the .30/30). **D**—The old Army Ball Cartridge, Caliber .30, Model 1898 (the .30/40 Krag). **E**—The .348 Winchester Center Fire, a recent and very good big-game cartridge. **F**—The .577 Cordite, a cartridge used in the British heavy, double barrel rifles, for elephant and similar big-game. **D**—Is shown here loaded with a hunting-type bullet.

and Peters Companies, and which lists every cartridge by name and gives a good cut of each. Also see the tables of velocities and trajectories in the appendix of this work which lists almost all modern cartridges, and gives the weight of bullet of each.

In identifying cartridges the following commonly used abbreviations will be helpful.

S.S.	Single shot (also Sharps Straight)
R.F.	Rim fire.
C.F.	Center fire.
W.R.F.	Winchester Rim Fire.
W.C.F.	Winchester Center Fire.
Rem.	Remington Arms Co.
Sav.	Savage Arms Corporation.
O.L.	Outside lubricated.
B.N.	Bottle necked.
B.P.	Black powder.
H.P.	High power.
H.V.	High velocity.
Ptd.	Pointed bullet.
Flat	Flat point bullet.
Express	Light bullet with cavity in point.
M.C.	Metal cased.
F.M.P.	Full metal patched.
S.P.	Soft point.

Low Power. A cartridge giving a muzzle velocity of less than 1850 f.s.

High Power. A cartridge giving a muzzle velocity of between 1925 and 2500 f.s.

High Intensity. A cartridge giving a muzzle velocity of over 2500 f.s.

Magnum. In England a cartridge giving a muzzle velocity of over 2500 f.s. The name originated in England. In America a cartridge giving a velocity of over 2500 f.s., or a cartridge that is loaded to a much higher velocity than that to which that cartridge was originally loaded when it was first introduced.

Small Bore. In America any cartridge of .30 caliber or smaller. In England any cartridge of under .450 caliber.

Big Bore. In America any cartridge in caliber larger than .30. In England any cartridge larger than .450. In England, generally speaking, big bore cartridges are used for the hunting of elephant, rhinoceros, and buffalo in Africa and Asia.

Wild Cat Cartridge. One that is not regularly manufactured by any cartridge company, but that has been designed and fabricated by an investigator or inventor. Wildcat cartridges are also often furnished by a small rifle maker who furnishes rifles chambered for them. Usually such cartridges are made by necking down, or expanding, or reforming existing cartridge cases to take bullets of different caliber and weight, and different amounts of powder from that for which originally designed. There is almost no limit to such cartridges. Often such cartridges result finally in standardization and regular production, and this is one of the ways in which American ammunition is constantly being improved.

Handloaded Cartridges. The brass case is the most expensive component of a center fire cartridge. After the cartridge has been fired the case can be reloaded with new primer, powder charge, and bullet, and used again, and some cases will stand reloading many times, thus making a material saving in the cost of ammunition. Small tools for such reloading are furnished by a number of companies. The original load can also be varied as much as desired within the limits of safety. Thus center fire smokeless high velocity cartridges can be reloaded with light, lead bullets and light charges of powder for small game shooting or for target practice at short distances; with lead bullets having their base protected with a copper gas check for higher velocity, more powder, and target practice up to 500 yards; and with jacketed bullets of many weights and types, with more or less velocity than the standard cartridge. In some instances it is also possible for a skilled hand loader to hand load fired cases with charges which will be superior in accuracy to the factory product because the factory cartridge must be of such a size that it will fit in and be safe in rifles of minimum chamber and bore, and in barrels that have become slightly corroded. But the reloader uses cases already perfectly chambered to fit the chamber of an individual rifle, and can size his bullets to exactly fit the bore of this rifle.

List of the Most Popular Cartridges of the Black Powder Period, About 1895

Rifle	*Pistol*
.22 Short.	.32 Smith & Wesson.
.22 Long Rifle.	.32-44 S & W Target.
.25-20 Single Shot.	.32 Long Colt, O.L.
.32-20 W.C.F.	.38 S & W.
.32-40-165.	.38-44 S & W Target.
.38-55-255.	.38 Long Colt.
.38-40 W.C.F.	.38-40 W.C.F.
.40-70-330 Sharps Straight.	.41 Long Colt.
.40-82-260 W.C.F.	.44 S & W Russian.
.44-40 W.C.F.	.44-40 W.C.F.
.45-70-500 U.S. Govt.	.45 Colt.
.45-90-300 W.C.F.	

Between the above and the following list there are a great many cartridges which have enjoyed a certain amount of popularity, but which have now come more or less into disuse because better cartridges of more modern design have appeared, or because weapons adapted to them are no longer made. For example, the .30-40 Krag cartridge, once the most popular high power smokeless cartridge made, but now falling into disuse because rifles are no longer made for it, and because it has been superseded by the more efficient .30-06 cartridge.

List of Popular Modern Smokeless Cartridges, 1942

Rifle	*Pistol*
.22 Long Rifle.	.22 Long Rifle.
.22 Long Rifle, H.V.	.32 S & W and Colt Long.
.218 Bee.	7.63 mm Mauser.
.22 Hornet.	7.65 mm Luger and Colt.
.220 Swift.	.38 S & W and Colt Special.
.25-20 W.C.F.	.357 S & W Magnum.
.250-3000 Savage.	.38 S & W.
.257 Roberts.	.38 Colt Auto.
.270 Winchester.	.380 Automatic Colt.
.30 W.C.F. (.30-30)	.44 S & W Special.
.300 Savage.	.44-40 W.C.F.
.30-06.	.45 Colt.
.300 H & H Magnum.	.45 Colt Auto.
.32 Win. Special.	.45 Auto Rim.
.35 Rem. Auto.	
.348 Winchester.	
.375 H & H Magnum.	

Super-X. Super-Speed. Hi-Speed. Trade names, used respectively by the Western, Winchester, and Remington cartridge companies to designate modern cartridges loaded to the maximum in volocity and pressure that is consistent with safety and good performance.

.22 Rim Fire Cartridges. There are so many different .22 rim fire cartridges, and some are so popular, that an extended description seems advisable.

.22 Short. A small cartridge with short case, loaded with a 30 grain lead bullet for short range shooting. In rifles chambered and rifled for it exclusively it is often a very accurate cartridge up to 50 yards, and used to be very popular for indoor gallery shooting. It is still used almost exclusively in the shooting galleries at pleasure resorts. It can be loaded and fired in any rifle chambered and rifled for the .22 Long Rifle cartridge, but its extended use in such a barrel will eventually erode the chamber so as to make the barrel worthless, and it is not particularly accurate in such barrels.

.22 Long. A poor, out of date cartridge that should be obsoleted. Same length of case as the .22 Long Rifle cartridge but loaded with a bullet weighing 29 or 30 grains. Can be used in any rifle chambered for the .22 Long Rifle cartridge. Accuracy and power mediocre. Only popular throughout the Southern States.

.22 Long Rifle, Regular, Smokeless, Lubricated Lead Bullet. The most common and generally useful type. Loaded with 40 grain bullet. M.V. 1050 to 1100 f.s.

.22 Long Rifle, Regular, Smokeless, Copper-plated Greaseless Bullet. 40 grain bullet loaded to 1050 to 1100 f.s. Developed to meet the demand for cartridges which could be carried loose in the pocket without the lubricant coming off or picking up dirt. As a rule they are not quite so accurate as the preceding type, and they cause a little more wear in the bore.

.22 Long Rifle, Special Target. Known generally by the trade names of Precision, E.Z.X.S., Palma Match, Super Match, Dewar, etc. Loaded with a lubricated lead bullet of about 40 grains to about M.V. 1100 f.s. Special pains are taken in their precise manufacture so as to insure the very finest accuracy in match rifles such as the Winchester Model 52 and Remington Model 37. They are in demand among well informed riflemen who indulge in competitive small bore shooting outdoors at ranges of 50, 100, and 200 yards, because of their exceptionally fine accuracy. They are generally sold only by those firms who cater to the needs of such riflemen, and sell at a slightly higher price than the common .22 Long Rifle cartridges. In almost all rifles they are decidedly more accurate than the other types of this cartridge.

.22 Long Rifle, High Velocity. Known generally under the trade names of Super-X, Super-Speed, and Hi-Speed. They are usually loaded with either lubricated lead, or copper plated lead bullets, either 40 grains solid, or 37 grains hollow point, and to a muzzle velocity of about 1375 to 1450 f.s. Those loaded with lubricated lead, and with hollow point bullets are usually a trifle more accurate than the others. But as a rule none of these high velocity cartridges are quite so accurate as the cartridges of regular velocity (1050 to 1100 f.s.) loaded with lubricated lead bullets. The high velocity cartridges are usually deflected more by side winds than are the regular velocity cartridges. For these reasons they are preferred by hunters seeking more killing power rather than by target shooters. Particularly those loaded with hollow point bullets are quite destructive and killing on medium size birds and smaller mammals such as squirrels and rats.

All the above cartridges can be loaded and fired in any modern rifle which is chambered and rifled for the .22 Long Rifle cartridge.

.22 Extra Long. A much longer cartridge than any of the above. It will not fit in any modern .22 rim fire rifle. Rifles have not been chambered for this cartridge for many years, and it is now obsolete.

.22 Winchester Rim Fire, also called **.22 Remington Special.** An inside lubricated cartridge, loaded with 45 grain bullet to the regular velocity of 1100 f.s., and also with high velocity loads and 45 grain solid and 40 grain hollow point bullets to about 1450 to 1475 f.s. It can be used only in rifles that are specially chambered and rifled for it. In its heavier loadings it has a little more killing power than the high velocity .22 Long Rifle cartridges. It is also very convenient where it is desired to carry ammunition loose in the pocket. In the five years prior to World War II this cartridge was loaded to a very high degree of accuracy and reliability in the high velocity type, and it is thought that it is deserving of a great deal more popularity for hunting purposes than it has received.

.22 Automatic. An inside lubricated cartridge loaded with 45 grain bullet to M.V. 1050 f.s. This cartridge was made only for the Winchester Automatic rifle, Model 1903 and a somewhat similar Remington rifle. As these rifles have not been made for some years the cartridge will gradually go out of use.

.30-06 Cartridges. When the U.S. Rifle, Caliber .30, Model 1903, popularly known as the "Springfield Rifle," was first issued to our Regular Army in 1905 to replace the formerly standard U.S. Magazine Rifle, Caliber .30, Model 1898, popularly known as the "Krag Jorgensen Rifle" it used a rimless cartridge loaded with a 220 grain bullet, and with a muzzle velocity of 2300 f.s., later reduced to 2200 f.s. This cartridge was known officially as the "Ball Cartridge, Caliber .30, Model 1903." About this time Germany made a change in the ammunition for their Model 1898 rifle, altering it to shoot a light bullet weighing 154 grains at the very remarkable velocity (in those days) of 2800 f.s. This light bullet had a very sharp point, and was known as a *spitzer* bullet. The flat trajectory of this German cartridge presented such military advantages that it was decided to rechamber all of the Model 1903 rifles that had already been issued for a similar cartridge and thereafter to make all new Model 1903 rifles for this cartridge. The cartridge as finally designed was loaded with a 150 grain cupronickel jacketed bullet with a sharp point, and the muzzle velocity given it was 2700 f.s. See Figure 54. This new cartridge was officially called the "Ball Cartridge, Caliber .30, Model 1906." Thus we had a *Model 1903 rifle taking a Model 1906 cartridge.* This cartridge was the forerunner or father of all the vast number of cartridges which have become to be popularly known as ".30-06" cartridges. It is the most popular cartridge in existence at this writing, both for extreme accuracy on the target range or for use in the hunting field.

From now on will the reader please notice the difference between the official U.S. Army names for rifles and cartridges as compared with the commercial, sporting, and popular names. This Model 1906 cartridge, and all its various more modern military types has remained the standard military cartridge in the United States for the various infantry rifles that have been adopted for our army.

All of the following types of ".30-06" cartridges can be used in any of the following rifles, all of which are chambered and rifled alike:

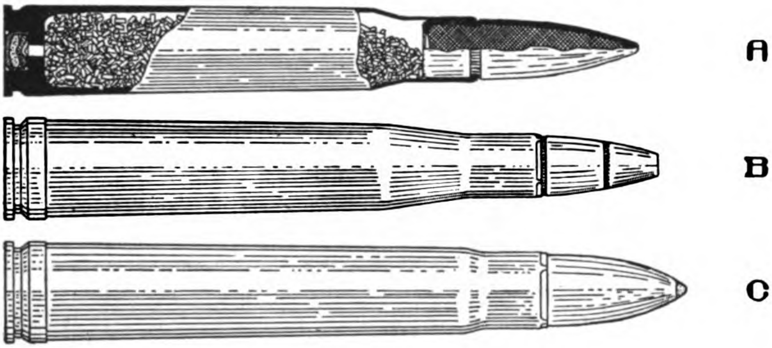

FIGURE 54. MODERN RIMLESS AND BELTED CARTRIDGES

A—The .30'06 service cartridge, known in the Army as the caliber .30, M2. Shown in sectionalized form.

B—The .300 Holland and Holland Magnum, a "belted" cartridge, so termed from the belt formed around the base of the case. The cartridge positions against the forward shoulder of this belt, which comes to a stop against a similar shoulder in the chamber of the rifle. Headspace is measured from the base of the case to this forward shoulder. The added metal in belted case heads permits their safe use at chamber pressures somewhat higher than the ordinary rimless case can safely stand.

C—The .375 Holland and Holland Magnum, another belted cartridge. These two H. & H. Magnum cartridges are here shown loaded with sporting bullets; these bullets being retained in the case with the "segmental" crimp which type of crimp is now being used to an increasing extent by some of our American cartridge manufacturers.

U.S. Rifle, Caliber .30, Model 1903, popularly known as the Springfield Rifle, or Springfield Model 1903.

U.S. Rifle, Caliber .30, Model 1917, popularly known as the Enfield Rifle.

U.S. Rifle, Caliber .30 M1, popularly known as the Garand Rifle, the present semi-automatic rifle of our army.

Winchester Model 1895 Rifle when chambered for the .30 Government 06 cartridge.

Winchester Model 54 Rifle chambered for same cartridge.

Winchester Model 70 Rifle chambered for same cartridge.

Remington Model 30 Rifle chambered for .30-06 cartridge.
Remington Model 720 Rifle chambered for .30-06 cartridge.
Savage Models 40 and 45 Rifles chambered for the .30-06 cartridge.
Sedgley-Springfield Rifles chambered for the .30-06 cartridge.
Also many custom built and remodelled rifles chambered for the .30-06 cartridge.

The cartridges of this type now used in our military service, and their official names are as follows:

Ball Cartridge, Caliber .30, Model 1906. The original cartridge, used in World War I, loaded with 150 grain pointed bullet jacketed with cupronickel. M.V. 2700 f.s. Now obsolete.

Ball Cartridge, Caliber .30, M1. The standard cartridge from 1925 to 1939. 172 grain boat tailed, pointed, gilding metal jacketed bullet. M.V. 2640 f.s. Manufacture of this cartridge has now ceased.

Ball Cartridge, Caliber .30, M2. The present standard military cartridge. Loaded with a 150 grain pointed, flat base, gilding metal jacketed bullet. M.V. 2805 f.s.

Cartridge, Armor Piercing, Caliber .30, M2. Bullet has a hardened steel core and a blackened tip.*

Cartridge, Tracer, Caliber .30, M1. Bullet has a red tip.*

Cartridge, Incendiary, Caliber .30, M1. Bullet has a purple tip.*

Cartridge, Gallery Practice, Model 1906. Lead bullet.

Cartridge, Guard, Caliber .30, Model 1906. Case has six short corrugations just below neck.*

Cartridge, Guard, Caliber .30, M1. Short, round nose, lead bullet.*

Cartridge, Dummy, Caliber .30, Model 1906. Six longitudinal corrugations on tinned case. Before 1940 3 holes were drilled through the case in addition to the corrugations.

Cartridge, Dummy, Caliber .30, M1. Tinned brass case and no primer.

Cartridge, High Pressure Test, Caliber .30, M1. Pressure 68,000 pounds. Tinned case. Used only in factory proof testing.*

In addition to the above military cartridges, a great many different varieties of sporting and target cartridges are made in this caliber. These cartridges are called ".30 Government '06" by Winchester, and ".30 Model 1906," or just ".30-06" by the other commercial cartridge companies. Quite generally they are loaded with weight and type of bullet, and with muzzle velocities as follows:

* Cartridges starred are never issued except in the military service, and are never sold. The Armor Piercing, Tracer and Incendiary Cartridges are for military use *only* and should never be used on the target range or in the hunting field.

Bullet, Weight and Kind	*Muzzle Velocity*
110 grain, hollow point	3,500
150 grain, pointed expanding	2,900 to 3,000
172 grain, boat tail, full jacketed, Target	2,700
172 grain, boat tail, exp.	2,700
180 grain, pointed, flat base, Target	2,700
180 grain, expanding	2,700
180 grain, open point boat tail	2,700
220 grain, expanding	2,300 to 2,400

The heads of cases made at Government Arsenals, and by private factories under government contract are stamped with the initials of the manufacturing plant and the year in which the case was manufactured. Cases made by commercial companies for sporting or target use are stamped on the head with the initials of the company, and the figures ".30-06," except that in the last few years Winchester have been stamping their cases "Super Speed" instead of "W.R.A.Co." and Western have been stamping theirs "Super-X" instead of "Western."

The .30-30 Cartridge. Many men have the erroneous idea that the "Springfield rifle was made for the .30-30 cartridge." This is not so. The .30-30 cartridge has never been used for military purposes by the United States Government. It is a medium size sporting cartridge intended for the shooting of deer and similar sized game. It was originated by the Winchester Repeating Arms Company in 1896, and is called by them the ".30 Winchester Center Fire." This cartridge has probably been used in America for deer shooting more than any other cartridge. See Figure 55. No service rifle, made by our Government for use by our armed forces, has ever been chambered for the .30-30 cartridge.

.30-30 Series. Hunters often refer to the ".30-30 series of cartridges." This series includes the .30-30, .30 Remington Auto, .32 Winchester Special, and .32 Remington Auto. cartridges. While these cartridges cannot be used interchangeably in the same rifle, and while each requires that the rifle be chambered and rifled specially for it alone, yet so far as ballistic results are concerned they are "as alike as two peas." Their bullets of standard weights are all of about the same diameter, weight, and sectional density. Their muzzle velocity, trajectory, penetration, and accuracy are alike very similar. One could hunt alternately with rifles using any two or all of them for a lifetime without being able to tell that there was any difference in their accuracy, killing power, or trajectory.

Packing of Metallic Ammunition. .22 rim fire cartridges are packed 50 rounds in a pasteboard box; ten of these boxes, or 500 rounds, are further wrapped in a pasteboard carton, and a total of 10,000 rounds are packed in a strong wooden box called a *case*. Pistol and revolver cartridges are also packed in 50 round pasteboard boxes, and usually in pasteboard cartons of five boxes or 250 rounds. These boxes and cartons are then packed in a wooden *case* which contains a total of 2,000 rounds. Short rifle cartridges having an overall length of cartridge not to exceed about 1½ inches are similarly packed. Larger rifle cartridges are packed 20 rounds to a pasteboard box, and 1,000 rounds to a case.

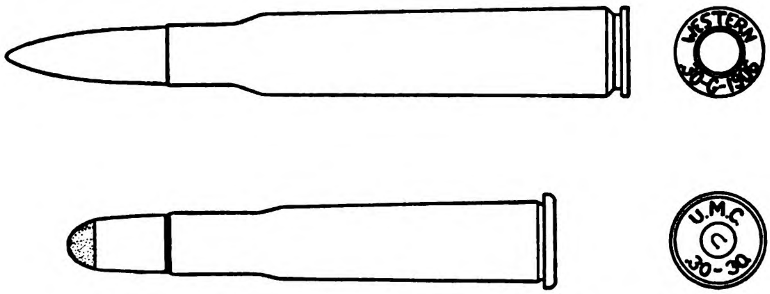

FIGURE 55. TWO POPULAR CARTRIDGES OFTEN CONFUSED

Here are shown two very popular cartridges which are often confused by members of the armed forces and by others.

At the top is shown the standard service "Ball Cartridge, Caliber .30, M 1906 or M2," popularly called the ".30-06" or ".30 Govt. '06." This has been the standard rifle and machine gun cartridge of the U.S. Army since 1906, and is the cartridge adapted to and used in the Springfield 1903, Enfield 1917, Garand and other rifles, and in the Browning automatic rifles and machine guns.

At the bottom is the .30 Winchester Center Fire cartridge popularly known as the ".30-30." It was originally made for the Winchester Model 1894 lever action rifle, but many other sporting rifles have been built for it. It is essentially a deer cartridge. No military rifle has ever been made for it, nor has it ever been adopted by any Government.

Both cartridges use a bullet of the same diameter (.308-inch) but not of the same weight, but the two cartridges will not interchange, nor can they be fired in the other rifle. *It is entirely erroneous to refer to the service Springfield 1903 rifle as the ".30-30 Springfield."*

Military cartridges, Caliber .30 (.30-06) for use in our military service are packed somewhat differently. Some of them are packed similarly to commercial cartridges, 20 rounds to a pasteboard carton or box. Others for use in the M 1906 rifle (Springfield) are packed in a bandoleer of olive drab cotton cloth which is divided into six pockets, each pocket containing two five round clips of cartridges, or a total of 60 rounds to a bandoleer, which weighs 4 pounds. For the M1 rifle (Garand) each pocket contains one 8-round clip, or a total of 48 rounds to a bandoleer which weighs 3½ pounds. The mouths of the pockets are folded so that the clips are secure therein but easily accessible. If the soldier does not wish to fill his cartridge belt from the clips he can readily carry the bandoleer over his shoulder. It is commonly presumed that the soldier will enter a battle with his cartridge belt full of clips, and with a bandoleer swung over each shoulder. All of these cartridges are further packed in wooden boxes containing 1,000 to 1,200 rounds. The wooden box has a waterproof metal liner, the cover of which is closed by soldering, but can be readily torn off by means of a wire handle.

In all the above, commercial and military, the small pasteboard box or carton of 50 or 20 rounds, and the large wooden box or case is stamped or printed with full information as to the caliber and name of the cartridge, and weight and kind of bullet.

Use the right cartridge. The shooter should always be certain that he uses the correct caliber and type of cartridge in his rifle, pistol, or revolver. This is most important. With commercial and sporting arms the name of the cartridge to use is always stamped on the barrel of the weapon. Using the wrong cartridge will almost always result disastrously or lead to a most serious accident.

For example, the .22 Short cartridge can be fired in any rifle chambered for the .22 Long Rifle cartridge, but the use of a few hundred rounds of .22 Short cartridges in such a rifle or pistol will so erode the chamber as to ruin the barrel. In a .22 caliber revolver, however, the .22 Short cartridge can be used without any bad results.

Some cartridges will seemingly fit in a rifle made for another cartridge, and can be fired, but with poor or no accuracy, and only with great damage to the bore. For example a .30-30 cartridge can be fired in a rifle chambered for the .32 Winchester Special cartridge, but will quickly ruin the barrel.

In other cases there will be a serious accident. For example the German 8 mm or 7.9 mm cartridge looks very like our .30-06 cartridge, and it can be loaded into a .30-06 rifle and can be fired, but a single round of such ammunition will blow up the .30-06 rifle, and probably seriously injure or kill the shooter. Such accidents are liable to occur in wartime when so many German Mauser cartridges are picked up on battlefields and find their way back to this country.

Shotgun Shells

Development of rifle and pistol ammunition has always been directed, first towards securing better accuracy and higher velocity in order that small targets can be more surely hit at a greater distance; and second at reducing erosion and corrosion which wear out barrels. Killing power is largely a matter of weight and velocity of the projectile. In these directions our inventors have gone a long way since the black powder and lead bullets of our fathers, as has been evidenced in the preceding nomenclature.

With shotgun ammunition the problem has been quite different. We do not speak of "accuracy" with regard to shotguns and their shells, but rather of *"evenness of pattern"*; that is the confining of the flying shot in a small cone of dispersion so that at the target they will all, or nearly all, be confined in a small circle, say 30 or 40 inches in diameter at 40 yards, and the pellets will be more or less evenly distributed throughout that circle so that were a bird flying through that circle there would be no open spots within its diameter where the bird would not be struck by at least two or three pellets. Evenness of pattern is the one most important characteristic that any shotgun shell can have.

Except for ignition and breech loading, shotguns reached almost their present development two hundred years ago. The shotgun target always has been flying birds, they have always been shot at almost exclusively from the standing position, and the range, by reason of the dispersion of the shot and the difficulty of hitting has always been about 20 to 50 yards. In England where the sporting shotgun was first developed it was soon found that to handle it promptly and to shoot it well on flying birds it had to weigh from 6¼ to 8 pounds and have 26 to 30 inch barrels. A lighter gun gave too much recoil and a heavier one was too slow. In such a gun an ounce to an ounce and a quarter of shot was about right to give a dense enough pattern to kill birds at 20 to 50 yards, and also with such a load a charge of about 3 to 3½ drams of black powder gave sufficient penetration of the shot to kill. Heavier charges gave too much recoil. Such a load was best handled with a gun of 10 to 14 gauge. Such then were the shotguns and their loads in the early days.

It would be a fine thing if we could increase the velocity in our shotguns and their ammunition as this would give greater penetration at greater distances and increase our killing range if other things remained the same, and also it would cut down the lead necessary on flying birds and enable us to hit more easily. But unfortunately this is something we cannot do to any great extent on account of the limitations under which we must work.

A shotgun and its ammunition must be balanced. There must be a certain fine balance between pressure, velocity, pattern, recoil, and weight of gun. In no other ballistic problem is this balance so important and so closely limited. The only way we can get more velocity is to increase the powder charge or decrease the amount of shot. To do either to any extent means to increase the recoil or open the pattern. The recoil is now as heavy as we can stand, and to open the pattern would decrease the killing range. We could decrease the recoil by increasing the weight of the gun, but that would make the gun too unwieldy and slow to hit flying birds with. Increasing velocity also automatically increases pressure, and that requires a heavier gun with more steel in it to withstand the pressure. Even so if we were able to increase velocity, to do so would open the pattern by giving us a larger proportion of shot that would be deformed in the bore and that would decrease the killing distance.

Nearly two centuries ago British sportsmen found that the best balanced load which gave the greatest efficiency in the shotgun of about 12 gauge was one consisting of 3 to 3½ drams of black powder and an ounce to an ounce and a quarter of shot. Since then we have not been able to vary much from these proportions and still be able to hit a large percentage of flying birds. Thus there has been little improvement as compared with the great advances that have been made in rifles and their ammunition. Every way we turn we are up against a limitation.

We do not wish to create the impression that there has been no improvement in shotguns and their ammunition for the past two hundred years, but rather that they have been relatively small. The modern breech loading, choke bores, hammerless and repeating shotguns are a far cry from the muzzle loading, flint lock, cylinder bores guns of 1750 to 1820, and the modern smokeless non-corrosive shell is similarly a big improvement over muzzle loading with black powder. But the load still remains about the same, equivalent to about 3 to 3½ drams of black powder and 1 to 1¼ ounces of shot for a 12 bore gun, with a killing range of about 20 to 50 yards. These details will be more fully discussed in the chapter on shotgun ballistics.

Modern shotgun shells are now most commonly made in 12, 16, 20, 28, and .410 gauge. Ten gauge shells are but little used today, and 8 gauge and larger shells have been legislated against to conserve the game birds. The shells of today are most commonly furnished with the following loads:

12 gauge	3 to 3¾	drams powder *		1 to 1¼ ounces shot	
16 "	3 to 3¼	"	"	1 to 1⅛ "	"
20 "	2¼ to 2¾	"	"	⅞ to 1 ounce shot	
28 "	1¾ to 2¼	"	"	⅝ to ¾ "	"
.410 bore	1¼ to 1¾	"	"	⅜ to ¾ "	"

* Smokeless equivalent of drams of black powder.

The 12, 16, and 20 gauge charges are commonly loaded in shells that are 2¾ inches long, for which length of shell almost all American shotguns of these gauges are now chambered. The standard length of 28 gauge shells is 2⅞ inches. .410 gauge shells were originally standard at 2½ inches, but in recent years most guns of this bore have been chambered for 3-inch shells. The length referred to is the length of the paper shell before it is loaded. Loading reduces the length by reason of the turn-over of the crimp, so many shells loaded properly for a gun with 2¾ inch chambers actually measure about 2⅝ inches long. The use of shells longer than that for which the gun is chambered results in high and sometimes dangerous pressures, with poor patterns, while shorter shells result in slightly more open patterns.

In recent years 12 gauge Magnum shotguns chambered for 3-inch shells, and weighing 8 to 9 pounds, have been introduced for long range wildfowl shooting, and are often called "heavy duck guns." They are too heavy and slow for upland bird shooting, but give an increased range up to about 60 yards for wildfowl. The 3-inch Magnum 12 gauge shells for these guns are loaded slightly heavier than the 12 gauge shells of usual length, and they cannot be used in the regular guns chambered for 2¾ inch shells.

Shotgun shells as above are loaded with various sizes of shot according to the species and size of birds it is desired to hunt. The sizes of shot commonly employed for various game bird shooting is as follows:

	Size
Early ducks over decoys	6 or 5
Late ducks over decoys and all pass ducks	4
Geese, all species	2 or BB
Early quail and small shore birds, Band-tailed pigeons, small winged predators	8 or 9
For above in late season	7, 7½ or 8
Pheasants, prairie chicken, grouse, Hungarian partridges, squirrels and rabbits	5, 6, or 7
For Trap Shooting	7½
For Skeet Shooting	9

Shells are commonly loaded with buckshot for deer shooting in thick brush, and also a single ball of the size of the choke portion of the bore of the gun is sometimes used for a similar purpose. But the modern shotgun projectile for deer and other big game shooting at distances up to 100 yards is the **Rifled Slug.** This slug of lead, of the diameter of the choked portion of the bore of the gun has a hollow base and rifled sides which cause it to fly point to the front up to 100 yards at least, and greatly increases its accuracy and power. These rifled slugs deliver finer accuracy at 100 yards than do the single round ball loads at 50 yards. They are furnished in

12, 16, 20, and .410 gauge, and can always be told from shot loads by looking at the mouth of the shell as there is no top wad and the slug itself can be seen.

The different sizes of American chilled shot, with their diameter, and the number of pellets to an ounce are as follows

No.	*No. in Oz.*	*Diam. In.*	*No.*	*No. in Oz.*	*Diam. In.*	*Buckshot*		
						*Eastern * Size*	*Western Size*	*Diameter, Inches*
Dust	4,565	.04	3	109	.14	4	...	.24
12	2,326	.05	2	88	.15	3	8 or 9	.25
11	1,380	.06	1	73	.16	2	7	.27
10	868	.07	B	59	.17	1	5 or 6	.30
9	585	.08	Air Rifle	55	.17½	0	4	.32
8	409	.09	BB	50	.18	00	3	.34
7½	345	.09½	BBB	42	.19	000	2	.36
7	299	.10	T	36	.20			
6	223	.11	TT	31	.21			
5	172	.12	F	27	.22			
4	136	.13	FF	24	.23			

* Note that there are two sizes of buckshot, Eastern and Western.

High Velocity Loads. In recent years shotgun shells of the better grades have been loaded with a progressive burning powder which gives slightly increased velocity while maintaining the density and evenness of the pattern, and these shells have other slight advantages over many of the older shells for reasons that will be given in the chapter on shotgun ballistics. With the high velocity they of course give deeper penetration of the shot pellets, and hence greater effective killing range. Such high velocity shells are manufactured under the trade names of Super-X, Super-Speed, Hi-Speed, and High Velocity.

By reason of their higher velocity these shells give greater recoil than the regular shells, and so are chiefly useful in the heavier duck guns weighing 7 to 8 pounds. Their recoil is rather unpleasant in lighter guns, and indeed their increased velocity and penetration is of little or no use on upland birds. They are essentially duck loads, but for this purpose are quite a little superior to the regular loads.

Damascus and Twist Barrels. A caution for safety reasons here becomes necessary. Prior to about 1900 most shotguns were made with Damascus or Twist barrels. These barrels were made of thin wires of alternate steel and iron, wound into a cable, and the cable was then twisted around a mandrel and the edges of the cable welded together. The mandrel was then withdrawn, leaving the hole in the welded cylinder. This cylinder was then smooth bored on the inside, and finish turned on the outside into the finished barrel. Such manufacture resulted in a tougher and stronger barrel than could be manufactured in other ways until recent times. Such barrels can always be told by the twisted or inter-twined pattern as the strands of steel and iron did not blue or brown to the same color.

While Damascus, Twist, or Laminated barrels had ample strength to withstand the pressure given by the older black powder shells, which were the only shells that were available in the days when such barrels were made, they positively do not have nearly enough tensile strength and elastic limit to stand the pressures given by any modern smokeless shotgun shells. No matter how high the grade of the gun, or who its maker was, or in what perfect condition it now is, if it has Damascus, Laminated, or Twist barrels it is absolutely unsafe to shoot it with the present smokeless shotgun shells. Sooner or later the barrel will burst wide open over the chamber, and the shooter will be extremely lucky if he does not lose his fingers, hand, or eyesight. Also it makes no difference if such barrels have in the past been used with such shells with no accident. An accident may take place the first time such a shell is fired, or the gun may successfully fire five thousand such shells and burst on the five thousandth and one. It does not pay to take chances with guns having such barrels. If it is desired to use such a gun, have shells loaded with black powder specially for it. See Figure 56.

The impression seems to prevail among some shooters that very moderately loaded smokeless shells, say 12 gauge field shells, or game loads, loaded with the equivalent of 3 drams of black powder, and 1⅛ ounces of shot, may safely be used in a high grade Damascus barrel gun that is in good condition. This is not so. All modern shotgun shells give approximately the same breech pressure. The high velocity loads give the same pressure as the moderate field loads, the higher velocity being obtained with the same pressure by using a progressive burning powder. The pressures given by *all* modern smokeless shotgun shells are approximately three times that given by the black powder shells that were used safely in Damascus, Laminated, and Twist barrels. Therefore modern shells are unsafe in such barrels. It is not possible to load a satisfactory smokeless shell that would be safe in such barrels because our present day

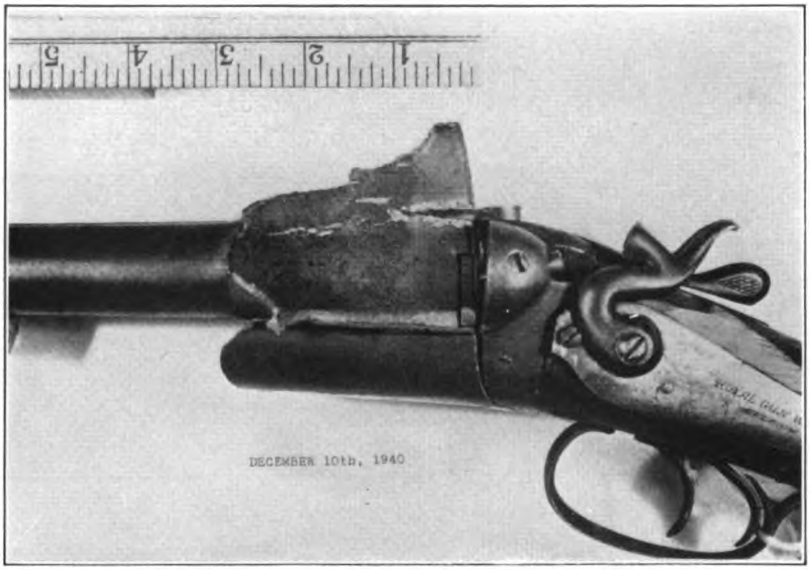

FIGURE 56. A RATHER COMMON ACCIDENT

The result of firing a modern smokeless shotgun shell in an older shotgun having Damascus, laminated, or twist barrels. In the days when such barrels were fitted to shotguns black powder shells only were made, and the breech pressure seldom exceeded 4,000 pounds per square inch. Today the pressure given by all smokeless shotgun shells, field, trap, skeet, game, or high velocity alike, is 10,000 to 11,000 pounds. The old Damascus, laminated, or twist barrels, which show the braided or twisted pattern of alternate strips of iron and soft steel of which they are made, will not stand such smokeless pressures, and sooner or later the barrel will burst at the breech as shown. It makes no difference who the maker was, what the initial cost of the gun was, or how good a condition it is in. Such barrels should positively not be fired with any present day smokeless shell. Use black powder shells only.

FIGURE 57. AN OBSTRUCTION IN THE BORE

Hunters and other users of 12 gauge shotguns should be careful that there are no 20 gauge shells in the pockets of their hunting coat or elsewhere. A 20 gauge shell might inadvertently be loaded into the 12 gauge gun. It will enter the chamber and bore up to the cone, and will thus disappear, and the gun will look as though it was not loaded. If a 12 gauge shell is then inserted (an easy thing to do) and the gun is fired an accident like the above will occur every time. Quite a few such accidents occur every year.

When a barrel bursts or bulges forward of the chamber it is practically always caused by an obstruction in the bore. It may be a bullet stuck in the bore, a cleaning patch or a section of a cleaning rod similarly stuck, mud, snow, or dirt that has gotten into the muzzle, or even very heavy grease in the bore, or of course a 20 gauge shell stuck in the forward end of a 12 gauge chamber as above.

smokeless powder must be loaded to a certain pressure to burn satisfactorily.

20 Gauge Shells in 12 Gauge Barrels. It sometimes happens that in the hunting field 12 and 20 gauge shells may become mixed up. A hunter may even find that he has a few of each gauge in the pocket of his hunting coat. A 20 gauge shell can, of course, be inserted in the chamber of a 12 gauge gun. It will go in until its head or rim is stopped by the cone in the forward end of the 12 gauge chamber. Thus the 20 gauge shell will disappear in the 12 gauge barrel, and it may look as though it had never been put in the barrel. But the shooter, looking at the apparently empty chamber, may think that he has not loaded the barrel, and may then insert a 12 gauge shell in on top of the 20 gauge shell. The 12 gauge shell will go in easily. If the gun be then fired with the 20 gauge shell in front of the 12 gauge shell the barrel will burst viciously every time, and this too may blow off fingers or hands or blind the shooter. Take care never to mix the two sizes of shells. Fig. 57.

Packing and Marking. Shotgun shells of all gauges are now commonly packed in pasteboard cartons called *"boxes"* containing twenty-five shells each. Twenty boxes, or a total of 500 shells are further packed in a wooden box which is called a *case.* A box of shells therefore means 25 shells, and a case means 500 shells.

The brass head of the case is stamped with the makers name, the trade name of the shell, and the gauge. The top wad over the powder is usually stamped with three numbers, the first being the amount of powder, the second the weight of the shot charge, and the third being the size of the shot. For example a top wad stamped "3¼-1⅛-6C" means that the shell is loaded with a smokeless equivalent of 3¼ drams of black powder, and with 1⅛ ounces of No. 6 chilled shot. Sometimes these markings are placed on the side of the paper portion of the shell instead of on the top wad. With high velocity shells the number indicating the powder charge is usually omitted because such shells are always loaded with the maximum permissible powder charge. Full information about the load is always printed on the pasteboard box and on the wooden case. Always look at these markings and read them carefully to see that you are getting the proper gauge and length of shell, with the load of powder and shot you desire.

Corrosion and Waterproofing. All modern American shotgun shells are now loaded with non-corrosive primers and powder, and the shell is made as waterproof as possible.

This does not mean that the shotgun barrel need not be cleaned when such shells are fired, because the small amount of fouling remaining in the bore may collect dampness from the air and thus an uncleaned barrel may rust. Also some small amount of lead is almost always deposited on the surface of the bore, and this should always be removed by cleaning in the proper manner.

Neither is it possible to make shotgun shells absolutely waterproof, although they will withstand a shower in the field. They will be ruined if immersed for any appreciable time under water, and if subjected to very unusual dampness for a long time the paper portion of the shells may swell so that they cannot be shoved into the chamber of the gun. Shotgun shells should be stored in a dry, cool place. Do not store them in a hot attic as that might dry out the powder and make it much more powerful and unsafe.

CHAPTER VIII

Ammunition

Primers

THE primer is the most important of the components that go to make up a complete cartridge. It is also the most dangerous. If a primer misfires you have no cartridge at all. In the next instant your enemy may kill you, or your game escapes, or you lose the shooting match. You tell your friends about a misfire, and those friends tell many others, and soon the business of the company that made that cartridge is ruined in that locality. Nothing will do more to ruin the morale and courage of an army than misfires and duds in their ammunition.

Hangfires are almost as dangerous as misfires; sometimes more so, for the weapon may be opened just as the cartridge goes off.

That little primer, half the size of a pea, is just as dangerous as a bomb filled with T.N.T. In fact that is exactly what it is, a little high explosive bomb. Exploded outside of the cartridge and weapon, its metal components may fly off with sufficient force to penetrate a man's hand, eye or brain, and the flash may cause a very serious burn. If a small batch of the primer composition were to go off during incorporation or mixing it might easily wreck an entire factory. If a young boy were to get ahold of a live primer and attempt to pry it apart with a sharp instrument a very serious accident would be almost sure to occur, and it might kill, blind or maim him for life. All with a little primer smaller than a pea.

Is it any wonder that the cartridge companies guard their primer manufacture with all the safeguards they can surround it—safeguards against misfires, hangfires, and accidents. Visitors to a cartridge factory are seldom privileged to see the primer department, and are never allowed anywhere near the primer mixing room. Each company likewise holds all information relative to primer manufacture as strictly confidential.

On the other hand the writer, along with hundreds of other experimenters, has handled millions of primers throughout his life, and loaded them into cases without an accident of any kind. A primer is not in the least dangerous if it is stored properly, loaded properly in a suitable cartridge, and the loaded cartridge stored and handled properly—and no "damn-fool monkeying."

Priming mixture is not a gunpowder—it does not burn in the sense that gunpowder or smokeless powder burns, but rather explodes or detonates. It is a high explosive like T.N.T. or nitroglycerine, just as dangerous as these and many times more dangerous than dynamite, because it will not only explode from heat or shock, but also upon being crushed or from friction; that is, it is a percussion mixture. When the pellet of the priming mixture is crushed by the blow of the firing pin it explodes and instantly gives off a large and very hot flash, a flash large enough in volume to almost fill the powder chamber in the case or shell, driving in with force between the grains of propellant powder, and igniting them with great speed. The time interval from the crushing of the priming mixture to the ignition of the powder has been roughly calculated as about .001-second.

Early priming mixtures were composed largely of fulminate of mercury, but this ingredient is now seldom used as the mercury amalgamates with the brass of the cartridge case, and makes the brass brittle, also fulminate of mercury has a strong affinity for water, and primers containing it deteriorate very rapidly in damp climates. Up until 1928 the chief ingredient in our priming mixtures was chlorate of potash, which if powdered finely and mixed with a granular, inflammable substance like sulphur will explode from friction or crushing. Chlorate of potash is still the principal ingredient in U.S. Government priming mixtures because of the excellent ignition and stability given by it. The famous **F.A. 70 (Frankford Arsenal No. 70) mixture** has the following composition:

Potassium Chlorate	53	per cent
Antimony sulphide (Stibnite)	17	" "
Lead sulpho-cyanide	25	" "
Tri-nitro-toluol (T.N.T.)	5	" "

These ingredients while being mixed are moistened with gum water, and the mixture while damp is spun into the rims of rim fire cartridge cases, or pressed into the primer cups of center fire primers, and the pellet in the center fire primer cup is then covered with a disc of shellacked paper. The assembled rim fire cases or center fire primers are then thoroughly dried in a dry-house, which increases the sensitivity of the mixture to the desired extent. The entire process of compounding and handling the mixture and loading it into the cases or primer cups is surrounded by many safeguards, and even so is the most dangerous of all the cartridge making operations.

Primers containing the F.A. 70 mixture are known as **chlorate, non-mercuric primers.** They have many excellent qualities, and but one serious disadvantage. Upon explosion the potassium chlorate becomes potassium chloride, a salt very similar in nature to common table salt, and this salt together with the powder fouling, coats the surface of the bore of the weapon. Everyone knows what happens to steel if it be covered with salt. It starts to rust as soon as the salt absorbs moisture from the air, which it does almost at once on a damp day, or always by nightfall even on the dryest desert. Thus the chlorate primer has been the chief cause of the rusting of bores of firearms. However, this trouble is easily prevented by cleaning the bore with water not later than the evening of the day on which the weapon was fired. The potassium chloride dissolves almost instantly and very completely in water, and in almost nothing else. Oils or oily solvents will not dissolve it, but water always will. Then it is only a matter of drying and oiling the bore.

However, it seems to be a matter of religion with some to keep water from a firearm, and others are lazy or forget to clean the bore before night, and in the days when chlorate primers were used almost exclusively most rifles and pistols were ruined by corrosion long before they were worn out by erosion. The matter of the proper cleaning of firearms will be covered in a subsequent chapter.

It was a great boon therefore to all users of small arms when all the commercial ammunition makers in the United States introduced the "Non-corrosive, non-mercuric primer" about 1928 to 1930. Such primers are now manufactured and all commercial and sporting ammunition made in the United States is primed with them exclusively.

The chlorate primer (F.A. 70) however, still remains in use by the U.S. Government for all the .30-06 series of cartridges made for army use, and for the .45 Colt Auto. cartridge. All of these cartridges made at Frankford Arsenal (the arsenal of the Ordnance Department, U.S. Army where all Government small arms ammunition is manufactured), and also all that are made under contract for army use by the commercial cartridge companies, are still, at date of writing, being primed with the F.A. 70 chlorate, non-mercuric primer. There are two reasons why the Government still retains this primer. First, up until about 1941 (and perhaps even yet) there was no sure evidence that the non-corrosive primer would stand tropical storage indefinitely without deteriorating, and of course it is highly essential that army ammunition stand such storage. Second, at the start of World War I the army encountered considerable primer difficulty in its small arms ammunition and many misfires resulted from one of the primers then in use. These misfires almost caused a public scandal, and resulted in the adoption of the F.A. 70 primer as standard. No ordnance officer would care to swap horses in the middle of the stream of a big war for any primer at all likely to be less stable than the good old reliable F.A. 70.

However, let the writer hastily set down here that except for a slight doubt as to their ability to withstand very damp and warm tropical storage for a long period of time, these new non-corrosive primers have proved entirely reliable and remarkably successful in

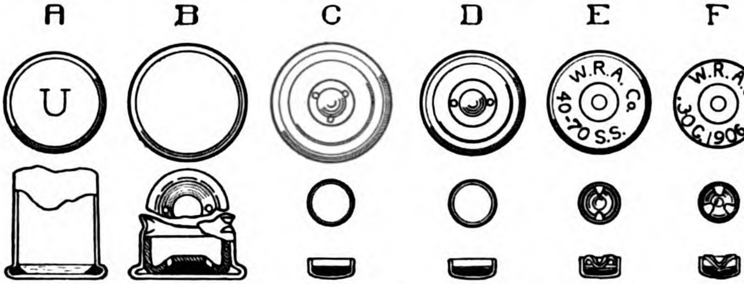

Figure 58. Cartridge Priming Methods

Sketches above show the methods by which American cartridges have been primed since the development of metallic ammunition.

A—The original method of priming American metallic cartridges; the .44 Henry Flat rim fire, primed by having its rim filled with fulminate composition. This method has remained the standard for rim fire ammunition to this day.

B—An early development of the copper "rim fire" case but primed with an inside primer for use in center fire rifles. This shows the Martin primer as loaded into the regulation .45/70 Springfield cartridge. Developed in the '70s and used on up into the early '80s. Some of the later lots of these cartridges carry the F.A. head stampings and date of loading.

C—Example of an early American cartridge primed with the Berdan primer, this one having three flash holes leading into the powder chamber of the case.

D—Another type of American cartridge primed with Berdan primer and having but two flash holes. There was also a type of case taking the Berdan primer and having but one centrally located flash hole, it is not very common.

E—An early type of American cartridge taking the Boxer primer, which fired through one centrally located flash hole, or "vent." This type of ammunition was possible of easy reloading and soon outmoded the Berdan primer here in America. Note the peculiar type of separate anvil used in this primer.

F—The present day type of Boxer primer as used in our American ammunition. This three-flange anvil has become the standard type for use in primers loaded into central fire cartridges.

The priming compounds in above drawings are shown in solid black.

every way, and constitute indeed the greatest improvement in small arms ammunition that has occurred since the adoption of smokeless powder. They are the primers of the future as they are of the present, they are here to stay, and they are of the type to use in all experimental work.

The Remington Arms Company were the first to introduce the non-corrosive primer in America, although such primers had been manufactured in Germany previously. Remington gave this priming the trade name of "Kleanbore." Other companies call their mixtures "Staynless" or just non-corrosive. All these mixtures have been very greatly improved since they were first introduced, and the particular mixture now used by each of the commercial ammunition companies is regarded by them as confidential. But as an indication of their composition it may be said that all contain one or more of the following ingredients, and perhaps others:

Barium Nitrate.
Nitro-amino-guanyl-tetracene.
Lead tri-nitro-resorcinate.
Antimony Sulphide.
Calcium Silicide.

When these non-corrosive primers are used in conjunction with all modern American propellent powders the combined primer and powder fouling deposited in the bore of the weapon is just what the name implies—non-corrosive. The fouling will not of itself cause rust.

When a cartridge thus loaded contains a lubricated, lead alloy bullet (as for example the .22 Long Rifle cartridge or the .38 Smith & Wesson Special cartridge, loaded with lubricated or greased lead bullet), the fouling is not only non-corrosive but is rust preventing as well. From the standpoint of rust prevention the bores of small arms fired with such cartridges need no cleaning unless they are to be placed in storage for long periods. The fouling serves to prevent rust even in a fairly damp climate.

When however, the cartridge is loaded with a metal jacketed bullet, while the fouling is non-corrosive, it is not, strictly speaking, rust preventive. It is possible for the fouling to absorb moisture from the air, and holding it in contact with the bore, rust may develop. Therefore when non-corrosive ammunition loaded with jacketed bullets is fired, to be safe the bore should soon thereafter be swabbed with an oily patch. Complete instructions for the cleaning of small arms will be contained in a subsequent chapter in the second volume of this work.

As will be indicated below, a number of different types and kinds of primers are manufactured for various uses in cartridges and shells of different sizes and calibers. Each is designed to ignite the powder charge used in the most efficient manner. A primer intended for use in a large, high pressure rifle cartridge could give very disastrous results if employed in a pistol cartridge, while the pistol primer would probably not ignite the powder in the rifle cartridge. Generally speaking, also, the non-corrosive primers designed for use in the larger rifle cartridges give a higher order of ignition than do the F.A. 70 chlorate primers, together with a considerably higher breech pressure with an equal amount of powder. Therefore, if for a certain cartridge a maximum powder charge has been established with the F.A. 70 primer, that charge of powder must be decreased three to five grains if a non-corrosive primer be substituted. In other instances also the stronger N.C. primer may overignite the powder charge, even a reduced charge of powder, and poor results may occur. For example the most powerful Winchester N.C. primer is the No. 120, it being correct for full charges in large cartridges like the .30-06. But it will sometimes give poor results in accuracy, and sometimes dangerous pressures when used in much smaller cartridges such as the .25-35, for which cartridge the correct Winchester primer is the No. 115. Particularly the No. 120 primer seems to overignite the newest du Pont powder known as No. 4759, no matter what the weight of the charge.

The primers manufactured by the cartridge companies are all numbered, although each company uses a different sequence of numbers. The proper primer to use with each cartridge is published by the cartridge companies, and tables showing correct primers of all makes are also published in the reloading handbooks published by the Lyman Gun Sight Corporation, Middlefield, Conn., and Belding & Mull, Philipsburg, Penna. Those who load or reload their own cartridges should be sure to use the correct primer for the size of cartridge and the powder.

Types of Primers

There are two general types of rifle and pistol primers, the **rim-fire primer** and the **center-fire primer.**

Center-fire primers are further divided into two types, the **American or separate anvil primer,** used almost exclusively in the United States, and the **Berdan primer** used almost exclusively in England and Europe.

The American or separate anvil primer is manufactured in three different sizes, and in each size is loaded with different amounts or kinds of priming mixture to give proper ignition with the type of cartridge and powder for which it is designed. The three sizes of these primers have cups of the following diameters.

.175-inch for small rifle and pistol cartridges.

.211-inch for large rifle and pistol cartridges.

204-inch for .45 Colt Auto. cartridge of Frankford Arsenal manufacture.

Shotgun primers differ in construction and size from all the above.

Rim-fire Primers

Figure 59 shows a rim fire cartridge case with the priming mixture in the rim. The case is made of copper or soft brass, and is comparatively thin and light as compared with a center fire case, so that its rim can easily be indented by the firing pin. Notice the hollow rim into which the wet priming mixture is spun while the case is revolving rapidly so that the hollow rim all the way around its circumference is filled with the priming mixture. The primed

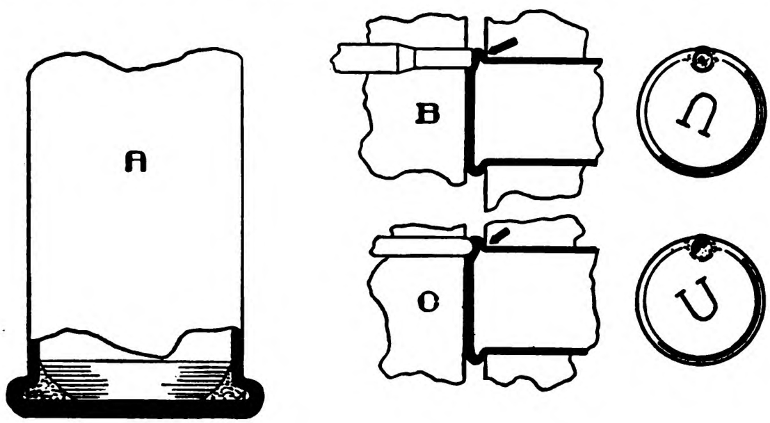

FIGURE 59. THE RIM FIRE PRIMER

A—Sectionalized rim-fire case, showing the priming mixture "spun" around the entire circumference in the rim.

B—Action of a flat pointed firing pin, which gives the best ignition with rim-fire cartridges.

C—Action of a round pointed firing pin, which does not crush the priming mixture evenly over a large enough area, and which often causes faulty ignition and poor accuracy.

Note that with the rim-fire assembly, the "anvil" is formed by the rear end of the rifle barrel—and it is imperative that this area around the chamber-firing pin be kept clean and true-surfaced, otherwise faulty ignition will result. This "anvil" should never become dented through snapping the rifle with an over-length firing pin. Arrow indicates "anvil." Correct and absolutely uniform ignition is of utmost importance in the case of rim fire ammunition, or accuracy will suffer.

cases are then sent to a drying room to dry out the priming mixture and increase its sensitiveness before being loaded with powder and bullet.

When the firing pin strikes the relatively thin, hollow rim of this case it indents or compresses the rim between the nose of the firing pin and the rear end of the chamber (which acts as an anvil), and the priming mixture is crushed. This explodes the mixture which gives off a hot flame and ignites the powder charge. A rim fire cartridge having once been fired there is no way in which the case can be reprimed and reloaded again. The advantage of the rim fire case is its cheapness. Its disadvantages are that due to thin construction it will not stand high pressures or heavy charges, and it cannot be reloaded.

American (Separate Anvil) Center-fire Primers

These primers consist of a cup, anvil, charge of priming mixture, and a shellacked paper disc, all assembled into a complete primer. This primer is then pressed into the primer pocket which is formed in the center fire case. See Figure 60.

Primer cups are stamped out of thin sheet brass for rifle primers, and of thin sheets of gilding metal for pistol primers. Gilding metal (copper 90 to 95 per cent, zinc 5 to 10 per cent) is used for pistol primers because it is easier indented with the relatively weaker mainspring of revolvers and pistols. As stated above, these primers are made in three sizes of cups, having outside diameters of .175, .211, and .204-inch. The inside of the cup is then filled approximately half full with the correct amount and kind of wet priming mixture, this charge being called the *pellet*. On top of this pellet is seated a thin disc of shellacked paper to keep it in place and to assist in waterproofing it. Then, while the priming mixture is still wet, the dome shaped brass anvil is pressed into the mouth of the cup. The assembled primer then goes to the drying room before being loaded into the cartridge case.

The anvil is stamped from a thin sheet of brass, is curved high or domed in its center, and has two or three circular cuts in its edge for the primer flame to pass through, as shown in Figure 60. When seated in its cup its base projects several thousandths of an inch above the outer edge of the cup so that when the primer is seated down in the primer pocket of the cartridge case it rests on the anvil rather than on the cup.

This primer, when completely assembled and dried, is then pressed into the primer pocket of the cartridge case so that the base of the anvil rests on the bottom of the pocket, and the top of the cup is just slightly below the surface of the base of the case. All United States primers of a certain cup diameter should fit all cartridge cases with that diameter of primer pocket, and they usually do so to a fairly satisfactory degree, but interchangeability between factories is not one hundred per cent perfect, and usually a perfect fit is assured only by using primers and cases of the same manufacture. Sometimes a primer of one make will appear to the uninitiated

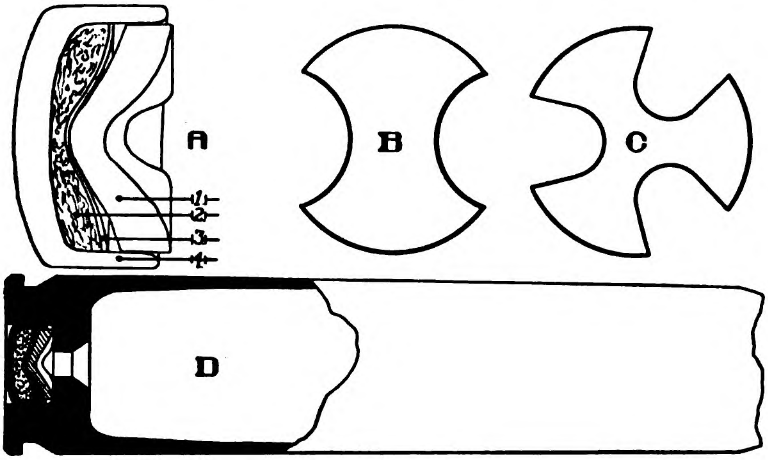

FIGURE 60. THE AMERICAN CENTER FIRE PRIMER

A—Cross section showing details of primer construction; 1 is the anvil, 2 is the pellet, 3 is paper disc, 4 is the cup. B and C show top views of anvils; there are two types in general use, one having two cuts and the other three cuts in the edge through which the flame passes to the flash hole in the primer pocket of the case. D shows cross section of cartridge case with the primer seated properly in the primer pocket.

This type of primer is often referred to as the Boxer primer.

to fit a case of another make perfectly, but there will be a slight misfit inside which results in the anvil not being supported quite as it should be, and this may slightly affect ignition and accuracy.

In the rifle or pistol the firing pin indents the cup, and crushes the primer pellet between the inside of the cup and the dome of the anvil. The pellet explodes and its flame flashes through the two or three circular cuts in the edge of the anvil, then through the flash hole in the bottom of the primer pocket of the case, and ignites the powder. Faulty ignition can occur from the firing pin not striking a hard enough blow, by the firing pin not striking the center of the cup and thus not crushing the pellet against the dome of the anvil, or by the primer having been roughly handled before or during insertion into the pocket so that the primer pellet has been powdered. If the firing pin strikes too heavy a blow, or if the point of the firing pin has too sharp an edge, making it in effect a punch, the primer cup may be pierced, resulting in what is known as a punctured primer, and powder and primer gas and flame may escape to the rear into the breech mechanism of the weapon with more or less disastrous and sometimes dangerous results. "Percussion" is also important, the blow must be a sharp, sudden one.

The center-fire cartridge having been fired, the case can be reloaded again by punching out the old primer with an ejector pin inserted from the mouth of the case through the flash hole. The empty and slightly expanded case can then be resized, a new primer inserted, and the case reloaded with powder and bullet, resulting in a considerable saving as compared with new ammunition, as the cartridge case is the most expensive of the cartridge components.

In most Government small arms ammunition the primers, after being inserted in the cases, are crimped into the pocket. This is done to absolutely insure against a primer falling out, or coming out during firing and jamming the mechanisms of automatic weapons. If such cases are to be reloaded these crimped in primers have to be removed with a specially strong ejector pin, and afterwards

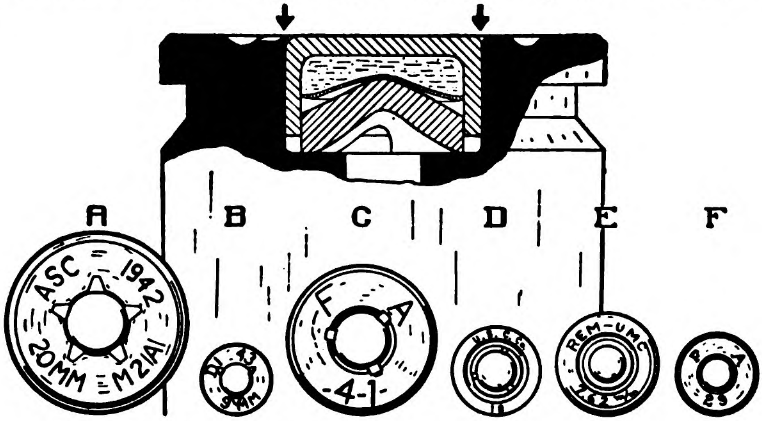

FIGURE 61. PRIMER CRIMPING METHODS

The First World War brought the machine gun into full use and prominence and with it came the automatic shoulder rifle. It immediately became necessary to take additional precautions to insure that the primer be retained in the primer pocket during operation of such guns, and to this end cartridge manufacturers added an operation to their manufacturing process—the crimping of the primer into the case pocket. At first, this was carried out by actually crimping a rim around the pocket edge, much as the bullet was crimped in place; this rim being "spun" over and such a cartridge was said to have a "crimped primer." Shortly afterward, a much simpler method was devised, whereby the primer was retained in place by means of small segments being turned over it at intervals, done by means of a punching operation; this method is practically universal today, the crimp has to be removed from the primer pocket, and the pocket reformed to exact size and diameter with a special tool.

The Berdan Primer

Berdan primers are used almost exclusively for rifle and pistol cartridges in England and on the continent of Europe, but have been made only experimentally or on foreign contracts in America. The two types, American and Berdan, will not interchange, nor can cartridge cases made for the one be used with the other.

The Berdan primer differs from the American primer in not having the anvil assembled in it. Instead, the anvil is formed in the primer pocket of the case, and is a part of the case itself. The primer cup, priming mixture or pellet, and disc of shellacked paper are essentially the same as in the American primer. Cartridge cases intended for Berdan primers can readily be told from American primer cases by their having two or three flash holes around the edge of the bottom of the primer pocket instead of one flash hole in the center of the pocket. Also the bottom of the primer pocket is raised in its center, in the form of a dome, to form the anvil. See Figure 62. The action of the Berdan primer is exactly the same as with the American primer. The firing pin indenting the cup, crushes the pellet of priming mixture against the anvil in the primer pocket of the case, and the flash enters the propellant powder chamber through the two or three flash holes around the edge of the pocket.

Extensive experiments have been made to determine which form

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and such cartridges are said to have "staked primers." This style of fastening is occasionally referred to as "stab crimped primers."

A—Illustrates a staked primer in a 20 mm gun cartridge, a powerful automatic weapon where continuity of fire is of extreme importance and where the primer is retained by means of five turned-in segments.

B—A Canadian-made 9 mm cartridge, having a three-point staked crimp.

C—Example of a .50 machine gun cartridge with staked primer.

D—.30/06 Springfield cartridge, manufactured in 1918 by the U.S. Cartridge Company, originally designed with a ring spun around the primer pocket and intended to be turned over around primer edge, but later changed to the staking method.

E—Cartridge for the 7.62 mm Russian rifle, having a deep rim spun over primer edge, this is occasionally known as a "ring crimp."

F—The experimental .276 Pedersen cartridge, designed for use in the Pedersen military rifle. This cartridge has a crimped primer, consisting of a shallow ring folded down around primer's edge and done by means of a flat punch larger than the primer pocket.

The enlarged sketch at rear shows a section of cartridge through the primer area, with metal stamped and turned over in segments, as taken from example D. A staked primer.

of primer is the more efficient. One year, in an attempt to determine this, the issue of .30-06 National Match ammunition, made with particular accuracy for the National Matches, was primed with a Berdan primer. Such is the importance of the primer that if one form were more efficient than the other it would certainly be universally adopted. But our ballistic engineers have come to the conclusion that there is no difference between the two types. In England and Europe they use the Berdan primer because they started with that type, and all factories are tooled up for it alone. We use the American type for a similar reason, and because it greatly facilitates reloading the cartridge case, which reloading is practiced very

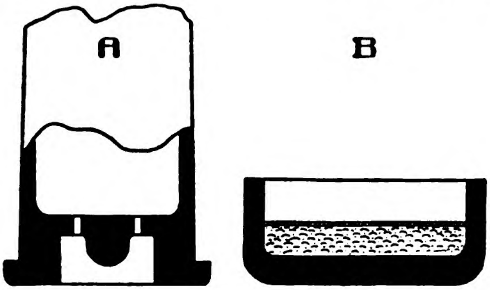

FIGURE 62. THE BERDAN PRIMER

A—Showing cross section of typical European cartridge case, with anvil and two flash holes incorporated in the case web for use with the Berdan type primer, which is universal in Europe and Great Britain. Some such cases have three flash holes. Case shown is a .303 British, which uses an unusually large diameter primer.

B—Enlarged view of construction of the Berdan primer. It has no anvil inside its cup.

extensively in the United States. There are but two ways of decapping a cartridge case which is loaded with a Berdan primer. The primer may be pierced from the outside with an awl pointed tool, and the primer pried out of the pocket sideways, much as one would remove a cork from a bottle with the point of a knife. This soon distorts the continuity of the primer pocket and ruins the case. Or the case may be filled to the mouth with water, the base set on a socket with its base drilled in the center to allow the primer to be ejected, and a wooden rod, snugly fitting the neck of the case is inserted and struck with a mallet. The compression of the water "pops" out the primer. It is advisable to wear a bathing suit, and afterwards the cases must be dried thoroughly.

The American experimenter labors under many difficulties if he attempts to use Berdan primers. They must be imported, not being manufactured in the United States, and steamship companies often refuse to transport them. Also the foreign makers do not, as a rule, understand American cartridges or propellant primers, and it is difficult to surely get Berdan primers which will be loaded with the correct type and amount of priming mixture to function perfectly with the size cases we intend to use them in, and for the particular propellant powder we propose to use.

Shotgun Primers

Both American and British shotgun primers are of the same general type, having the anvil incorporated in the primer itself, and are thus similar in construction to American rifle and pistol primers. But because of the construction of the paper shot shell, the shotgun primer is much deeper from head to base, and it is inserted in a *battery cup* and the battery cup is then inserted in the primer pocket in the shell.

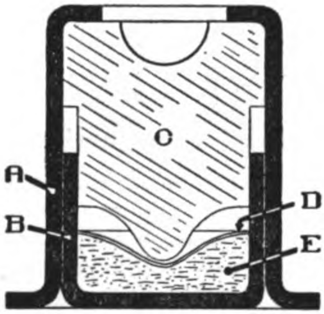

FIGURE 63. PRIMER FOR PAPER SHOTGUN SHELLS

A—The battery cup. **B**—The primer cup. **C**—The anvil. **D**—The paper disc. **E**—The priming mixture.

The base of the shotgun shell, because it is reinforced by a thick base wad, is much thicker than the bases of rifle and pistol cases, and the primer has to be deeper (longer) to bring its flash in close proximity to the powder charge. Also the brass head of the shell is made of relatively thin metal, and the heavier battery cup is required to reinforce the primer pocket and support the primer rigidly against the blow of the firing pin. The sides of the battery cup, also, are required to protect the base wad from the flash of the primer. See Figure 63. The primer is made deeper by making the anvil much longer, as will be seen in the sketch.

In the United States generally two sizes of shotgun primers are made, the regular size being for 10, 12, 16, and 20 gauge shells, and a smaller size is made for 28 gauge and .410 bore shells.

Testing of Primers

After the primers have been assembled and dried a certain proportion of each batch manufactured is given a very thorough test to insure freedom from any defects. Those taken from the batch for test are first inserted in cartridge cases, and are then subjected to what is called the *drop test* in a special testing machine. The primed case is inserted in a recess on the bottom of the machine which is exactly like the chamber in a rifle, pistol, or shotgun. A heavy breechblock containing a firing pin is then slid over the head of the case, locking it in the chamber. A steel ball, weighing from three to five ounces is then dropped from a height onto the top of the firing pin. By varying the height from which the ball is dropped the strength of the blow on the firing pin can be varied. From a minimum height of fall no primer should explode, proving that they are not too sensitive and dangerous to handle. From the normal height of fall every primer being tested should explode one hundred per cent, and the sound of the explosion should be "normal." From the maximm height of fall no primer cup must puncture. When the selected primers have passed this test, then the batch from which they were taken is released for loading into completed cartridges.

Packing and Storing

Primers sold separately for hand loading or reloading use are packed in small, flat, partitioned boxes containing one hundred primers. These boxes have wooden strips dividing them into partitions in which the primers lie in rows of ten side by side, and thus both the top of the cup and the bottom of the anvil are protected from contact with anything except the soft partition, and from shaking. Ten of these boxes are then packed in a pasteboard carton which thus contains one thousand primers.

Primers should be stored in a dry, fairly cool place; never in a hot attic or damp cellar. They should not be removed from their boxes and placed in a corked bottle with a view to keeping them dry as is sometimes done because the rattling and shifting of the primers in the bottle might crack or powder the primer pellets, or distort the correct position of the anvil in the cup. It would perhaps be most ideal to place the unopened boxes in a wide mouthed glass jar having a glass stopper. But simply storing the cartons in a dry, fairly cool place, such as a living room, and where children cannot have access to them, is entirely satisfactory.

Primer Precautions

1. Never try to compound a priming mixture, nor to "manufacture" a primer. Leave all such work to the competent explosive chemist with proper equipment and safeguards.

2. Never try to take apart a live primer. Primers may be "killed" by soaking for several days in thin oil.

3. Never try to explode a separate primer, either inside or outside a case, by striking it with a pin or sharp instrument. It is extremely dangerous. Not only is the flame intensely hot, but the primer cup and anvil may fly off with great velocity and deep penetration.

4. Never under any circumstances try to insert a primer in the primer pocket of a case which already contains powder.

5. In priming a case never strike the primer with the insertion punch of the reloading tool. Press it in gently and slowly. If it does not go into the pocket smoothly it is because the reloading tool does not properly align the primer cup with the primer pocket, or else the primer or pocket are deformed, or not a proper fit one for the other. Also, when the primer is inserted the top of the cup should always be just slightly below the surface of the base of the case, so that a straight edge drawn across the base will not touch the top of the cup. If there is any trouble examine and rectify, but do not monkey with that primer.

6. Never try to punch a live primer out of a primed case. First place the case in the gun and snap on and fire the primer.

7. If, in the process of loading, primers drop on the floor, pick them up at once and discard them. Do not leave them there to be stepped on and perhaps exploded.

Some Pertinent Primer History

While this is in no sense an historical work, it is believed that a little of the history of the development of the center-fire primer in America may be helpful to a better understanding of the ignition problem.

After many experiments, two successful types of center-fire primers were developed—the Berdan primer, and the American primer, sometimes called the Boxer primer—already described. Both were satisfactory, but at the time they were developed, almost everyone reloaded their fired center-fire cases, and for this purpose the American primer was much more convenient, as when fired the old primer could easily be punched out of its pocket by a pin inserted through the mouth of the case and flash hole, while the Berdan primer had to be pried out by a motion which often distorted the primer pocket, or else forced out by water pressure. Therefore the American primer came into almost universal use and has remained so ever since.

Black powder was very easy to ignite. Just a mere spark would do it. Thus, in early black powder days, most of our small as well as medium sized rifle cartridges were made for the small .175-inch primers. Even the early .38-55 cartridges used this small primer.

The larger .211-inch primers with their larger and stronger pellet were used only in the largest rifle cartridges.

But when smokeless powder was invented, it was found to be much more difficult to ignite and so it became the rule to use the larger primers for all but the very smallest cartridges, so as to obtain a flash that was large enough and hot enough. The larger cartridges used a coarser grained smokeless powder, and the coarser the grains the more difficult it was to ignite. In fact, the very coarse grains used in field pieces and cannon, were so difficult to ignite that it was common practice in artillery ammunition to screw a long perforated brass tube into the powder chamber of the case as an extension to the flash hole and to fill this tube with fine grained black powder. The primer ignited the black powder and the latter ignited the coarse grained smokeless charge.

At this time it was also quite common practice for hand loaders of rifle cartridges who were using smokeless powder to load two to five grains of black powder in the bottom of the case and then load the smokeless charge on top so that the black powder would better ignite the smokeless and give better accuracy. At this time also the cartridge companies made two types of primers in all sizes; one the old black powder primer which was usually assembled in a copper cup, and the other the more powerful smokeless primers which were usually assembled in a tougher cup which generally had the initials of the loading company stamped on them. The smokeless primers were not very popular among hand loaders because they contained such a large amount of chlorate that they caused corrosion in the rifle bore, or such a large amount of fulminate of mercury that they made the cartridge cases brittle. So, many hand loaders continued to use the black powder primers and insert a few grains of black powder in the bases of their cases.

The Berdan primer, for its size, could be made to contain a much larger amount of priming mixture than could the American or Boxer primer, and in order to obtain better ignition and accuracy in the .30-06 cartridge, one year all cartridges for use in the National Rifle Matches were primed with a strong Berdan primer. The results did not show conclusively that the Berdan primer was an improvement.

Then the non-corrosive, non-mercuric primers were introduced. At the start these primers did not show any improvement in ignition. In fact, Winchester could not get enough of their early non-corrosive mixture in a .211-inch primer to properly ignite the large .30-06 cartridge, and for this and larger cartridges, they were forced to make a larger primer with a larger primer pocket in the case. But gradually the non-corrosive mixtures were improved, and also modern powders were made more easy to ignite, so that today these primers give very excellent ignition with all modern powders and reliability and accuracy have improved accordingly.

The modern non-corrosive primer is much more powerful, size for size, than the older chlorate primer, so much that a maximum powder charge that has been developed with the old chlorate primer must be reduced three to five grains in weight when a non-corrosive primer is used, or over-ignition and excessive pressures will result. Thus the ignition problem for the time being seems to have been solved very successfully.

CHAPTER IX

AMMUNITION

Cases and Shells

THAT component of the complete cartridge known as the **case,** (or with shotgun shells—the **shell**) serves two general purposes. It is a container for the primer, the charge of propellant powder, and the bullet or shot, whereby all can be breech-loaded into the chamber of the weapon in one complete motion. And it also serves as a gas seal to prevent any escape of powder gas to the rear into the breech of the weapon.

Cases used in metallic ammunition, that is ammunition for rifles and pistols, are made of copper or brass. Copper is generally used for the lighter loaded rim-fire cases, and brass for the high velocity rim-fire cases, and for all center fire cases. At times, particularly during war, steel has been used to some extent for center fire cases. Shotgun cases are constructed with a brass or steel head, a paper body or side, and a composition base wad. Shotgun shells constructed entirely of brass are also used for special purposes.

The Brass Case

Copper (rim fire) and brass (center fire) cases are constructed by a similar process of drawing and stamping. The brass used in the manufacture of cases is an alloy of copper about 68 to 71 per cent, and zinc about 32 to 29 per cent, the exact alloy and its physical properties being prescribed by the cartridge manufacturer according to the particular case that is to be made of it. Some cartridge companies have their own brass mills, and others buy their brass from commercial brass mills. It, and copper also, comes to the cartridge factory in long sheets, sometimes ten or more feet in length, a few inches to several feet wide, and of varying thickness according to what particular caliber and size of case the factory wishes to make from it.

The first operation in making a case consists in punching a round disc out of the strip of brass, and then pressing this disc into the form of a shallow cup, the two operations being done in a double action press which operates as shown in Figure 64.

It should be understood that when brass is cold worked, that is hammered, punched, or drawn or pressed through a die, it becomes harder, and with successive workings it will get harder and harder

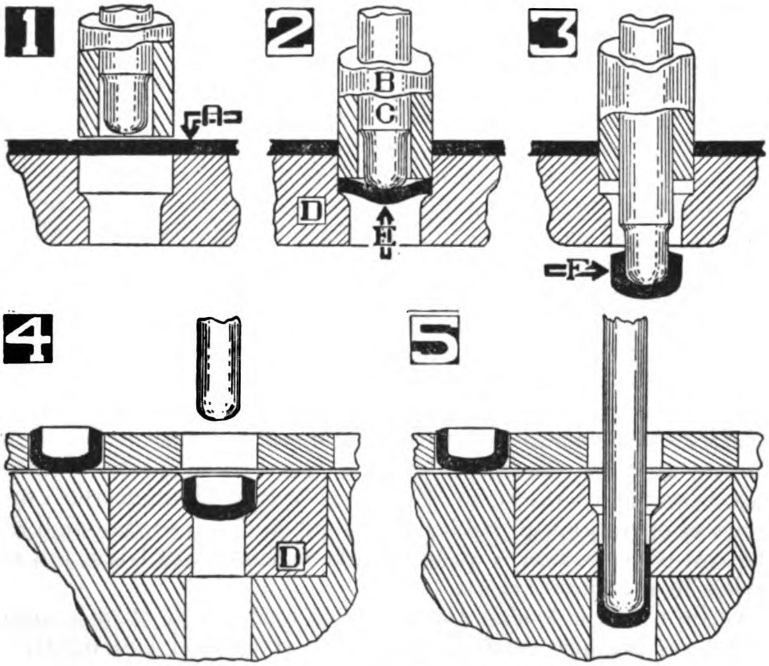

FIGURE 64. DIES, AND THE DRAWING OF THE CUP

Forming the brass cup and drawing it out. **1**—The original sheet of brass **(A)** as it comes from the brass mill, passes under the punches and above the die. **2**—The punches together descend, and the outer punch **(B)** punches out a round disc of brass **(E)**. **3**—The outer punch **(B)** then stops, but the inner punch **(C)** continues downward, pressing the brass disc through die **(D)** to form the cup **(F)**. **4** and **5**—In another automatic press, the cup is further drawn out by punch and die, as shown above, to elongate the cup.

until it becomes so brittle as to be useless. To obviate this the brass must be annealed by passing it through a furnace where it is brought to about a red heat. Thus the forming of the cup from the sheet of brass makes it hard, and it must be annealed before it goes to the first lengthening draw, and annealing also usually takes place between each of the subsequent draws until the case is formed into about its finished form. After each anneal the brass will be covered with scale. If scale and other dirt is allowed to remain on the brass while going through the operations it will cause fast wear on dies and punches, and it is also liable to become laminated into the brass, causing a weak spot where gas may break through on firing. So, after each anneal, the cases in progress are pickled and washed to remove scale and dirt. Also during the drawing the cups, dies, and punches are lubricated with a soapy water which continually flows over them.

After several draws the cup has gradually been formed into a long tube or ferrule with thin sides and closed at one end. Sketch 4 in Figure 64 shows how the dies and punches make these draws, operating so that the metal in the closed end is left quite thick. This closed end is then indented with the start of the primer pocket, and the ragged mouth is trimmed off for length, then the head and rim are formed with other punches and dies. Finally, if the case is to be bottle-necked the mouth is necked down to the desired size and location of shoulder. A final die insures the finished case being within the prescribed tolerance as to measurements. The number of draws and other operations, pickles, and washes and their sequence differ according to the size and type of case being constructed, but generally the process is about as shown in Figure 65. During all these operations there is continual inspection. In fact this exceedingly thorough inspection occurs through the entire series of operations of making cartridges, and it is so thorough that the cost of inspection is quite as high as the cost of labor and materials in the manufacture.

When a case is loaded and a normal charge is fired in it the internal gas pressure expands the case to completely and tightly fill the chamber, and if the brass were dead soft it would not spring back from the chamber walls after expansion, but would cling to the walls, extraction would be very difficult, the case might pull apart, or the extractor might cut through the rim. If, however, the brass is harder it springs back part way to its original dimensions after the pressure falls, its tight contact with the chamber is relieved, and it is easy to extract. But if the brass is too hard it will be brittle and will crack.

The most suitable hardness is not the same for all parts of the case. In general it must be hardest at the head or rear end, where it must be both hard and tough to stand the heavy breech pressure and back thrust of the gas. Then the case should get slightly softer towards its front end, but the neck must not be too soft, and must have enough spring to it to hold the bullet firmly, and to spring back from the chamber neck after firing.

The two most important qualities in a cartridge case are that the brass should be of good quality, and the case should be of suitable hardness and toughness in its various parts. These qualities make all the difference between an excellent case and one that is entirely unsatisfactory and very likely unsafe. Hardness and toughness are obtained by varying the draws and anneals. The drawing of cartridge brass cannot quite be said to be a science. Rather it is an art learned by long experience and experiment, and controlled

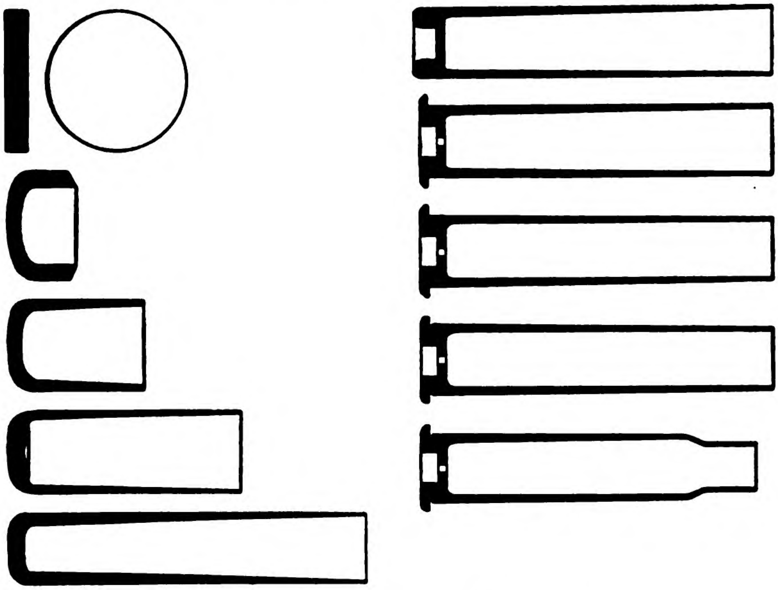

FIGURE 65. CARTRIDGE CASE "DRAWS"

Showing, in general, the various forms that the brass cartridge case passes through in manufacture, from the "coin" to the completed case.

by the microscope and Brinell tests. For a new design of case it cannot be calculated exactly in advance, and it may require many weeks of experiment, and many dollars in labor, materials, and laboratory services before the exact sequence of draws and anneals, and design of punches and dies is arrived at which will result in manufacturing this new case in an entirely satisfactory manner.

The hardness of brass may be determined by a Brinell test, or by a microscopic examination. The Brinell machine punches a small indent into the brass, the punch operating with a standard pressure. The depth of the indent determines the hardness of the material. The surface of the brass is first etched slightly with acid when it is to be examined with the microscope. Through that instrument the brass will then be seen to be composed of grains, flakes, and crystals. If these are large and angular the brass is soft. When the brass is cold worked these flakes and crystals are mashed and worked smaller. Hardness is determined by the size and appearance of this grain structure. The superintendent of a cartridge factory who understands this art of drawing brass is one of its most valuable employees. The writer will never forget the many conferences he had with Mr. Andrew Hallowell, the Superintendent at Frankford Arsenal, and Mr. Goss of the Scovill Manufacturing Company, one of the largest brass manufacturers.

The writer thinks that enough has been said to indicate that no individual in a one-man shop can possibly make satisfactory or safe cartridge cases. Neither can he machine a case up out of brass rod, because its portions would be entirely lacking in the essential hardness or softness. He cannot and should not attempt annealing because in the absence of a thorough metallurgical training and without instruments he cannot tell what the results will be—usually they will be the direct opposite of what he hoped for. Such being the case the individual experimenter or designer must take the manufactured case as it comes from the cartridge company. In his experiments he can slightly alter this case, or take certain liberties with it, but beyond this he cannot go. These liberties that are permissible within the factor of safety will be discussed below.

There are certain difficulties or troubles that may occur with cartridge cases that are not always caused by any lack of precaution on the part of the manufacturer, but occur merely because in the manufacture of millions of cases one defect or another is almost certain to occur once in a great while.

If a small hole, perhaps the size of the head of a pin, or elongated to perhaps 1/8 or 1/4 of an inch, appears in the wall of a case after it has been fired, the powder gas having leaked out through the hole slightly and blackened or burned its edges; this is usually caused by some impurity such as dirt or scale that has been laminated into the brass during manufacture. It may have been laminated in while the sheet of original brass was rolled in the brass mill, or the sheet may have been dirty on its surface before it went to the double action press that stamped out the cups, or it may be due to scale or dirt on the surface during manufacture. Such a defect may occur five or six times in one box or case of ammunition, and then never occur again in a shooter's lifetime, because the trouble occurred only with one sheet of brass or during one anneal and wash, the defective cases being kept close together during the process of manufacture. Such defects are very rare.

The case may be very slightly indented inward at some point, usually around the shoulder, as though it had been struck by a rounded punch or hammer. It is usually caused by an excess of oil or lubricant in the die. If it is not too large it causes no trouble at all and may be disregarded.

If a case cracks or separates around its circumference about half an inch in front of the head, where the web thickness of the wall

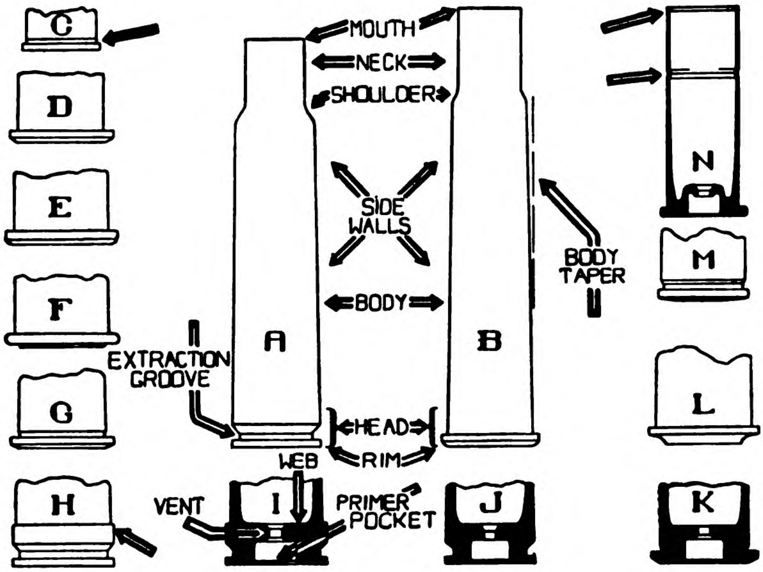

Figure 66. Nomenclature of the Cartridge Case

The present day brass cartridge cases frequently differ in small details of construction from those of early days, as well as in variations in type of case.

A shows the conventional type of rimless case, with its various sections designated by proper names.

B is the usual rimmed case, with parts designations. The sidewalls on this particular case run straight into its head, there is no "clearance groove" trimmed out by the head-turning knife during manufacture, as is shown on examples **C** and **G.**

C shows the head of an early revolver cartridge, where rim diameter is kept as small as possible. They did not have automatic ejectors on the first revolvers and this head was used only for positioning the case in the chamber, they made it as small as possible in order to keep size of cylinder down. Ammunition makers still have to put these inadequate rims on some revolver cartridges in order to keep them from overlapping when the cylinder is fully loaded.

D shows a chamfered rim. These beveled or chamfered rims were not always put on for appearances sake; they were made with an extensive bevel on some of the early rifle cartridges used in the falling block rifles so that the rising block would exert a considerable camming action on the base of the cartridge and thus seat it snugly into the chamber for that starts to decrease; this is caused either by excessive headspace in the chamber or case (the case being stretched lengthwise too much on being fired), or by too hard an anneal (brittle brass). This is dangerous and immediate investigation is indicated.

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last fraction of an inch it could not be seated by the fingers. Some of the early repeating actions did likewise. And in some revolvers, a chamfered base also pushes the cartridge completely into its chamber as the cartridge base slides across the recoil plate on the revolver frame, thereby seating it solidly and avoiding a misfire.

E is a rim with rounded edges.

F is an embossed head, or base. These were made up on some of the larger cartridges for the early repeating rifles and were necessary in order that the action seat the cartridge completely into the chamber.

G shows a chamfered rim on a cartridge case that also has a "clearance groove" trimmed out just ahead of the rim. This groove is not always necessary and it may or may not be on different lots of a certain caliber of case. It is cut out by the head trimming knife used to square up the rim surface under the head of the case, which is an easy and accurate method of correctly headspacing a rimmed case; such a groove probably also helps for more certain extraction of the fired case.

H is the head of the belted type of case.

I, J, and K are sectioned case heads of different types, with parts designated. Note that each type of case is shown with a different kind of vent (or flash hole, as this passage is often called). These differences in the shape of the flash holes are not intentional, in most cases it is intended that the flash hole be straight. The countersunk effects shown above are caused by manufacturing processes or troubles encountered during case manufacture. Excessive penetration of the piercing punch into the metal is one cause. A break-through of the metal on the die side into larger clearance between piercing punch and die (from worn tools) is another. Cases pierced on capping machines have the die on the inside of the case, and those pierced on reducers have the die on the primer side, which accounts for the bevel being on different sides. Simple, isn't it?

L is a type of case head seen only on a few obsolete foreign designed cartridges, generally of 10 or 11 mm caliber, designed for use in the early bolt action rifles where the bolt head fitted closely over the case base.

M shows the somewhat "dished" base of the Japanese 6.5 mm Arasiki cartridge which is one of the really few curved-base cases in existence. Their newer 7.7 cartridge has a flat base.

N is a sectionized sketch of a revolver cartridge case of the "balloon type" head construction. The mouth of this case is also chamfered on the inside, so the lead bullet can be seated without portions of its base edge being sheared off, in some cartridge plants this is called "burring." This case also has a "bullet stop ring" turned into its body at the proper place to position the bullet and retain it in place against receding from recoil when the cartridge is loaded with a charge of smokeless powder which does not completely fill the powder chamber. This groove is often termed a "cannelure" or "bullet seating groove."

If a case splits lengthwise in the body it is usually due to a combination of loose chamber and improper anneal. The crystals of the brass will resist a pulling force to a limited extent, depending on their hardness and toughness, after which they will separate at the point of strain and form a crack. This is why "wildcat" cases, formed by enlarging or "blowing up" standard factory cases, are liable to split, either when being formed or on firing. Wildcat cases will be discussed further along.

Another form of split, usually in the neck or shoulder of bottlenecked cases, is termed **season cracking.** The brass in this part of the case is under more strain than in the other portions due to its having been necked down so much. With proper hardness and toughness it resists this strain well, but after some years the brass gets "tired" and the crystals tear apart from the strain, and a split develops, usually in the neck. A season crack may develop when the case is fired, or a small or large proportion of them may show up in loaded cartridges that have been stored for some years. Season cracking splits that occur only on firing are not usually dangerous, although gas will escape through the split, and if this occurs a great many times the gas may score and burn the chamber walls, but usually the case expands sufficiently behind the split to prevent any gas getting to the rear. If a season crack is found in the neck of a loaded cartridge before it is fired it would be well to destroy that cartridge. The bullet is almost certain not to fly accurately, moisture may have leaked inside the cartridge and made it into a dud, the bullet may be forced down deeply into the neck of the case onto the powder charge, increasing the pressure, and worst of all one may load such a cartridge into his rifle, and then have reason to extract it without firing. The bullet may pull out unnoticed, and remain in the throat of the chamber, another cartridge may then be loaded, and the bullet of that cartridge may be forced back into the case so that the rifle is loaded with two bullets in front of the powder charge, which might result in a very serious accident.

Season cracking is almost never seen where one buys his ammunition from a dealer who has a fairly fresh stock of ammunition on his shelves, and then fires that ammunition within a couple of years. It is quite prevalent in old ammunition or in war ammunition that has been stored for a great many years. Well made ammunition should stand at least ten years of storage before developing any serious proportion of season cracks. It has recently been found that by not washing the cases after the last neck anneal the tendency to season crack is reduced. This is why one usually sees bottlenecked cartridges showing heat discoloration at the neck and shoulder. Also it is undesirable to wash or polish cartridge cases before reloading them.

When a primer pocket enlarges so that gas leaks around the outside of the primer, or the primer drops out, it is usually because the cartridge contained an excessive load and gave too high a pressure, but it may be due to the brass being annealed too soft at the head of the case. Enlarged primer pockets can also occur from the chamber being too large at its rear end, or the case being too small for a normal chamber, resulting in the case expanding enough to permit the primer pocket to enlarge.

When a cartridge case is fired, and its neck is then resized, and it is then reloaded we do not know precisely what occurs with regard to the hardness or toughness of the brass in the neck because, so far as the writer knows, no extensive research has been made into this matter. But we are inclined to think that when the case is fired the heat of the burning powder slightly anneals the neck, and then the cold working in neck resizing hardens it again to about its original toughness. At any rate good cases have often been fired, neck resized, reloaded and fired again as many as fifty times with no trouble of any kind except possibly a slight elongation which can be corrected by trimming the mouth occasionally back to standard length. But when the case is full length resized each time it is fired, trouble is more liable to occur sooner or later, due probably to the case having been cold worked out of all proportion to the slight anneal it received on firing. Full length resizing is sometimes necessary to make a case expanded from firing fit in a certain chamber, but as a rule it should be avoided, particularly as a regular practice.

The various defects, accidents, and malfunctions that may occur with cartridge cases, either during manufacture or upon firing, are further listed and discussed in Chapter XII.

The Case Neck

Under normal conditions of intelligent firing, reloading, and experimenting with well made cases, the neck of the case is probably its most important portion, and deserves rather full discussion.

With factory cartridges it is highly desirable that the bullet be retained firmly in the neck of the case so that there will be no danger of its falling out, or being pressed deeper into the case by handling or from pressure in a tubular magazine, or indeed from recoil in any magazine. Also a certain tightness of bullet fit is often desirable and sometimes essential to develop sufficient initial pressure to cause the powder to burn properly. This is particularly necessary in revolver and pistol cartridges. The degree of firmness or tenacity with which the bullet is retained in the neck is expressed in terms of pounds of *bullet pull*. The cartridge is clamped firmly in the bullet pull machine, jaws are clamped on the bullet, and the number of pounds of straight pull on the bullet required to extract it from the neck and mouth of the case is measured by a scale. As an example it has been found that for best results in the Ball Cartridge, Caliber .30, M2 (.30-06 service) the bullet pull should not be below 45 pounds. Great variation in bullet pull means variation in velocity, and results in a greater vertical dispersion on the target.

Bullets are retained firmly in the neck of the case in two ways. First by having the neck of the case small and inserting the larger bullet into it. This is called "friction tight." The elastic case neck hugs the bullet and holds it tightly. Second, by crimping the mouth of the case into a cannelure on the bullet. Factories usually employ a combination of these two methods.

The various methods of crimping the case on to the bullet are shown in Figure 67, shown on page 209. The usual crimp now employed in American metallic small arms cartridges is shown in Sketch G. The extreme mouth of the case is slightly turned or crimped inward, so that it bites all around its circumference into the crimping cannelure that is rolled into the bullet. This is a very good method of crimping as it prevents the bullet from either pulling out of the case or being driven down deeper into the neck. It also helps to waterproof the neck. If this crimp is applied carefully while the entire neck is held in a tight inclosing die the remainder of the neck does not buckle away from the sides of the bullet and the whole length of the case is friction tight on the bullet, preserving both the alignment and the waterproofing. But if the neck be not held in a die while crimping the downward force of the crimping die on the mouth of the case is liable to buckle the side of the neck outward away from the sides of the bullet below the crimp, so that the bullet is held only by the crimp. In this case the crimp still keeps the bullet from coming out or driving into the neck, but the neck is no longer waterproof, the bullet is loose in the neck, is not held in alignment, and the bullet can often be wobbled slightly in the neck or turned around.

Sketch C shows a variation of this crimp, known as the segmental crimp, the crimp being applied only around a portion of the circumference of the neck. This crimp seems to present no advantage over the typical American method above, and is not as waterproof.

When a bullet is fired from a crimped case the bullet does not smooth or iron out the crimped mouth of the case completely. What happens is that the case neck first expands to the full limit of the neck of the chamber. The freed bullet then starts forward. Some of the crimp thus remains in the mouth of the case, and if the case is to be reloaded that crimp must first be removed or it will scrape and deform the next bullet as the latter is pushed into the case in reloading. The crimp is removed by a small reamer which cuts a thin shaving from the mouth of the case and leaves it very slightly bevelled at the mouth. Or the crimp can be shaved off with a sharp knife, but not so uniformly. Of course the crimp in a fired factory cartridge case having once been removed this need never be done again unless that case is afterwards re-crimped.

Another method of removing the above crimp from fired cases preparatory to reloading is to insert a cone shaped plug just deeply enough into the mouth to very slightly bell-mouth the edge of the mouth.

Another method of crimping, shown in Sketch H, is frequently employed in foreign ammunition. It is not quite as secure as the American method and adds nothing to the waterproofing. For reloading such cases the indentation is easily removed when the case is neck resized and then expanded in the usual American resizing die which accompanies hand loading tools. The expander plug presses the indentation outward.

Sketch E shows the .45 Colt Automatic pistol cartridge. A crimp cannot ordinarily be employed here because this cartridge is positioned or headspaced in the chamber by the mouth of the case abutting against the square forward end of the chamber. Thus the mouth of the case must be left square to surely position and cannot be rounded. The walls of the neck of this, and similar cases, are made rather thick, and the neck is a little small in inside diameter, the larger bullet being forced into it and held friction tight therein. Security and waterproofing are still further secured by shellacking the inside of the neck. This sketch also shows a bullet stop ring rolled into the bottom of the neck of the case to prevent the bullet receding deeper into the neck. Such bullet stop rings are frequently seen in cartridges where the light powder charge does not completely fill the case and keep the bullet from receding. Sketch F shows a stab crimp that is occasionally employed, a slight indentation being made in the wall of the case and continuing into the bullet jacket. However, this is not considered good practice because when this indentation is stamped into the bullet jacket, there is a tendency for the jacket metal to rise around the stab and separate slightly there from the bullet core.

Crimping of some kind is often very essential in a cartridge in order to delay the separation of the case and bullet enough to set up sufficient pressure at the start to give good ignition and proper burning of the powder. This is particularly true of pistol cartridges and for two reasons: first, to properly ignite the small charge of powder which usually does not nearly fill the powder chamber of the case, and second, to prevent the sharp recoil from setting the bullets of those cartridges in the cylinder or magazine back into the partly empty powder chamber of the case and thus causing excessive pressure and poor accuracy, or malfunctions in automatic magazines. In some heavy caliber revolvers, the bullets may jump forward, from excessive recoil. In factory manufacture the firmness of the crimp is designated in terms of *bullet pull.*

The case is secured in the bullet pull machine, and an arm, like

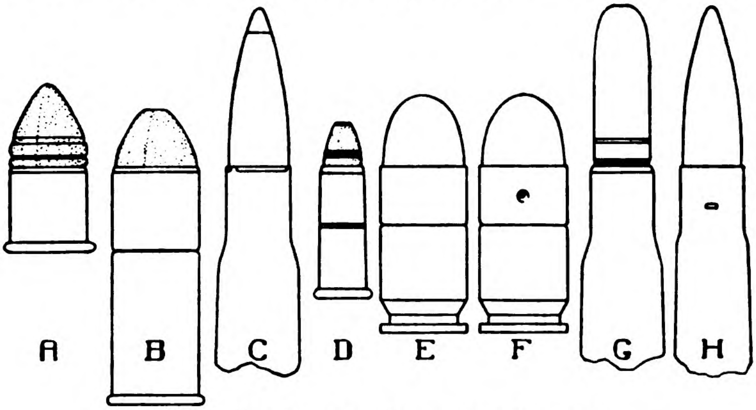

FIGURE 67. CRIMPING STYLES AND METHODS

Illustrating the various methods which have been employed to fasten the bullet into the cartridge case.

A—Showing the original crimp first used back around the '60s and here shown on the .41 Rim Fire cartridge, wherein the mouth of the case is turned into a groove rolled at the base of the heel of the bullet. In practice, quite a heavy "roll" is given this edge and the bullet thereby firmly secured, the crimp possessing certain waterproofing qualities after both bullet and upper end of case have been coated with a heavy coat of lubricant.

B—The same crimp as applied to a center fire case using a bullet with inside lubrication. This is the old .45 Colt revolver cartridge, by far the most powerful in existence when loaded to capacity and is here shown to illustrate another requisite of the crimp, namely to hold the bullet in place against recoil. In the case of this .45 Colt cartridge, a heavy crimp is made over the beginning of the bullet ogive which prevents the bullet from jumping out of the case from the excessive recoil of this particular cartridge. In certain other cartridges, this same kind of a crimp is necessary to help retain the bullet in place until the powder charge is fully ignited and thus assist in the initial combustion of the powder charge.

C—The segmental crimp, a type of fastening much employed in foreign rifle and revolver ammunition. Here shown is a 7 mm rifle cartridge as loaded by Eley, the great British ammunition firm. The Germans also employ this segmental crimp considerably. It merely pinches the case mouth against or into the bullet jacket but leaves small segments untouched.

D—The .22 Winchester Automatic cartridge, an illustration of the crimp assisting in the performance of this special cartridge. This gun and car-the beam of the scale is clamped firmly on the bullet. By extending a weight along the beam the number of pounds of direct pull required to draw the bullet out of the case can be determined. Each factory cartridge has its own prescribed bullet pull. For example, with the .30-06 cartridge, a minimum bullet pull of 45 pounds is prescribed, but it is believed that this heavy pull is given to make

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tridge were developed in 1903 and it was the first example of self-loading rifle to appear on the American market. It used smokeless powder and a greaseless bullet. The smokeless powder of that day was difficult to make perform well in an automatic action and so special precautions were taken to make the gun operative. This .22 Automatic cartridge was loaded into a copper case of special construction to withstand high pressures and the case was tapered appreciably to further proper functioning. The front edge of case was tapered down to furnish a smooth bevel to help guide cartridge into the rifle chamber and then a heavy crimp put on the assembly so as to offer resistance enough to help delay bullet travel until the powder was sufficiently ignited. For years, it was necessary to load a cardboard wad on top the powder charge of this cartridge, with a bit of air space between it and the bullet; finally the powder makers developed a smokeless powder of sufficient bulk and ease of ignition to fill this case properly and function without any wad. They also developed a smokeless powder enabling the regular .22 long rifle cartridge to be used in self-loading .22 caliber rifles and this special .22 Automatic cartridge is now fast going out of existence.

E—An example of retaining the bullet "friction tight" in the case. Here is the .45 Colt Automatic pistol cartridge and the requirements of this ammunition include that it must chamber or position upon the mouth of its cartridge case. This means that this case cannot be crimped or bent over in the least, as this would result in variation in the head space of the cartridge and in misfires, etc. Hence, the bullet in the .45 Auto cartridge is always pushed down into an undersized case mouth and held firmly in position by the resulting friction grip of the case, further assisted by the walls being shellacked before the bullet is inserted. For years the .30 Springfield service ammunition was so loaded, as such uncrimped ammunition is supposed to give superior accuracy.

F—An example of the "stab crimp"; the .45 Auto pistol cartridge is occasionally loaded into the case as described in E and then further reinforced by stabbing into the case at three equidistant points, punching into the bullet jacket also. Quite a bit of .45 pistol ammunition was so loaded during the First World War, but it was never a highly approved method of crimping.

G—The standard American "crimp," or method whereby the bullet is held in place by turning over the mouth of the case into a groove in the bullet. This groove, placed in the exact position necessary to insure the cartridge being exact overall length when bullet is crimped, is generally known as the crimping groove; although other grooves may be added for other purposes. Here is shown the service .30 Springfield case loaded with a 220 grain sporting bullet held in place with a stout crimp.

the cartridge secure against rough handling because fine accuracy, which is a proof of proper ignition and burning of powder, can be secured when the bullet is merely seated friction tight in an uncrimped case, where the bullet pull is less than twenty pounds.

From the standpoint of fine accuracy crimping is undesirable particularly with a lead bullet because the side walls of the soft bullet are more or less deformed as it tears itself through and out of the crimp. But with pistol cartridges, the effect on accuracy is less important than the poor ignition and burning of powder that would result without the crimp. With metal cased bullets, in most cases, there is no conclusive evidence that proper crimping is prejudicial to the finest accuracy.

When metal cased bullets are used it has been the common practice among our best reloaders of rifle ammunition to resize and then expand the necks of the fired cases so that their inside diameter is about .003-inch smaller than the diameter of the bullet. When the bullet is seated the neck holds it firmly enough for all normal handling, and the bullet pull is heavy and uniform enough to give excellent accuracy. Hand loaders do not, as a rule, crimp the mouth of the case onto the bullet unless the cartridge is to be used in a rifle with tubular magazine.

When lead alloy bullets are used, forcing the bullet into a small neck would reduce the diameter of the bullet, so the case neck is resized and then expanded to an inside diameter equal to the diameter of the bullet.

With revolver and pistol ammunition using lead bullets the case necks are sized and expanded to exact bullet diameter and after seating the case mouth is firmly crimped on the bullet. This tight crimping is very necessary to cause the powder to burn completely in the comparatively short chamber and barrel of these hand weapons, and no really good results can be obtained without firm crimping.

To illustrate further let us take the example of the .30-06 cartridge. Normally the metal cased or expanding point bullet has a diameter of .3085-inch. The case for this bullet, before it is loaded should have an inside neck diameter of about .306 to .307-inch. When the bullet is seated in this case the bullet being hard and strong will expand the case neck inside to its own diameter, and of course the outside of the case neck will correspondingly expand.

H—The British type of crimp for service ammunition is shown by this .303 Mark VII cartridge, where the 174 grain pointed bullet is held in place by three indentations rolled into the case so they project into a groove placed on covered end of the bullet. This is not a particularly tight method of fastening as the bullet can generally be rotated slightly by the fingers in much of their service ammunition.

The normal .30-06 chamber has such diameter at its neck that it will be about .003 to .004-inch larger than the outside neck diameter of this loaded cartridge. In other words there is about .003 to .004-inch clearance between the neck of the loaded cartridge and the neck of the chamber.

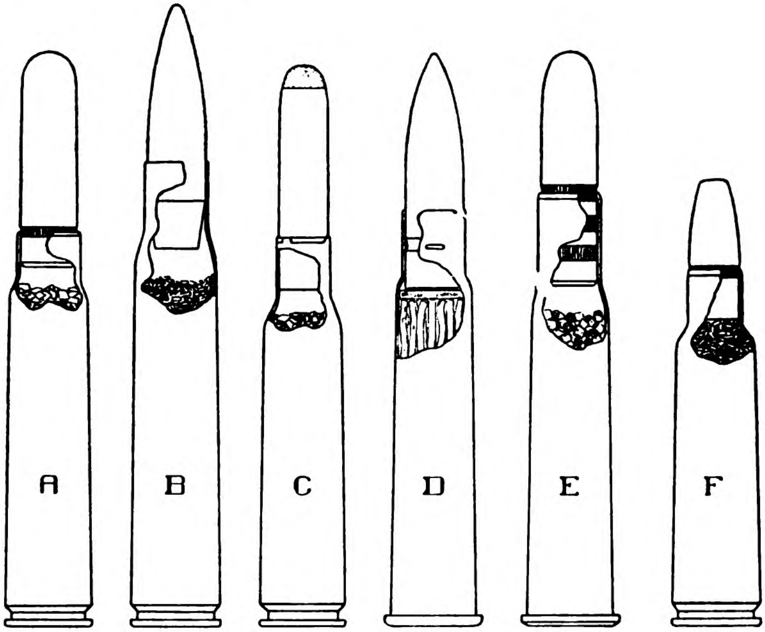

FIGURE 68. CASE NECK COMPARISONS AND METHODS OF LOADING

It is an established rule in ammunition manufacture that the overall length of a loaded cartridge shall meet rigid specifications as to the standard length, irrespective of what weight or type of bullet be loaded into the case. This is imperative in the case of military ammunition, as cartridges of varying lengths cannot work properly through rifle magazines or the actions of various automatic weapons. Sporting ammunition can be a bit more flexible in this respect, but as a rule we also find the commercial companies very exacting as to turning out standard sporting cartridges of uniform length. The handloader, of course, loads his ammunition to any length which suits him.

In this matter of accommodating bullets of varying length, weight and type, we find a cartridge case having a relatively long neck to possess definite advantages over one having a shorter neck.

A—The 7.65 mm Belgium Mauser cartridge is an example of a very short-necked cartridge case designed for a long heavy-weight bullet. It would be a problem to design an efficient spitzer light-weight bullet for this cartridge and have it function properly through the Mauser magazine

Now when this cartridge is fired the gas pressure at once expands the case neck to the full extent permitted by the chamber neck. As this expansion occurs a very small amount of powder gas rushes forward between the case neck and the still almost stationary bullet. (A spark photograph taken of the muzzle of a rifle at the instant

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without making some alteration to the latter to enable it to accommodate the shorter cartridge. Powder shown is the German square flake type.

B—The .30'06 Springfield cartridge was designed in 1903 and the standard bullet then was a 220 grain weight blunt-pointed projectile. The case was designed accordingly, with a long neck to cover and retain this bullet and keep it from reaching down into the powder chamber. In 1906, when the lighter 150 grain spitzer projectile was adopted, all Springfield rifles were redesigned and adapted to take a slightly shorter cartridge; .06" was trimmed from the length of the case neck; and all rifles in service recalled and rechambered to take the shortened cartridge. In the drawing above, the .30'06 case is shown loaded with the 172 grain boattail bullet, and it will be noted that this difficult-to-load projectile is accommodated very nicely with its base not too far down into the powder chamber. Any weight of bullet, from 220 grains on down to the lighter 145 grain spitzer point can be loaded into this case with the standard length of cartridge being maintained and the bullet base retained in the case neck. It is not considered good loading practice to load a bullet into a case and have its base protrude down into the powder charge; although this is sometimes done the best ballistic circles frown upon it. This .30'06 Springfield is without a doubt the most popular cartridge ever developed and its long case neck makes it a most versatile one, accommodating a wide variety of bullets of all lengths, weights and types.

C—A 6.5 mm Mannlicher-Schoenauer cartridge, German loading. Has the European segmental crimp, fastening a smooth jacketed bullet. Square flake powder. Case neck is of moderate length, accommodating bullet very well. These European designed cartridges, with so much bullet sticking out of the case neck, looked very odd to our American shooters when they first commenced showing up over here in the early part of the century.

D—The .303 British Mark VII cartridge, as loaded back in 1917 by Kynoch. Compare this .303 case with our .30/40 Krag case, shown as E, both cartridges having been developed about the same time. Notice that the British followed the European standards somewhat and developed their case with a rather short neck, an abrupt shoulder and considerable taper to the body of the case, this taper undoubtedly contributing much to the easy working qualities of their Lee-Enfield rifle. At the time it was introduced, this .303 British cartridge was loaded with a 215 grain round-point bullet, it and the Krag cartridge developing practically identical ballistics. About 1905 the British adopted the spitzer bullet, finally settling upon one weighing 174 grains and of peculiar construction (see Figure 93) so as to lighten its point and give superior ranging qualities. This is the bullet shown loaded in cartridge D and its base comes just below the case neck; however this bullet base is protected by a heavy jute wad, as shown. The powder in this cartridge is the famous cordite, in string form, the point of the bullet emerges clearly shows the puff or cloud of this small gas escape coming out of the muzzle ahead of the bullet.) A small amount of gas also escapes around the mouth of the case and starts to come back between the outside of the case neck and the chamber walls, and under normal conditions it gets back about 1/8 to 1/4 inch and blackens the outside of the case neck to that extent. By this time the case neck has fully expanded to hug the neck

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and both powder charge and wad are loaded into the case before the latter is necked down. This .303 cartridge is primed with an exceptionally large primer, of the Berdan type.

E—Sketch of the old .30/40 Krag, or .30 U.S.A. cartridge, designed about 1892 for use with the 220 grain metal cased bullet. Its designers followed standard American practice and gave it plenty of case neck, so much so that this case will accommodate any length and type of bullet safe to be fired in the Krag rifle. The bullet shown is of the style made around 1900, with three heavily knurled grooves, put on to assist in holding jacket and core together and with a ring of lubricant held in each groove. They soon made much better metal cased bullets and the lubricant proved unnecessary and of no real use. The powder shown is the old Laflin & Rand W. A. .30 Caliber brand.

F—A modern sporting rifle cartridge, the famous .250 Savage, introduced about 1912. Its designers were restricted to an overall length of cartridge that would operate through the revolving magazine and action of their Model 1899 Savage rifle, and they used the best of powders and components that were available at the time and turned out a very powerful cartridge for use in this rifle of an earlier decade. They put as much as possible of the case length into powder chamber and made the case neck of a length that would just accommodate the short 87 grain pointed bullet. This .250 case also had a very abrupt and short shoulder compared with previous cartridge making standards. Our present day designers are following this .250 Savage design to a considerable extent, and the wildcat cartridges now being brought out devote a maximum of case length to powder capacity with a minimum to case neck and bullet retaining area.

Up until the beginning of the present century, the lever action rifle was the outstanding arm amongst American sportsmen, one never saw a bolt action rifle in use except amongst the military. The design and operation of most lever action rifles was much more violent as regards the cycle of cartridge operation than is the case with modern bolt actions. Our American manufacturers and designers took this fact into account when designing cartridges for use in lever action rifles, and they saw to it that the bullet was firmly secured in a case neck of ample length so that bullet would not become distorted or worked loose when loaded into the magazines or worked through the actions of the rifles then in the hands of American sportsmen. This, plus the fact that we no longer use soft lead bullets with inside lubrication, where such lubrication must be covered by the case neck, permits us to use cartridge cases with greatly shortened necks.

of the chamber and shuts any further escape of gas around the case mouth. If the fired case is blackened much further down than 1/4 inch from its mouth it usually indicates that the neck of the chamber is rather abnormally large. Just as soon as the case neck has expanded and freed the bullet the latter starts forward and up the bore.

The bullet having left the muzzle, and the bore pressure being reduced to zero, the case neck springs away from its tight contact with the neck of the chamber due to its elasticity resulting from proper anneal of its brass. But the stretching has enlarged this neck some so that it now, in this fired case, measures somewhere about .310-inch inside. The neck is now entirely free from contact with the chamber walls, and the body of the case has likewise been undergoing a similar expansion and partial contraction so that extraction of the case from the chamber is easy.

Now we have a fired case with an inside neck diameter of about .310-inch and of course, if we desire to reload it with a metal cased bullet again the neck must be resized in the reloading tool so it measures about .306 to .307-inch inside.

If, however, we desire to reload this fired case with a lead alloy bullet we will find on investigation that generally speaking such a bullet to give best results in a .30-06 rifle having a groove diameter of .308 to .309-inch should have a diameter of .311-inch. To seat this large bullet in the neck of the case without distorting its soft lead the case neck should first be resized and then expanded to measure .311-inch inside. This cartridge loaded with this large bullet will then have a clearance between the neck of case and neck of chamber of about .0005 to .0015-inch.

It will be noted that we have said that fired cases must be *resized and then expanded* to have the bullet fit securely when reloaded. This brings us to another story. As we have seen, cartridge cases are formed in dies and punches. They are not turned to exact diameter and uniform thickness, nor are they absolutely round. The dies and punches are scarcely ever in accurate alignment with one another, nor can they be kept so. Moreover they wear as they are used, the die getting larger and the punch smaller. We cannot replace them when they show just a little wear because they are too expensive, so we change them only when they begin to approach prohibitive wear. As a result cases are scarcely ever of uniform roundness or uniform wall thickness around their circumference. A case wall may easily be .001-inch thicker on one side than on the other. Also if we run a .3075-inch expanding plug into the neck of a slightly smaller case, when the plug is withdrawn the neck will spring back to an inside diameter of somewhere between .3065 and .307-inch. That is why we said that case necks for .3085-inch metal cased bullets should measure *about* .306 to .307-inch inside. We cannot attain absolutely accurate dimensions or absolute uniformity on a lot of brass cartridge cases, but the small variations from perfection do not make any *appreciable* difference if they are not carried too far. Ordinarily we would suppose that if the case is not uniform it will not hold the bullet in exact alignment with the axis of the bore, even if the chamber be in exact alignment with the bore. Or, as the cartridge has to be just slightly smaller than the chamber, to be correct we would say that the un-uniform case will not hold a uniform position in the bottom of the chamber into which it sinks from gravity, or in some other position in the chamber into which it is forced by the pressure of the extractor spring on its head. But all these little variations in the position of the loaded cartridge in the chamber before firing have little effect on the alignment of the bullet with the axis of the bore because, as we have seen, the first thing that happens when the gas pressure begins to rise is that the case expands against the chamber walls. At this instant the bullet is free from the case and is floating in gas, having not yet started forward appreciably. The bullet now starts forward, and its base being free, it "wabbles" forward into the leade of the bore just in front of the chamber, and the leade straightens the bullet up so that its axis is *approximately* in line with the axis of the bore.

Notice that we have used the word "approximately," and we have said that these little variations *make no appreciable difference if they are not carried too far.* They do make some difference depending to what extent they exist. With the modern precision machinery now in general use in the manufacture of rifles and cartridge components, the lack of uniformity in the highest grade weapons and ammunition is surprisingly small and rather inconsequential because it now allows us to approach in accuracy of fire groups of shots having an extreme spread of around one minute of angle when conditions are as correct as the well informed rifleman can make them.

We have lately found that we run up against another case neck condition when we use the .220 Swift cartridge and reload our fired cases. This cartridge has the highest muzzle velocity of any being regularly manufactured today—4,140 f.s. The pressures are extremely high. Under these, and possibly other conditions, the brass of the case extrudes forward into the case neck, making the walls of the neck thicker. If a .220 Swift cartridge be fired, and then if the fired case be reloaded again with full charge, it will usually be found that after the third reload enough brass has extruded forward into the neck as to cause the outside of the neck to be a very tight fit in the neck of the chamber before the cartridge is fired, and to allow no room for expansion of the neck and normal freeing of the bullet from the case neck. This may result in very considerable and extremely dangerous increase in breech pressure. In practice it has been found to be extremely unwise to reload .220 Swift cases more than three times unless the case neck is reamed to restore its normal wall thickness. Do not disregard this caution as to do so might cause a most distressing accident.

It will be noticed from the various illustrations of cartridges that some bottle-necked cases have very long necks, and some have relatively shorter lengths. The older cartridges, as a rule, have the longer necks. Necks were made long in black powder cartridges, and the bullets were seated deeply in them in order that the neck would cover up all the lubricating grooves. Also necks were made large so they would firmly secure a long bullet and help to waterproof the junction. The .30-40 Krag case, for example, has a rather long neck, made long to cover the three lubricating grooves of the original bullet, and because the bullet exposure itself was long and required plenty of grip to overcome the leverage which from rough handling might loosen the bullet in the neck.

In any case the neck should be long enough so that the base of the seated bullet does not extend down below the neck into the powder chamber of the cartridge. Thus the initial thrust of the powder gases is confined to the base of the bullet.

With modern cartridges the tendency is toward shorter necks, particularly where fine accuracy is a consideration. With the shorter neck, more of the bullet is exposed out of the case and can extend up into the throat and leade of the chamber, and the bullet is thus more effectively straightened up in line with the bore axis before it is fired. But in any case there must be enough bearing of the bullet in the case for security and fair waterproofing. Usually the bullet should be seated never less than its full diameter in the neck—that is not less than .30 inch deep for a .30 caliber bullet.

The brass cartridge case is the weakest link in the chain of rifle and ammunition. It will successfully withstand only just so much pressure. Above this pressure it enlarges, splits, breaks, and burns. Through many of these injuries intensely hot gas under great pressure rushes to the rear into the mechanism of the weapon, there to often wreck things generally, and perhaps injure the shooter fatally. Study Figure 69.

The cases of modern well made cartridges with thick heads in such high intensity calibers as .30-06, .270 Winchester, .300 H & H Magnum, .257 Roberts, and .220 Swift, under normal conditions and in good weapons will successfully withstand being loaded to a pressure of 52,000 to 53,000 pounds per square inch. Loaded to a higher pressure than this a certain proportion of these strongest of all cases will give way in some manner or another, the proportion that do so depending on the amount of pressure. In military service, cartridges are subjected to conditions that in ordinary times of peace would be described as being negligence on the part of the shooter. They must stand dust, sand, mud, dents and injuries from rough handling, water, cold, and particularly the heat of desert sun for long periods. Our army therefore has a rule that no .30-06 cartridge will be loaded to a higher pressure than 48,000 pounds.

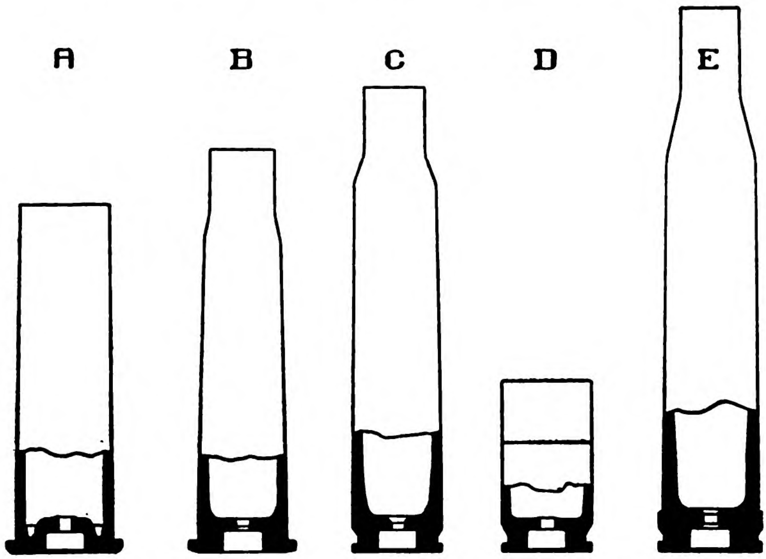

FIGURE 69. HEAD CONSTRUCTION OF MODERN CARTRIDGE CASES

Here are shown the slight but important changes which have gradually been effected in the heads of modern cartridge cases as each of the various "new type" cartridges was designed to develop superior ballistics and consequently was required to withstand definitely increased pressures.

A—Illustrates case head construction of a cartridge for the .45/60 Winchester, which rifle was first manufactured around 1876 and adapted for use only with black powder. Safe breech pressures should not exceed around 20,000 pounds and the construction and design of this old rifle is such that modern smokeless loads should not be attempted in its cartridges. This .45/60 case shown is of the original solid head design, with primer pocket formed by a process developed during the late '80s and today used only for low-pressure revolver and rifle cartridges; this type of case should not be used where pressures run above 25,000 pounds.

B—The .30/40 case, designed about 1892, for use in the Krag rifle with smokeless powders intended to develop around 38,000 pounds pressure. This type of case is now known as solid head (or solid web) construction. Drawing was made from a case manufactured around 1900. Both A and B cases are of the rimmed type, intended to be used in rifles designed to

The old .30-40 Krag case is a strong one, but not so strong as those referred to above. It can be loaded safely to pressures approaching 48,000 pounds for use in strong, well made rifles. But look out here because the Krag Jorgensen rifle (U.S. Magazine Rifle, Caliber .30 Model 1898) to which this cartridge is commonly adapted, has a

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enclose the entire cartridge, rim and all, within the chamber or with the case head fully covered by the bolt face while rifle is fired. It is hardly possible to have a case head blow out when fired in a properly locked chamber of this type. Modern rimmed cases, such as **B**, as made today, are safe at pressures around 45,000 pounds.

C—The .30'06 Springfield case, designed about the year 1902, for use in bolt action rifles of the Mauser type. This design of cartridge positions against the shoulder of the case and the cartridge is not entirely enclosed within the chamber of the rifle, the base end projecting out into the lug well to a greater or lesser extent. To make the firing of such rifles safe, the base of the rimless cartridge is made extra stout, of brass sufficiently thick so that when properly backed up by chamber walls and action it can withstand modern pressures, which run around 50,000 pounds in maximum loads. This type of case can be recommended as being entirely safe at pressures of 45,000-50,000 pounds in properly constructed rifles, with head space adjustments carefully checked. Note that the thickness of this case "web" (the wall of brass through which the primer flash hole runs) is appreciably greater than that in the **B** case, designed a decade earlier.

D—The .45 Colt Automatic cartridge case, a rimless case designed around 1906, for use in the service pistol of the U.S. Army. This case is of modern solid head construction, but designed to withstand sustained pressures while the fired case is backing out of the pistol chamber. The chamber pressures of this .45 Colt run around 15,000 pounds and this type of case head is excessively stout for such comparatively low pressures; however it must be remembered that some of these automatic actions practically "blow" the fired case out of the chamber, such cases must act as a gas seal until the bullet leaves the barrel and their heads must not rupture and so permit hot gases to rush back into the mechanism. All of our automatic pistol cartridges have stout case heads. The base of this .45 Colt case is rather long, so designed to give sufficient "reach" to permit it sticking well out of the chamber and insure extraction; note also the very adequate extraction groove on this case, which works exceedingly well in most full-automatic firearms of light machine gun type.

E—Here is the most modern type of brass rifle cartridge case, the .280 Dubiel, a special cartridge made by necking down the .300 Magnum case. This is a belted case, designed for use in thoroughly modern bolt action rifles developing extreme velocities and pressures. Like other rimless cases, its base projects out into the action of the rifle in which it is fired and this belt around the case base is an extra safeguard against blown out case heads. Study Figure 16 and note how strongly supported against rearward action are the burning powder gases in these belted cases, and note that the case walls are also appreciably stouter towards the case head. Cases of the belted type, made as the sketch illustrates, are safe at pressures up safety factor of not to exceed 42,000 pounds, due to its one locking lug and the character of the steel of which its bolt and receiver are made, and for use in it .30-40 cartridges should not be loaded to exceed that pressure. This is one of the few cases where it is not strictly true that the case is the weakest link.

The older smokeless cartridge cases such as those for the .30-30 series of cartridges should not be loaded to exceed a pressure of 42,000 pounds, and the limit for the older black powder cases with folded heads is about 25,000 pounds.

The point is that, generally speaking, the rifles in which these cartridges are used will successfully withstand much higher pressures. But we cannot make the brass cases stand more pressure than those indicated without considerably increasing the wall and base thickness and that would decrease the powder capacity of the case, and we could not use enough powder to get the velocities we desire.

The Case Head

This matter of the ability of the brass case to stand pressure brings us to a consideration of the head of the case. As we have already seen, the brass walls of the case at the neck and at the forward part of the body are thin and these walls get thicker around the rear of the body and at the head. When the cartridge is fired, the thin forward walls expand easily and hug the chamber walls very tightly. The rear walls, being thicker, do not expand so readily and do not hug the chamber walls so tightly. The neck, while the pressure is at its height, is stuck fast in the chamber, but the rear of the case, not being stuck so tight, could slide slightly to the rear under the heavy back thrust of the powder gases, and thus the case might stretch lengthwise and might even tear apart if it were not fully supported by the breechblock or bolt, or if the brass there were not thick enough.

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around 55,000 pounds, which average pressure is about the limit to which brass withstands; as pressures mount up above 60,000 pounds the brass head of the cartridge case is apt to soften up and flow back into the bolt head orifices and openings.

Note the differences in construction of the flash holes in the above series of cartridge cases, some being countersunk from one side, some from the other side, some from both sides. These differences may or may not be intentional, generally they are caused by the system of manufacture in use in the factory in which they are made, or by the action of the cartridge brass at time of manufacture. These bevels can be caused by excessive penetration of a piercing punch into the metal; by a break through of metal on the die side; or by larger clearance between piercing die and punch. Cases pierced on capping machines have the die on the inside of the shell and those pierced on reducers have the die on the primer side.

As shown in the accompanying drawing, (Figure 70) Sketches B and C, center fire cases were first constructed by folding the brass at the head, and the head was sometimes reinforced by a brass cup inserted inside the head. Such cases were said to have a folded head. This is a weak construction but it served fairly well in early black powder days when breech pressure seldom exceeded 20,000 pounds per square inch. But, particularly in those early days, it was the practice of almost every shooter to reload his fired cases. Reloading tools were almost always purchased with the rifle. These folded head cases did not stand reloading well. Particularly they would

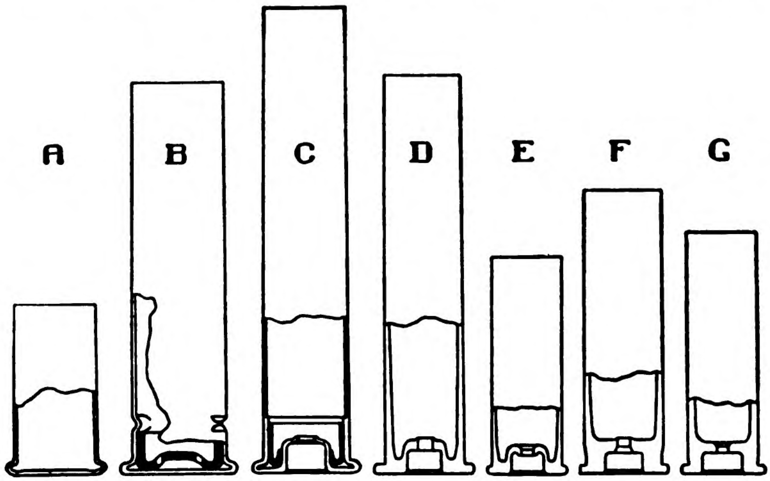

FIGURE 70. DEVELOPMENT AND CONSTRUCTION OF RIMMED CASES

A—The earliest American type of metallic, primed cartridge case; the .44 Henry Flat case. Rim fire, with priming compound spread evenly around entire rim of the case. 1866.

B—A type of center fire cartridge having an internal primer; it looks exactly like rim fire ammunition and is often mistaken for such. Case shown is the .45/70 Government, developed around 1870 and loaded up into the early 1880s. This type of case was not reloadable. Primer insert had two flash holes, and is shown in black, priming compound filled into open space in center of base. Known as the Martin cartridge.

C—A .40/70 Sharps Straight case of the early '80s. This example is shown in the original "folding head" construction. It was made with an extra reinforcing band inserted in bottom of case, which is shown in black. The case shown was primed with a Boxer type primer having one central flash hole, but much of this early folding head ammunition was loaded with the Berdan primer, having two or three flash holes. These early folding head cases are not adapted for use with smokeless powder, even though suitable smokeless primers should be obtainable, as the circular brass insert is very likely to blow forward into the bore of the rifle if it not stand repeatedly punching out the old primer and inserting a new one. During this period, therefore, we find "Everlasting Shells" frequently being supplied at a cost of ten to fifteen cents each. These shells were of very much heavier brass, particularly at the head, and were turned on a lathe from solid brass rod. They could be reloaded with black powder practically indefinitely. Folded head cases would be entirely too weak to stand even one loading with modern smokeless powders.

Then a way was found to draw the brass case so as to leave much more metal and greater wall thickness in the head of the case, as described at the beginning of this chapter. Sketches D, E, F, and G show these solid head cases. D and E are the earlier examples, illus-

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is not assisted to remain in place through a coating of corrosive, gummy, black powder fouling. The bases of these folding head cases will collapse very easily from repriming.

D—Here is an example of the first, true "solid headed" cartridge case, an old .38/55 case made during the early 90s. These cases were made by the deep drawing process and the entire head formed by additional punching and forming operations. They were featured as being greatly superior to the earlier folded head cases and were guaranteed to withstand many reloadings. The example shown has the letters "S H" stamped on case base, meaning Solid Head; many calibers carried this designation for years. This .38/55 case was intended for use with black powder and was primed with the smaller size of primer, which was entirely adequate for ignition purposes even with such a large case.

E—A case for the .38 Special revolver cartridge, of modern construction. But today, we find this type of cartridge case referred to as the "folding head type," or "balloon head type" of case construction. It is almost universal for revolver cartridges where the pressures run below 25,000 pounds, and will stand reloading for a great many times; occasionally the sidewalls of the primer pocket will part and the front portion be blown forward from the case.

F—Present day type of case construction, and known as "solid head" or "solid web" case. Specimen shown is the .401 Winchester case, a semi-rimless type designed for use in a self-loading action where the case must do its part in supporting gas pressure to the rear. Improved extrusion and punching methods now make this type of cartridge case possible of manufacture by precision machinery working at high speed.

G—Here is the .357 Magnum case, for the most modern type of revolver cartridge. Pressures for this most modern revolver run up into the 40,000 pounds area, and the case is designed accordingly, with solid web and stout walls at base to retain such high pressures. A few other high power revolver cartridges are also now loaded into this type of case, as are practically all of the automatic pistol cartridges where a stout-bodied case must do its part in retaining burning gases while the case is backing out of the pistol chamber.

None of the above cases is primed.

trating approximately the amount of brass in the rear walls and head of cases manufactured during the late black powder and early smokeless powder periods. Early smokeless cases, such as those for the ".30-30 Series" of cartridges, have such heads which, generally speaking, will stand charges giving breech pressures up to 38,000 to 42,000 pounds as previously described. They will also stand almost unlimited recapping and repriming. But with the introduction of high intensity loads giving pressures up to 50,000 pounds, still heavier heads became necessary than shown in Sketches G and F.

But ability of a case head to stand and retain breech pressure depends not only on the thickness of the brass in its head, but also on the way it is backed up by the chamber walls and the face of the breechblock or bolt. Without such backing, brass alone, no matter how thick, would not stand very heavy pressures. The brass would begin to give or move, and when it begins to move it very quickly begins to flow, almost like molasses.

Let us now refer back to Figure 69 showing the shapes of heads and rims in various cartridge cases. Sketches A and B show the common rimmed cases. Such cases were, and usually are completely supported by the steel of the chamber and breechblock. The chamber walls (in a well made chamber) completely supported the walls of the case right up to the rim, and the rim groove or counterbore in the chamber supported the forward and side edges of the rim, while the face of the breechblock or bolt completely supported the flat head of the case. There was no place or direction in which the head of this case could expand or flow. It just stayed there and took the pressure successfully. Provided this be a solid head case with plenty of brass in the head, B type is still the strongest case known.

But soon more modern weapons were developed, with the double column—Mauser—magazine and with the various magazines and feeds seen in automatic arms, and rimmed cartridge cases would not operate smoothly or surely in such mechanisms because the rim of a cartridge below or above in the magazine or clip would catch on the adjacent cartridge, causing a jam or malfunction.

So the rimless cartridge case shown in Sketches C and D, Figure 69 was developed for such more modern weapons. With these cases positioned in the chamber, the rim proper of the case is held in a recess in the bolt head, and there is a space, including the extractor groove, and from 1/16 to 1/8 inch of the rear body of the base, between the head of the bolt and the side walls of the chamber, where this case is entirely unsupported by steel. As a result, these cases have to be very thick in their brass head so the gas will not burst out at the exposed sides of the head where there is no steel support. Their solid brass head should be continued up to and a little beyond where the chamber walls give complete support, but this is not always done, and when it is not done there is an area of weakness, frequently in evidence when rimless cases expand at the head from high pressure.

As we have explained before, the rimmed cases are positioned in the chamber or headspaced by the rim abutting solidly against the rim groove or counterbore at the rear end of the chamber. The rimless case, on the other hand, is positioned or headspaced by the shoulder of the case (in rear of the neck) abutting against the corresponding shoulder in the chamber, or in the matter of the straight case shown in Sketch E, by the square mouth of the case abutting against the square forward edge of the chamber. Neither of these methods is nearly as effective as the positioning method of the rimmed case, and the rimless case must be regarded as a rather unsatisfactory design which has been forced on us by modern breech mechanisms and modern magazines.

In order to overcome the above disadvantages of the rimless case, the belted case, shown in Sketch E, Figure 69, was designed. This case has a slight belt, or rim on the body, in front of the extracting groove and the case is positioned in the chamber or headspaced by this rim abutting against a corresponding rim cut in the side-walls of the rear of the chamber. This belt or rim is used solely for positioning and not for extracting, and therefore can be made very shallow; so shallow that it does not in any way interfere with one cartridge sliding over another, and such belted cartridges operate smoothly through double column magazines, and the magazines and mechanisms of automatic arms. If the solid brass interior walls of this case be continued well up above the belt it forms a very strong and solid breeching, sufficient for any pressure that any brass will withstand, and such cases are the best type for strictly modern arms using cartridges of high intensity. If the design is proper they should successfully withstand working pressures of 55,000 pounds.

With automatic arms that part which gives the greatest trouble is the extractor. There are two reasons why cartridge cases for use in automatic weapons should have straight bodies with very little taper, and one why they should not. Many automatic arms use the residual pressure in the bore to complete the extraction of the fired case, and a straight body operates as more or less of a gas dam to retain this residual pressure in front of the case long enough to complete the extraction. Also straight body cases stack up better in a magazine having a capacity of ten or more rounds. But a case with a nearly straight body is much more difficult to extract than one with a more tapered body.

Extraction is always very violent in automatics as the gas pressure retracts the bolt very quickly at the start, with great power, so that the power and the remaining momentum may be sufficient to completely function the arm. The extractor gives the case a powerful jerk. If the extractor rim of the rimless case be not quite thick and strong the extractor hook may cut through it, leaving the case in the chamber. Or the extractor hook may break off. Both these troubles often occur with automatic arms. Therefore, the design of a new rimless case for an automatic arm should include a broad and strong extracting rim which will not tear through, and a very wide extractor groove ahead of the rim so a thick and strong extractor hook can be used. In addition there should be more brass in the head area to reinforce that portion of the head that is unsupported by the bolt head and chamber walls. See Figure 71.

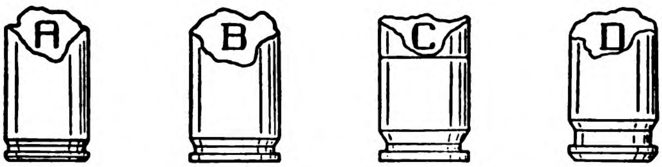

FIGURE 71. EVOLUTION OF THE CASE EXTRACTION GROOVE

Modern autoloading and automatic firearms make imperative the use of a true rimless case for their cartridges, as only the fully rimless cartridge will permit smooth, uninterrupted action and dependable repetition of fire for sustained periods; the slightest rim projection is likely to cause a cartridge to hang up or jam at some stage of the firing cycle. As fire power is becoming of increasing importance these days and more and more in demand, we find that the design and construction of the rim of the cartridge case has radically changed with the passing of time.

A—Here is an actual copy of the base of the .30 Blake cartridge, designed during the late '90s for use in the Blake rifle and tested by the U.S. Government for adoption by the Army. It was one of the very first rimless cases known in this country. Note its shallow and inadequate extraction groove, one hardly sufficient for certainty of extraction even in a manually operated rifle.

B—The base end of the .30'06 Springfield case, designed about 1902 for ues in the 1903 Springfield, a manually operated rifle. Its extraction groove is not any too sufficient for use in a bolt action rifle, and were it possible today to modify this cartridge for proper functioning in automatic rifles and machine guns, its base would most certainly be changed somewhat along the order of the one shown in D.

C—Base of the .45 Colt Automatic pistol cartridge. Here is shown a cartridge designed solely for use in a semi-automatic or fully automatic firearm. Its extraction groove is much larger and more roomy than the one shown in B, permitting the base to extend back into the receiver and allow extractor claw to get a good grip in the slot.

D—Here is the latest type case head of a cartridge designed mainly for use in fullv automatic rifles and machine guns; the French 7.5 mm, period 1925-1930. This has an extremely stout base and head, with thick rim and

Steel Cases

The matter of the ability of the case to stand pressure brings us to a consideration of steel instead of brass as a material for cartridge cases. Why not use a steel case to get a greater safety factor and higher velocity? In World War I, and also in the present war, we have been nearly compelled to use steel for our cartridge cases, not to stand higher pressures or to obtain higher velocities, but because of the scarcity of copper. Brass is composed of copper to the extent of about seventy per cent, and in time of war copper is in most urgent demand for a thousand and one munitions. The requirement of copper for ammunition is larger than for any other article in war, and if we could find some substitute for copper in small arms ammunition we would have plenty of it for the thousand other war needs. Mild, soft steel or iron is the logical substitute. The Germans could not get copper in World War I and had to resort to steel for both cartridge cases and bullet jackets, and they were able to solve the problem in a fairly satisfactory manner. At Frankford Arsenal during World War I we experimented with drawing cases from steel so that we would have the process up our sleeve in case copper became so short that we would have to resort to it. We found that we could draw mild steel into satisfactory cases on the same presses, and with the same dies that we used for brass cases, provided that we first gave the sheets of steel a thin plating with tin. The tin lubricated the steel and caused it to run through the dies smoothly. In the present war the process has been still further perfected, and steel is being used to some extent for cartridge cases, particularly for the .45 Colt Auto cartridge. The exact method is still regarded as one of our war secrets, but it is understood that it has been very satisfactorily solved, including the important detail of making the case practically rust proof.

It is possible that steel may be used for cartridge cases more extensively in the future. Only time will tell. It would possibly increase the safety factor and permit us to attain higher velocities and flatter trajectory. But it is understood that the use of steel greatly increases the labor cost of making cartridges, and that may be a deterrent factor in time of peace, and possibly in war also. And the steel case may corrode badly, with the passing of time.

The writer is indebted to the Remington Arms Company for the following information relative to steel cartridge cases, and the particular type of steel best for such use.

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long "reach"; cartridges of this type should work splendidly in automatic firearms despite rough chambers, sand, grit, or rust and with wartime ammunition of poor quality.

Steel for Cartridge Cases

During the first and second World Wars steel was experimented with by the principal belligerents as a substitute cartridge case material for brass. The latter, which is employed in many different types of Ordnance material as well as in electrical circuits for maritime ships and aircraft, has been a critically short material in both wars. In peacetime, the chief interest in steel cartridge cases arises from the fact that steel is inherently a good deal stronger than brass. In fact, it can be said that, in general, plain, low-carbon steel which has the deep drawing characteristics required for cartridge manufacture can be treated so that its strength is virtually double that of cartridge brass. Despite the fact that steel is cheaper, more available and stronger than brass the latter has been employed for more than a century for cartridge case material, chiefly for the following reasons:

1. Good corrosion resistance;
2. Easy workability in blanking, cupping and drawing;
3. The stiffness or "springback" of brass is such that in conjunction with its strength characteristics it results in easy extraction.

These three factors will each be considered briefly:

Corrosion Resistance: As is well known, steel must be given some form of protection against corrosion since otherwise the bulky corrosion products would prevent chambering of the cartridge and finally the corrosion would so weaken the case that the cartridge would be unserviceable. Brass, on the other hand, can be used as processed and without any further treatment.

Workability: The lower strength of brass combined with its excellent ductility results in easy workability, a good tool life and accordingly, relatively easy manufacture. Steel, on the other hand, requires heavier presses and a considerably greater energy to be formed. In addition, special tool materials are preferably employed since steel draw pieces tend to "pick up" on the steel dies normally employed with brass draw pieces. Special tungsten carbide tools have therefore been developed to process steel.

Stiffness: The property of stiffness is a little difficult to define. The engineer refers to it as "modulus of elasticity." It is associated with the "springback" of a metal and can perhaps best be illustrated by an example—

> If two beams, one of brass and one of steel, having exactly the same dimensions, particularly length and cross section, are clamped in a vise so that they extend horizontally, an interesting experiment can be run to demonstrate the difference in stiffness between the two metals. Suppose two objects of equal weight are hung at the end of each beam; suppose further that these weights

are insufficient to cause permanent bending of the beams, i.e. as soon as they are removed the beams spring back to their original unbent horizontal position. Under these conditions it will be found that the end of the brass beam will deflect downward twice as far as the end of the steel beam. Moreover, when the weights are removed, the end of the brass beam will spring back twice as far as the end of the steel beam so that both are again horizontal. The engineer would express this by stating that the modulus of elasticity of steel is twice that of brass, being approximately 30,000,000 pounds per square inch for steel and approximately 15,000,000 pounds per square inch for brass. Another way of phrasing this is to say that the steel is twice as stiff as brass and has only half its elasticity or springback.

This property of stiffness is peculiar to a material and cannot be appreciably altered, e.g. a piece of cold-worked brass has the same modulus of elasticity as a piece of dead soft annealed brass and a piece of hardened tool steel has the same modulus of elasticity as the same tool steel which has been completely annealed. In the case of the beam experiment mentioned, the annealed material could not be deflected as far as the hardened material without taking a permanent set but before a permanent bend was impressed on the beam the hardened material would deflect under a given load just as much as the annealed material.

This property of stiffness is very important in comparing steel with brass as ammunition case material since the lower the modulus of elasticity the greater the springback and hence the easier the extraction of the component after firing. It happens that the strength of cold-worked brass, with its relatively low modulus of elasticity, gives a combination which results in easy extraction. When steel components are made to function in the same guns as brass components, hard extractions and associated troubles such as partial and complete transverse body ruptures occur unless special means are taken to raise the strength of the steel to almost double that of brass. With such strengths, steel can be made to extract as easily as brass.

Thus, despite the lower cost and higher strength of steel, brass has remained the preferred ammunition case material because of its better corrosion resistance, lower modulus of elasticity and relative ease of processing.

The necessary physical properties required of steel for satisfactory ammunition case performance can be obtained in various ways. This is in contrast to brass which is a homogeneous alloy of copper and zinc. The metallurgist refers to brass as a single phase alloy which can be hardened only by cold work. Steel, however, can be considered to consist essentially of two phases; the majority phase being that of ferrite or iron with a small amount of a second phase which is a com-

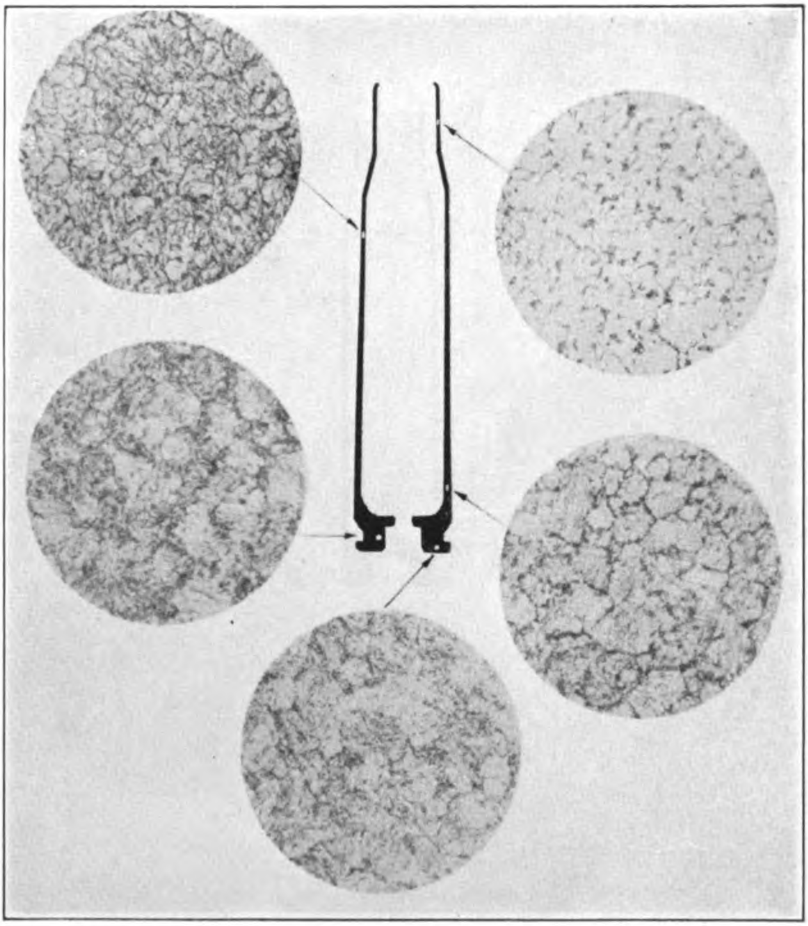

FIGURE 72
Brine-Quenched 0.20% Carbon Steel. Magnification, 500 times.

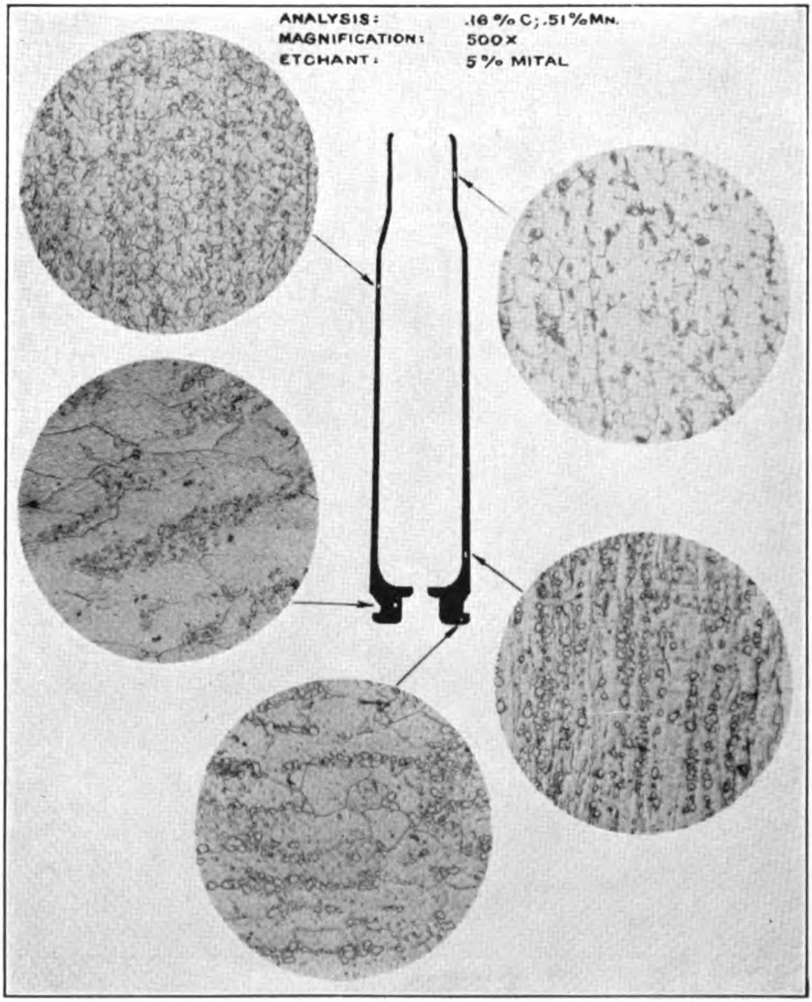

FIGURE 73
Spheroidized 0.20% Carbon Steel, Cold-Worked into a cartridge case.

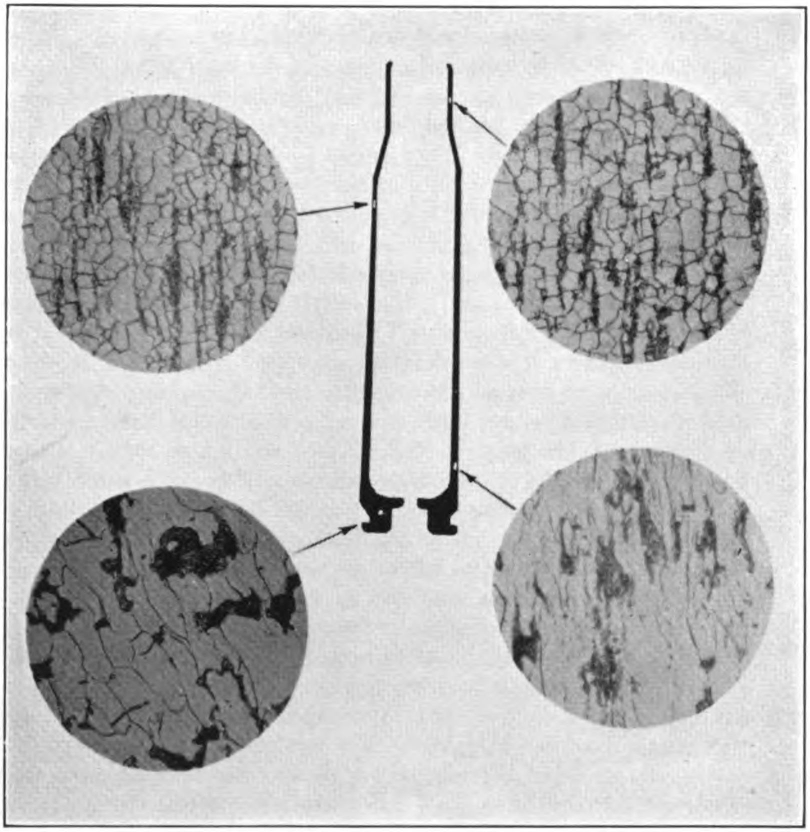

FIGURE 74
Normalized 0.20% Carbon Steel, Cold-Worked into a case.
Magnification, 500 times.

pound between iron and carbon with the formula Fe_3C. Depending on its heat treatment, steel can exhibit a variety of structures. Three of the commonest structures which are suitable for steel cartridge case manufacture are illustrated in the accompanying photographs. Figure 72 shows the quench-hardened structure of a plain carbon steel containing about 0.20% carbon. It will be noted that the structure appears to consist of a large number of needles of fairly uniform length. Actually, these needles are cross sections of small plates which form on quench hardening. This structure is termed martensite and is the hardest structure which can be obtained in steel by either cold work or quench hardening. Figure 73 illustrates photomicrographs taken from a steel cartridge case which was made from steel which had a so-called spheroidized structure, i.e. the steel was heat treated prior to fabrication into a case so that the hard Fe_3C compound formed small spheres (hence the term spheroidized) which in cross section appear as irregular circles in the photomicrograph. The physical properties in the case shown in Figure 73 were developed by cold working just as are the strength properties in a brass case. The effect of the cold work on the microstructure can be seen by comparing the structure in the side wall near the base of the case with that in the base. It is seen that in the side wall the cold working has developed a so-called "fiber structure" by elongating the ferrite grains. The spherical carbide grains are unaffected by the cold work. Figure 74 illustrates the structures obtained on a steel case which was also fabricated without any heat treatment. However, in the case of Figure 74, the structure prior to fabrication into the case was "normalized," i.e. the iron carbide instead of being dispersed as small spheres forms small plates which alternate with small ferrite plates. Thus each dark section in the photomicrographs of Figure 74 consists of alternate plates of ferrite and Fe_3C. By comparing the structures in the base with those in the side wall, it is seen that the cold working of fabrication markedly elongates the dark areas which the metallurgist terms pearlite.

Satisfactory firing performance has been obtained with steel cases with all three of these structures. However, the most consistently satisfactory structure appears to be the quench-hardened or martensitic one.

Wildcat Cartridges

We have said that certain liberties may be taken with a well made brass case up to certain limits of safety. These liberties are being taken today with certain newly developed "wildcat" cartridges. A wildcat cartridge is one that differs radially from any regular commercial or military cartridge. It is the brain child of an experimenter or inventor that has not yet become sufficiently of age to be adopted for regular use or commercial manufacture. Generally it differs from standard cartridges by using a case of different size or shape, designed to burn the powder differently, and usually to give higher velocity to a given bullet than could be obtained when using standard cases.

The lone experimenter or inventor could not make his own special cases for reasons already given, so he was forced to take a commercial case and modify it to meet his own ideas. So long as he modifies it in a manner that does not disturb the strength and toughness of the brass he usually gets away with it in a fairly successful manner. But sometimes he goes beyond the physical limits of the brass and then he gets into trouble. As these wildcat cartridges almost always involve an extensive alteration in the normal cartridge case it is thought proper to discuss them to some extent in this chapter.

Many years ago Mr. Adolph O. Niedner, the founder of the Niedner Rifle Corporation, and a most skilled rifleman and machinist, desired a .25 caliber woodchuck cartridge that would have a higher velocity and flatter trajectory, and consequently a longer sure hitting range, than any existing .25 caliber cartridge. The heaviest .25 caliber cartridge in existence at that time was the .25-35 cartridge which was loaded with a 117 grain bullet, and attained a muzzle velocity of only 2,000 f.s. He needed to burn a much larger charge of powder than the .25-35 case would contain. So he took the much larger .30-40 Krag case, and in a die he reduced the neck from .30 to .25 caliber, and thus was born one of the first wildcat cartridges, the .25 Krag-Niedner. His experiment was highly successful because it was possible to neck a well made case down only .05-inch and not seriously decrease the hardness, strength, and spring in the brass at the neck. The wall thickness in the neck may get slightly thicker, but the rifle can be chambered for this thicker neck, or the neck can be reamed to a normal thickness of wall. With his new wildcat cartridge, and with the propellant powders available at that time, Mr. Niedner was able to attain a muzzle velocity of about 2,600 f.s. with a 100 grain bullet, or close to 3,000 f.s. with an 86 grain bullet, which was a great improvement over the 2,000 f.s. formerly obtainable. Later a number of other cases were modified in a similar manner, usually to obtain a greater powder capacity to give higher velocity.

Then in 1930 the .22 Hornet cartridge was conceived by Captain Grosvenor L. Wotkyns, was further developed by three experimenters at Springfield Armory, and was finally turned over to the Winchester Repeating Arms Company for commercial production. It was originally made by taking the old .22 Winchester Center Fire case, and loading it with a charge of smokeless powder and a 45 grain copper jacketed bullet. Really what made it successful was that the Hercules Powder Company became interested in it and developed a new powder known as Hercules No. 2400, which gave most excellent results under the conditions that the case and bullet presented.

It proved to be a very remarkable cartridge. It was very small but it drove its light bullet at a muzzle velocity of 2,600 f.s., and with remarkably fine accuracy. In fact its accuracy up to 200 yards was superior to any other factory cartridge of its day. The high velocity in such a small case, and the accuracy seemed to be due to the conditions under which it burned its charge of No. 2400 powder.

The .22 Hornet started a number of other experimenters to thinking and working in an attempt to develop a cartridge on similar small lines which would give still greater velocity, together with fine accuracy. The .22 Hornet was a sure hitter and killer on woodchucks and large hawks to 175 yards, and on crows to 125 yards. The experimenters wanted another small, light cartridge, with light report and no recoil that would have a still greater effective range.

One of the first improvements on the Hornet cartridge was made by Mr. Hervey Lovell, a gunsmith in Indianapolis. He took the old and almost obsolete .25-20 single shot case and necked it down to .22 caliber, thus obtaining a greater powder capacity than the Hornet case had. He attained a muzzle velocity of 3,000 f.s. with the same 45 grain copper jacketed bullet. See Figure 75.

About this time Mr. Lysle D. Kilbourn conceived the idea that he could increase the velocity of the Hornet cartridge by increasing the powder capacity of the Hornet case slightly. He thought that if he rechambered a barrel with a shorter neck, a more abrupt shoulder, and a larger body in rear of the shoulder, that he could put a standard Hornet cartridge in this chamber, fire it, and the gas would blow out or expand the case to the new shape. Then these blown up cases could be loaded with a larger powder charge to give a higher velocity. He tried it and it worked, and he was able to obtain a muzzle velocity of 2,900 f.s. and still retain the fine accuracy of the Hornet. Mr. Kilbourn right there started something of which we have by no means seen the end—the practice of increasing the powder capacity of existing cases by firing them in an enlarged chamber. And in addition, and quite as important, he seems to have proved that under certain conditions powder can be burned more efficiently in a case with a very abruptly sloping shoulder than in one with a gentle slope to the shoulder.

Shortly after this Mr. H. A. Donaldson of Little Falls, New York started to try to improve the .22-3000 Lovell cartridge in the same manner that Mr. Kilbourn had improved the Hornet cartridge. Mr. M. S. Risley cut a number of experimental chambers for Mr. Donaldson, the second one, which they called the "2-R" chamber proving to be the most successful one. The original .25-20 Single Shot case was first necked down to .22 caliber, and was loaded with a light charge of powder and a metal cased bullet, and was then fired in this chamber. This altered the case to that shown in Sketch B, Figures 75 where it can be compared with the original Lovell case shown just beside it. This expansion apparently takes place without seriously injuring the grain structure of the brass. At least times without number cases thus altered have been reloaded and fired dozens of times with heavy charges without developing any defects. The resulting cartridge is now known as the .22 Donaldson 2-R, often abbreviated to just "2.R."

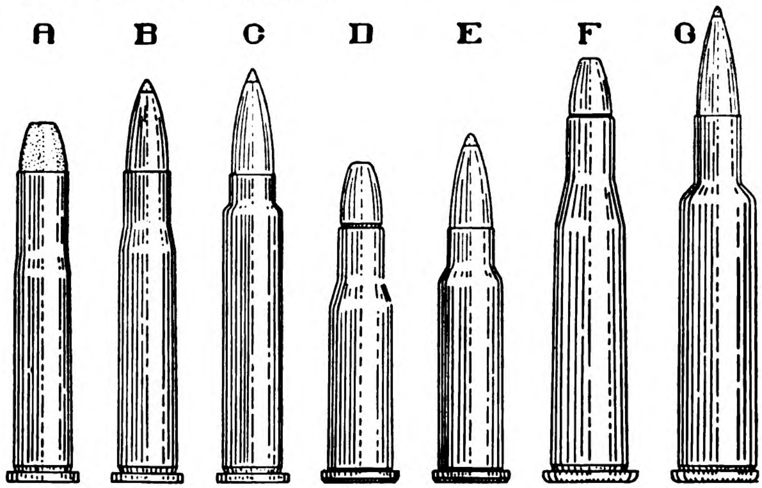

FIGURE 75. WILDCAT CARTRIDGES AND SHOULDER SHAPES

A—The old .25/20 Single Shot cartridge, developed back in the '80s, burning black powder and throwing soft lead. From its cartridge case has been developed

B—the 2R Lovell, or the .22/3000, as modified by Mr. Donaldson. The old .25/20 S. S. case was first necked down to .22 caliber, and then "blown out" to give larger powder capacity and a sharper shoulder. M.V. 3,000 f.s. with 50 grain bullet. This is a very successful and most popular wildcat cartridge.

C—The Maximum Lovell, another variation of the .25/20 S. S. case.

D—Here is the .218 Bee cartridge, from which has been developed

E—the Kilbourn Bee cartridge.

F—Is the .219 Zipper cartridge, from which came an odd modification in the shoulder shape termed the

G—Maximum Zipper.

Another Wildcat cartridge is the .280 Dubiel, the case of which is shown as E in Figure 69. So few rifles and cartridges of this caliber have been made that it should be classified as a "wildcat." It was designed before

The 2-R cartridge has been more than successful; in fact it has become exceedingly popular. Rifles have not yet been produced for it commercially by any of the large factories, but literally hundreds of suitable rifles have been rebarrelled for it by custom gunmakers. For best results the barrel should have a groove diameter of about .2235-inch, and a twist of 14 to 16 inches. Suitable breech actions are the Winchester single shot with heavy action and high side walls, Remington Hepburn, Sharps Borchardt, and Stevens No. 44½, all fitted with smaller firing pin, and the Winchester Models 54 and 70 bolt actions which were originally made for the .22 Hornet cartridge.

About 1939 Winchester began to make 2-R cases under contract for the firms of Griffin & Howe, and Smith's Custom Loads. These firms sold these cases to reloaders, and in addition sold loaded cartridges, so that the 2-R cartridge may be said to have almost passed out of the Wildcat stage, although none of the large cartridge companies make it as yet, nor is a complete commercial rifle yet available for it. Generally speaking almost all of the many users of this cartridge hand load their ammunition.

Let us see how successful this 2-R cartridge is and why. Many different weights and types of bullets have been used in it, with weights running from 40 to 60 grains, and with powder charges from light ones for squirrel shooting to the heaviest that the case will contain. Perhaps the most successful charge has been the Winchester No. 116 non-corrosive, non-mercuric primer, 17 grains of du Pont No. 4198 powder, and either the 50 grain pointed Sisk-Lovell copper jacketed soft point bullet, or the 47 or 48 grain pencil pointed Wotkyns-Morse 8-S copper jacketed soft point bullet. It is

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the advantage of an abrupt slope of shoulder was appreciated, and this case was given a gentle slope in order that the very large charge of powder employed would not increase the breech pressure to a prohibitive figure. Such a gently sloping shoulder does not present a good stop for positioning or headspacing, and is only possible with the belted or rimmed type of case.

Now turn back to the old .30/30 type of case, as shown in C, Figure 51. In order to keep the overall length of this cartridge the same as that of the .32/40 and .38/55 cartridges (for which the Model 1894 Winchester rifle had originally been constructed) and to get enough powder into the case to propel the .30 caliber 160 grain bullet at M.V. 1,960 f.s., the powder capacity of the case had to be increased by making it bottle necked, but in necking down the shoulder was made as gentle as possible in slope, as it was thought in those days (1896-1898) that the bottle neck case, while a necessary evil, tended to increase pressures. It probably did, but those higher pressures were necessary to make the new smokeless powder burn correctly.

impossible to get 17 grains of 4198 powder in the 2-R case when the powder is thrown from a powder measure, so the powder charge is poured slowly into the case through a long stemmed funnel which causes the powder grains to nest tightly against each other, and the charge just fills the case to the mouth. Then the bullet is seated about .22-inch deep in the neck, and of course considerably compresses the powder charge. Ordinarily this compression of a charge of modern smokeless powder is a very dangerous procedure, and results in exceedingly high pressures. But in this 2-R case, and with this particular powder, it apparently results in burning the powder extremely efficiently. We do not know what the breech pressure is, but in well made rifles with strong breech actions the results are more than good in every way.

The resulting muzzle velocity from this 2-R charge in a 28-inch barrel is approximately 3,200 f.s. The accuracy is superb, ten shot groups at 100 yards averaging about one inch extreme spread under best conditions. The trajectory is very flat; when the rifle is sighted to strike one inch above the point of aim at 100 yards, the bullet drops only about one inch below the point of aim at 200 yards. The two bullets described, at M.V. 3,200 f.s., appear to be drifted less by side winds than almost any other cartridge. Thus the accuracy, trajectory, and killing power are ideal for use up to about 275 yards on such varmints as woodchucks, jack rabbits and large hawks, and to about 200 yards on the smaller targets presented by prairie dogs and crows, and there is enough killing power to make it successful for coyotes and foxes. When the 2-R cartridge is loaded with a lighter charge to give about M.V. 2,400 f.s. it is a most satisfactory load for wild turkeys, and at M.V. 1600 f.s. for squirrels or grouse. The cost of reloading one hundred cases is a little less than three dollars. The accuracy life of the barrel exceeds 7,000 rounds and is perhaps considerably more. The report is very light and the recoil inconsequential.

Another Wildcat cartridge that has been outstandingly successful is the .22 Varminter as developed by Mr. J. E. Gebby of Dayton, Ohio. Mr. Gebby has copyrighted the word "Varminter" and what follows refers to rifles custom built by him. Of all the standard American factory cartridges, the one having the most abrupt slope of neck is the .250-3000 Savage. Experimenters were attracted by the possibilities of necking this case down to .22 caliber, and while the idea did not originate with Mr. Gebby, he seems to have brought it to its greatest success.

The forming of the .22 Varminter case is comparatively simple. The neck of the .250-3000 Savage case is reduced to .22 caliber in a simple die in one operation, apparently without any injury to the grain structure of the brass. The original headspace (shoulder position) of the .250-3000 case is retained, which obviates all forms of headspace trouble. A barrel of good chrome-molybdenum steel, .2235-inch groove diameter, and 14 inch twist (the same as the .220 Swift rifling) is used. See Figure 76. The result is that with permissible pressures a 55 grain copper jacketed bullet can be given a muzzle velocity of about 3740 f.s., a 50 grain bullet about 4,000 f.s., and a 45 grain bullet about 4100 f.s., thus approaching the velocities obtained with the .220 Swift cartridge. The 55 grain bullet is perhaps the most practical weight because its sectional density gives it the greatest remaining velocity and flat trajectory over the longer ranges.

Mr. Gebby has built to date approximately 375 rifles for his cartridge. Almost all of them have been built for well informed and skillful riflemen, and we have had very full reports on the performance of a majority of these rifles. It is believed that it is entirely correct to state that the .22 Varminter is the most accurate cartridge that has ever been developed for use up to 500 yards. It is fully as accurate, if not more so, as the best of the muzzle-breech

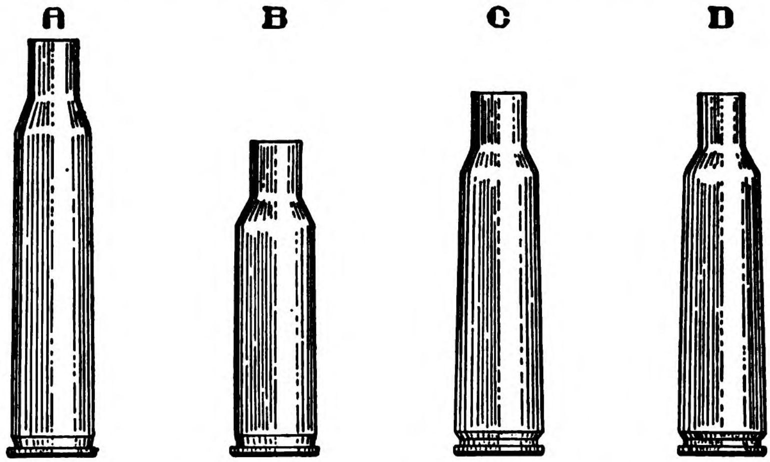

FIGURE 76. RIMLESS WILDCAT CARTRIDGES

A—The .220 Swift cartridge case, from which has come the

B—.220-30 Barr cartridge case. This is the latest wildcat known at the time of writing and was designed by Mr. A. H. Barr of the Technical Division, National Rifle Association. The .220 Swift case was cut off to shorten it and then necked down to .22 caliber, giving an extremely wide body with a very abrupt shoulder. The idea was to set up a turbulence inside the case, churning up the powder gases, so as to burn as large a charge of powder at the greatest efficiency possible. The cartridge was made shorter to keep the overall length down to approximately that of loading Pope rifles, and in practical accuracy far surpasses the Pope because its trajectory is so much flatter, and it is not nearly as much deflected by wind. The writer has seen, not merely a few selected groups, but dozens and dozens fired from many different Varminter rifles that at 200 yards would have an extreme spread of 1.60-inch or less for ten shot groups.

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the 2R Lovell cartridge. This .220-30 cartridge is still in its development stage, but the results so far have been very promising.

C—The .250/3000 Savage cartridge case, developed around the year 1912. In order to keep the overall length of this cartridge equal to that of the old .303 Savage, for which the Model 99 Savage action was designed, and yet to have sufficient powder capacity to drive the 87 grain bullet at M.V. 3,000 f.s., this case had to be given a large body and consequently the slope of the shoulder had to be quite abrupt. This steep neck slope did not give the high pressures expected, but the idea was not very promising for a number of years owing to the fact that much of the early .250 Savage ammunition split open at the neck very quickly, due to then existing methods of working the cartridge brass and to the fact that in those days manufacturers did not neck anneal the loaded cartridge as they do today. This writer well remembers opening many boxes of .250 Savage cartridges and finding that the greater part of the 20 rounds had cracked case necks. Despite this fault, the .250 Savage proved a most successful cartridge with exceptionally fine accuracy. It was not realized for a long time that its more abrupt shoulder shape resulted in cleaner and more evenly burning of the powder charge. From this .250 case has come

D—The .22 Varminter cartridge, designed by Mr. J. E. Gebby, the most successful of the Wildcat cartridges to date. It is simply the .250/3000 case necked down to .22 caliber, using bullets of 40 to 60 grains weight. The rather abrupt slope of the shoulder results in burning the powder charge under very ideal conditions for a cartridge of this size. Very exceptionally fine accuracy has been obtained in all of the 350 odd rifles that Mr. Gebby has made for this cartridge.

With both the .22 2R Lovell and the .220-30 Barr cartridges, a charge of powder is employed which fills the case to the mouth, and the seating of the bullet then considerably compresses the powder. This is typical "wildcat" prastice. It undoubtedly results in very high pressures, and at these pressures the powder charge burns exceptionally well. How high these pressures are is not known, as no pressure guns have to date been made for these cartridges. Possibly pressures are so high that it would not be practical to load factory cartridges in this manner, as certain conditions such as high temperature, etc., might subsequently run the pressures up to a very dangerous degree. Thus, a positive statement as to the practicability of such design and loading cannot be made until the large cartridge companies have had an opportunity to make a laboratory examination and study of these cartridges, impossible so far due to the war. But in the hands of careful experimenters these cartridges have shown most remarkable ballistic efficiency, velocity and accuracy.

With this Varminter case very superb accuracy can be obtained with a large variety of loadings from the full charge to light loads for gallery and squirrel shooting, which is not strictly true of the .220 Swift cartridge. Then there are two other advantages that the Varminter seems to have over the Swift. Varminter cases can be fired and reloaded with full charges at least a dozen times and perhaps more without any tendency for the brass to extrude up into the neck, and with simple neck resizing. And the accuracy life of the Varminter barrel seems to be almost double that of the Swift. The few Varminter barrels that have been worn out by erosion so far have apparently maintained their fine accuracy for about 3,500 rounds of heavy loads. Thus the Varminter case has other features to recommend it in addition to accuracy.

Thus far these two cartridges, the 2-R and the Varminter, have been the most outstandingly successful of all the Wildcat developments. They do not represent the ultimate achievement in velocity by any means, but they are the most reliable, and the most consistent performers, and their accuracy has not been surpassed. Dozens of other experimental cartridges have been developed on similar lines in the past three or four years, using as a basis the cases of almost every center fire factory cartridge. One of the most recent of these, developed by Mr. A. H. Barr of the Technical Division of the National Rifle Association is shown in Sketch B, Figure 76. It is made by re-neckening and shortening the .220 Swift case, and forming it with a very sloping shoulder. The overall length of the case has been reduced to only 1.55 inch. Experiments with this case have not been completed, but it is thought that the powder will be burned with a better relationship between pressure, velocity, and weight of charge than with any other of these high intensity .22 caliber cartridges. With a comparatively light charge of powder a muzzle velocity of about 3,600 f.s. is expected with a 55 grain bullet.

We do not know precisely what is taking place in these wildcat cartridges with these sharply sloping shoulders. So far as known no pressure barrels and gages have been built for any of them, and there has been no study made of the pressures, and of the rate at which pressure is built up and maintained. Most of these wildcat developments have occurred since the start of World War II, and all of our professional ballisticians, who have the needed facilities of the fully equipped testing laboratories at the large ammunition plants at their disposal, have been too busy with war work to undertake any thorough investigation of these cartridges. In the absence of such tests it would be well to suspend opinion on them, and to approach tests of them or future new developments with caution.

With regard to the steeply sloping shoulder it may be said that the informal experiments so far seem to indicate that it is an advantage with light bullets at high velocity, but that the more gently sloping shoulder appears to be better when heavy bullets are used. The abrupt shoulder seems to burn slowly burning powder better than a gentle shoulder, and also it appears to burn reduced loads better. Apparently also the powder gases are more "churned up" in the sloping shoulder, and a larger proportion of the powder charge is completely ignited and burned inside the case, and this leads to lower temperatures in the bore ahead of the case so that erosion is slower and barrels last longer.

There is also another phase of the enlarged powder capacity case with abrupt shoulder to consider, namely the manner in which experimenters are forming these cases from existing factory cases. Apparently this method of forming by blowing out the body in an enlarged chamber has been successful when comparatively little brass has to be moved a short distance, as with the 2-R case. But when an attempt is made to considerably alter and expand a much larger case by this method there is liable to be trouble. The crystals of the brass are more or less torn apart at the point of greatest strain, and a crack or an incipient crack is formed. Such a crack may develop and be visible when the case is blown up, or it may be hidden and may not show up until the final heavy charge is fired and then the results may be disastrous. This is not a good or safe manner in which to expand a case or reform a shoulder, but it is the only method open to the small experimenter who cannot make his own cases as they should be made but is forced to alter existing cases.

The writer does not desire to discourage such experiments. In fact this work is rather intended to encourage them for it is by just such experiments that we progress. It is desired rather to point out the difficulties and dangers, and to advise that every safety precaution be taken.

The Shotgun Shell

The modern shotgun shell is composed of a paper body, a thin brass head, and a paper or composition base wad. This rather weak construction is made practical because the breech pressure in the loaded shotgun shell does not exceed about 11,000 pounds per square inch. The advantage of the paper shell as compared with a solid brass one lies in its cheapness and light weight.

The paper body (side walls) of the shell is made by rolling a sheet of thin paper, impregnated with a waterproofing substance, onto a steel mandril, to form a long tube of the proper dimensions and thickness. The tube is thus formed of many thicknesses of this thin paper, impregnated together to make a strong and thick side wall.

It is important that the paper used be as nearly non-porous as possible as if there are pores in the paper the powder gases may penetrate these pores and burn slightly there, and if a number of these pores were in line the burning might weaken the wall enough to cause a separation, or as the manufacturers call it in the case of a shotgun shell a *"cut-off."* The long laminated paper tube is then cut into sections of the proper length for each shell.

The brass head is stamped out of a sheet of thin metal by dies and punches, in much the same way as rifle and pistol cases are formed. It has a pocket in its center into which the battery cup of the primer is inserted, when the shell is primed just prior to loading. There are three heights of brass heads—high, medium, and low—referring to the distance that they extend up the side of the shell from the bottom. This brass head is intended to close the rear end of the shell, to provide support for the primers, to prevent gas leakage into the breech of the gun, and to provide a strong rim that positions the shell in the chamber, holds the shell head against the blow of the firing pin, and provides the surface against which the extractor operates. The height of the brass head has no influence on the ballistic results, although usually manufacturers utilize high brass shells for high velocity loads, and in their more expensive shells. Some shooters think that the long brass head is a distinct advantage in aiding extraction of the shell.

The base wad is made by winding paper in a roll to the desired diameter to fit inside of the base of the paper tube, where it is held in position when the head is formed. This wad is inserted under pressure in the head of the shell while the paper tube and the brass head are held together in a supporting die. The assembly of paper tube, base wad, and brass head are then made secure by stamping cannelures in the brass head to crimp them all together. The manufacturer calls this operation "bumping." Sometimes, instead of a conventional cannelure, the manufacturers name or a trade name is impressed around the brass head which serves the same purpose.

Base wads are made low, medium, and high, and according to which height is used, the shells containing them are called low-base, semi-low base, and high base. The high base shells are used for dense powders, the charges of which occupy little space in the shell, and the low base shells are used for very bulky powders, in order that the length of the filling wad column will remain the same in both cases, and thus, irrespective of the powder used, the loaded shells will all have the standard overall length. See Figure 77.

Sometimes in shells that are intended for the more powerful loads, a thin sheet steel reinforcement is placed between the base wad and the brass head, covering the sides, rim and base. In one shell the steel reinforcement is brought up and crimped around the battery cup. The battery cup, forced through the head of the shell, is crimped to the base wad, thus riveting together all of the head components.

All the American ammunition manufacturers make several brands of shotgun shells designated by various trade names, and often

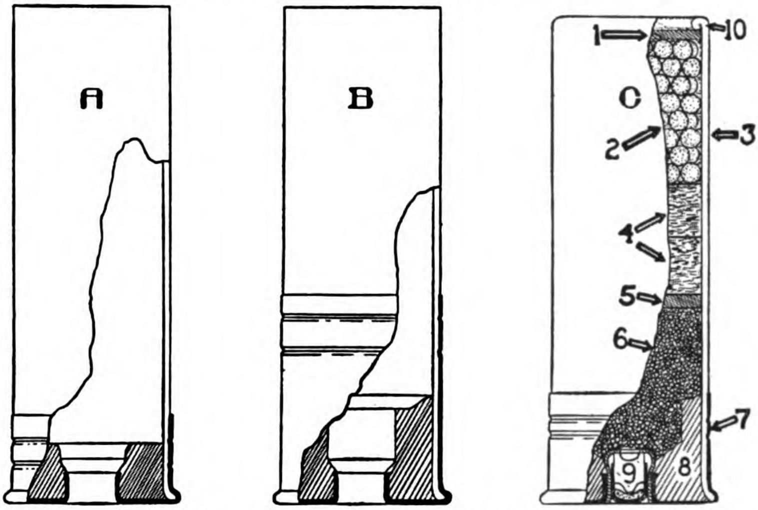

FIGURE 77. PAPER SHOTGUN SHELLS

A—Here is a low base and low brass shotgun shell case, sectioned to show details of construction. Note how the inside "base wad" is crimped tightly in place by the brass base, further reinforced by the knurlings turned from outside and into brass and body paper. This type of shotshell case is intended for black or bulk smokeless powders, in light or moderate loads which will develop relatively low pressures.

B—This is a high base and high brass shotshell case. Note that the inside base wad comes up higher in the powder chamber, this is to be loaded with a relatively more dense type of smokeless powder, used in smaller charges than in **A.** Manufacturers regulate the thickness, height and shape of these base wads very closely, so that when used with a definite kind and charge of smokeless powder and the standard amount of wadding the length of the loaded shell will be uniform, irrespective of what amounts of powder and shot are used. Note the extreme height to which the brass extends on outside of this case, this is a "high brass" shell intended to be used with heavy loads of smokeless powder working at high pressure—about the best the maker is able to give us in that gauge.

C—The loaded shotshell, or "cartridge" as the Englishman will have it. 1 is the top wad, or top shot wad as some call it. 2 the charge of shot. 3 is paper body. 4 are felt wads, or filler wads, or black edge wads. 5 is the over powder wad, or grease proof wad. 6 is the powder charge. 7 is the brass head. 8 is the base wad. 9 is the primer. 10 is the crimp, or turnover as some express it.

these brands can be had loaded with different kinds of powder, both bulk and dense, for which they have different heights of bases depending on the load. Shells are also made to a standard overall length before they are loaded so that when fully loaded they will be the correct length for the standard chambers. For 12, 16, and 20 gauge the standard length of unloaded shell is 2¾ inches, these being intended for shotguns with standard 2¾ inch chambers. In 12 gauge another magnum shell 3 inches long is also made for heavy duck guns with 3-inch chambers. In 28 gauge the standard empty shell is 2⅞ inches long, while in .410 bore shells are made either 2½ or 3 inches long for use in shotguns having the old 2½ inch, or the new 3 inch chamber.

After all these shells are fully loaded the overall length of the loaded shell will be reduced by the amount of turnover of the crimp at its mouth, so the loaded shell will actually measure about ⅛ or 3/16 inch shorter than the lengths given above. When the shell is fired the crimp straightens out as the shot moves forward, and the paper shell then fits correctly in the cone of the chamber. If the shell were too long for the chamber it would crowd into the cone and block and distort the shot charge as it passed through, and also cause high pressure; while if it were too short there would be a gap between the end of the shell and the cone into which the body of the shot charge would expand, and then have to contract again, thus also distorting the shot and spreading the pattern slightly.

Into this empty shell are loaded the primer, and the charge of powder. The powder, no matter what its kind, now fills the shell up to a certain standard point. Then a paper wad, and two felt or composition wads are placed over the powder, and are pressed down with a certain specified number of pounds pressure according to the pressure necessary to make the particular powder burn at best efficiency, then the charge of shot is loaded, and finally another cardboard wad is placed over the powder. The two felt or composition wads are thick, and these wads are manufactured of several different thicknesses, so that in loading the particular thickness can be used that will just bring the top shot wad to such height that there will be a certain amount of shell wall standing up above this wad that can be turned over into a firm crimp. Figure 77 shows a cross section of a loaded shell.

All wads are made of such size that they will fit tight inside the paper body of the shell, but they must not be so large that they will bulge the paper body outward. The over-powder wad and the shot or top wad are made of cardboard. The filler or powder wads must be made thick and of an elastic material so they will surely retain the powder gases behind them and not let any of the gas escape forward into the shot charge. They used to be made of thick felt, but in recent years it has been difficult to get good felt for this purpose, and various composition wads of cork, cork composition, rubber, and leather, either separate or in combination with each other have been successfully substituted.

In recent years some of our manufacturers have introduced a new form of crimp, called the "Super-Seal" or "New" crimp. The top wad over the powder is omitted and the paper body of the shell is turned over in such a manner as to hold the shot charge firmly in place. This has resulted in a better average of patterns because there is no top wad through which the shot charge has to plough. Particularly this new crimp has eliminated the occasional poor pattern.

The Brass Shotgun Shell

Standard American shotgun shells are so well made and loaded, and the loads are so well balanced, that defects do not often occur. There is one drawback, however, that all paper shells have. The paper portion is impregnated with a waterproofing compound, and while this successfully resists rain and ordinary dampness in any temperate climate, it will not withstand long immersion in water, or prolonged storage or field handling in exceedingly damp tropical climates. Sooner or later under such unusual conditions the paper portion absorbs enough moisture to swell the paper so that the loaded shell cannot be inserted into the chamber of the gun without using prohibitive force, and this dampness eventually gets to the powder and ruins it.

The writer took supplies of paper shotgun shells with him to the Philippine Islands and to Panama, in each of which places he was stationed for two years. Both climates are very hot and excessively damp during over half of the year. These shells were kept in a relatively dry and well ventilated house. During the first year, in both localities, no trouble whatever was experienced. During the second year the paper bodies began to swell, and became definitely damp and soggy, and during the latter part of the second year they had deteriorated to such an extent that they had to be thrown away.

There are other climates that have even a quicker effect on paper shells; the Amazon Valley in Brazil, and Burma for example. There these shells deteriorate so rapidly as to be worthless after several months.

Brass shotgun shells have been manufactured in America, and sold empty, not loaded, to some extent in the past. They are made by the same process as brass rifle cases, but require a slightly different primer and larger wads than those for paper shells. They are not as efficient as paper shells because they cannot be crimped so effectively, and the density and pressure of loading may vary because the wads are liable to loosen. Thus at the best patterns are not quite as good as with factory loaded paper shells. They used to be in demand in America because they could be cheaply reloaded almost an indefinite number of times with black powder, but one seldom sees them now-a-days in the United States.

But brass shells do not swell from moisture, and for this reason they have been used almost exclusively in exceedingly damp countries, the shooters loading them as required. South American sportsmen used to obtain most of their brass shells from Europe. It is probable that after this war these shells will come into demand for export, and our factories will give more attention to them than in the past.

CHAPTER X

Ammunition

Propellant Powders

UNTIL about 1846 when nitroglycerin was discovered **black powder** was the only explosive commonly known and used in small arms. It is a mechanical mixture of about 75 parts of saltpeter, 10 of sulphur, and 15 of charcoal. A mixture of sulphur and charcoal will burn if plenty of air be supplied, but it will not explode or generate a large volume of gas quickly because air (oxygen) cannot be supplied fast enough, particularly in the barrel of a gun. Saltpeter is very rich in oxygen and gives it up when heated, and thus black powder as above compounded supplies its own oxygen. Thus the burning of black powder results in an extremely quick conversion and expansion from the original grains to a very much larger volume of gas. This sudden expansion of gas is the force that propels the bullet.

Nitroglycerin, formed by the action of nitric and sulphuric acids on glycerin, is one of the strongest explosives known. Unlike black powder, it is not a mechanical mixture of materials that burn and other materials that supply oxygen fast to speed the burning. Rather it is a chemical compound containing a considerable amount of oxygen, and capable of rearranging itself into more stable compounds which are gases. Such rearrangement can be caused by shock, and once started it progresses so instantaneously that the result is an extremely violent explosion that no gun can contain.

Pure nitroglycerin is an oily mass liable to leak out of its container, and is dangerously sensitive, so it could not be used practically until it was discovered that when it was absorbed into a porous material it became safer and more convenient. When it is absorbed in porous earth it is called Dynamite, if in cotton it is called gun-cotton, and there are many other nitro-compounds that are very powerful explosives. One of these is tri-nitro-toluene commonly called T.N.T. Such compounds give off their gases very much more rapidly than black powder, too rapidly in fact for use in any gun, and are known as **High Explosives.** This expansion or rearrangement is called a *detonation* rather than an explosion, and is usually caused not by igniting them by a flame but by a shock such as that caused by a blasting cap or detonator. This usually contains fulminate of mercury, a substance that explodes with such great suddenness that it gives a severe shock, and that can be ignited by the spark from a burning fuse, by electricity, by friction or by concussion.

To make these nitro-explosives suitable for use in guns a way had to be found to prevent detonation and slow down their burning. It was found that gun-cotton could be dissolved in a solvent, and then evaporated into a glue-like substance called a "colloid" which does not detonate and which burns with a reasonable speed.

Gun-cotton, also called **nitro-cellulose,** can be dissolved in nitroglycerin, and the resulting colloid formed into grains, flakes, or cylinders, resulting in what is called **Nitro-glycerin Powder,** or **Double Base Powder.**

Or nitro-cellulose may be dissolved in ether and alcohol, also forming a colloid which is formed into grains, flakes, or cylinders, and is called **Nitro-cellulose Powder,** or **Single Base Powder.**

It is important to distinguish between high explosives which detonate with extreme violence, and **Propellant Powders** which burn and change into gas at a controllable rate.

If unconfined black powder, such as a small pile of it on a plate, be ignited by a spark or flame, it goes off into gas almost instantly with a big puff, flash, and much smoke. On the other hand if a small amount of smokeless powder be similarly ignited it burns much more slowly, it may take several seconds to consume the pile, and there will be relatively little smoke. If we moderately confine smokeless powder, as in the chamber of a gun with a bullet in front of the charge, it burns and changes into gas much faster due to the pressure. Different smokeless powders are manufactured to burn at different pressures. One may be made to burn correctly at only 9,000 to 15,000 pounds for use in revolver cartridges. Another may have a range of 30,000 to 50,000 pounds pressure for a certain general size of rifle cartridges. The rate and pressure of burning, so far as the powder is concerned, is regulated by its composition and its granulation. Small grains burn faster than large grains, and tubular grains slower than solid grains as will be explained later. As concerns the gun, the heavier, harder, and tighter the bullet, and the greater the density of loading (proportion of powder to powder chamber capacity), the heavier the pressure, and the faster the powder will burn. And finally the greater the pressure the greater the heat, and hot gas expands more than cool gas. Thus the design of the powder and the cartridge must balance each other to have the burning and pressure normal and within the limits of the gun to confine safely.

That in brief is what happens when the pressure is moderate and normal. On the other hand if we load an abnormal amount of powder into the cartridge, or use a heavier, or tighter, or harder bullet, or crowd a lot of powder into a small powder chamber, the pressure curve rises very rapidly. For example, if a maximum safe charge in a certain cartridge gives 50,000 pounds pressure, one grain by weight additional may give 60,000 pounds and cause the brass cartridge case to expand so much that it sticks tightly in the chamber and is difficult to extract, and 3 grains of powder above the max charge may give about 75,000 pounds and blow out the primer, and allow gas to get back into the gun's mechanism, and 5 grains above the normal max charge may disrupt the case entirely, and the powerful gas escaping to the rear may completely demolish the breech action of the weapon. Just one more example. The .30-06 U.S. Service cartridge, and the 7.9 mm German Mauser service cartridge contain roughly the same amount and kind of powder, and look very like one another, but the bullet of the former has a diameter of .308-inch, while the latter bullet measures about .321-inch. The Mauser cartridge can be loaded and fired in a .30-06 rifle, but because the bullet is so tight in the bore it will disrupt the case and completely wreck the breech mechanism of the .30-06 rifle every time.

As we have seen, there are many different kinds of smokeless powder, designed for different cartridges, and also for different kinds of loads in these cartridges. The experimenter or hand loader should understand these various types, their characteristics, the cartridges to which they are adapted, and the proper amount of powder to load in each case. He should not use too large or too small an amount of that powder, and he should assemble his cartridge in a normal manner with proper components—in other words he should balance his load correctly—to achieve satisfactory results with safety.

The writer has been shooting the rifle, pistol, and shotgun steadily since 1891. He won his first rifle match and shot his first deer in 1892. He has hand loaded thousands of rounds annually since 1898. This is written in 1944. Looking back over this lifetime of experience he thinks that the greatest improvement in rifled small arms has been in the propellant powder. He had the valuable experience of shooting and hand loading when black powder only was available. While the change from black to smokeless powder was a very great stride forward, it was not more so than the improvements that have taken place in smokeless powder in the past forty years.

It is not intended here to set forth the history of the development of powders. This has been covered adequately elsewhere. Also it would hardly be worth while to refer to obsolete powders because the shortage of powder has been such during the present war that all obsolete lots of powder that shooters or stores may have happened to have on hand have been exhausted long ago, and the experimenter and hand loader will no longer find them available. We will therefore describe only the modern American powders which are manufactured, available, and in general use at the present time. Foreign powders will not be covered because the writer is not sufficiently familiar with them, and who can say what foreign powders will be available when peace comes.

Although it is still manufactured, we will also regard black powder as obsolete. The practical objection to its use lies in the resulting smoke, which often conceals the target or enemy after the first shot, and discloses the location of the firer to his enemies. Ballistically the objections to it are the decided limitation in the velocity that can be obtained, and the excessive residue or fouling that is deposited in the bore which interferes with sustained accuracy. Cartridge manufacturers have decided to manufacture no more small arms ammunition loaded with black powder in the future, due to lack of demand for it.

Smokeless Powder

There are two general types of smokeless powder made in the United States.

Nitro-glycerin Powder is one having a base of nitro-cellulose with a smaller percentage of nitro-glycerin. These powders are generally referred to as **double base powders** although their main base is nitro-cellulose.

Nitro-cellulose Powder has a nitro-cellulose base and no nitro-glycerin, and is referred to as a **single base powder.**

In the United States smokeless powder for small arms is manufactured by:

E. I. du Pont de Nemours and Company.
The Hercules Powder Company.
The Western Cartridge Company.
The Ordnance Department, United States Army.

A large number of radically different rifle, pistol, and shotgun powders are manufactured and are in use at the present time. Some are intended for use only in .22 caliber rim fire cartridges, others only for pistol cartridges, others for center fire rifle cartridges of various sizes, and still others for shotgun shells only.

Rifle powders are intended to burn correctly in the relatively long barrels of these weapons. Some are designed for use with moderate bullets at normal velocities, and some for heavy bullets. Others for light bullets in reduced loads, others for light bullets in extremely high velocity loads, and still others to replace black powder and give normal velocities in older cartridges.

Pistol powders are all quick burning, designed to be completely consumed in the short barrels of these weapons. They are also designed to burn at relatively very low pressure because of the small amount of steel (low strength) in pistols, and because of the desirability of light recoil. To run the initial pressure up to the point that will cause them to burn fast and properly it is usually necessary to heavily crimp the bullet in the case of pistol cartridges. These powders are unsuitable for any other use unless it be for extremely light gallery loads in some rifle cartridges. Some pistol powders are so condensed that it is possible to load two full charges into the cartridge with disastrous results a certainty.

Shotgun powders are designed to burn under very different conditions from rifle and pistol powders, and generally speaking are suitable for use only in shotgun shells in closely prescribed loads. To give satisfactory patterns they must burn at a rate and pressure that will produce standard velocities. Some shotgun powders are more progressive burning than others, this enabling us to obtain standard velocities at normal pressures with heavier charges of shot, and not higher velocities to any extent as popularly supposed. To make the shotgun light and easy to handle when shooting at birds in flight the forward portion of the barrel has to be made very light, therefore the powder must exert its maximum pressure near the breech, and pressure towards the muzzle must be relatively light. All these conditions point to a fast powder that burns properly at pressures of from 10,000 to 11,000 pounds per square inch.

There is still another kind of powder called **Blank Powder** for use in blank cartridges intended for saluting purposes and in military maneuvers. It is almost a gun-cotton, and is extremely fast burning so that it will make a loud report at the muzzle, in the absence of a bullet. It must never be loaded with a bullet in front of it, which would cause it to detonate and burst the gun.

Canister Powders. Certain powders, due to lack of flexibility, are suitable for only one or comparatively few purposes, and would be unsatisfactory or dangerous if used for other purposes. These are sold only to the loading companies (cartridge manufacturers) for their specific use. Other powders have more general application and can be used with safety by individuals provided that a few simple rules are observed. These powders are sold alike to the loading companies and to individual hand loaders and experimenters. They are called "Canister Powders" because they are packed in small tin canisters containing a pound or half a pound, for sale to individuals.

A lot of powder is a batch of several or many thousand pounds that is made at one time in the powder mill so that all of it is alike in characteristics and burning. It is not practical to make different lots of the same kind of powder with precisely the same characteristics. The different lots will vary more or less, and the differences cannot be told until the lot is completely manufactured and tested. Each lot of each kind of powder is numbered. A certain one of these lots is selected as the canister lot, and is packed in canisters for individual sale. When a canister lot becomes exhausted another lot of similar burning characteristics is designated as a canister lot. The powder manufacturers have published tables showing for what cartridges the canister lots of their various powders are suitable, and the maximum and minimum number of grains of that powder that can be advantageously and safely used in each of these cartridges with bullets of certain weights. These tables are contained in the handbooks published by the various makers of reloading tools, and in certain works on ammunition.* Other lots of these powders which differ slightly in their burning characteristics from the canister lot are packed in large drums and are sold only to the loading companies who control their loading into cartridges with pressure guns and chronographs.

To illustrate more specifically take du Pont Improved Military Rifle Powder No. 4064. This is one of the powders that can be used advantageously in large rifle cartridges. The tables that are published for the canister lot of this powder show that in the .30-06 cartridge, and using a 180 grain metal cased bullet, and Frankford Arsenal No. 70 primer, the minimum charge that will burn correctly is 45 grains weight, which gives a muzzle velocity of 2380 f.s. Also the maximum charge that can be used without exceeding the safety pressure limit is 53.5 grains which gives M.V. 2785 f.s. with the 180 grain bullet. Now du Pont No. 4064 powder can be identified by the size and shape of its grains, and a shooter may open a .30-06 factory loaded cartridge and finding that it contains 4064 powder, he may weigh the charge and come to the conclusion that this is the proper amount of that powder to use in reloading to duplicate the factory cartridge. But this may be way off because the loading company used a lot of No. 4064 powder that was sold to them only, while the shooter is confined to the canister lot of that powder. Also the loading company was not using the F.A. No. 70

* Ideal Handbook, published by Lyman Gun Sight Corp. Middlefield, Conn. B & M Handbook, published by Belding & Mull, Philipsburg, Penna.

primer, but a special primer of their own make, probably a non-corrosive primer, and this would make a considerable difference in the rate of burning and the charge required. We will speak again of this matter of primers when we come to discuss rifle powders in particular.

Measuring Powders. Charges of powder for rifle and pistol cartridges are designated and measured in grains weight. Shotgun powders are likewise now measured in grains weight, but formerly the dram (drachm, Apothecaries Weight) was used. There are $27\frac{11}{32}$ grains in one dram. The grain is the same in all tables, there being 7,000 grains Troy or Apothecaries weight in one pound Avoirdupois. Powder is bought by Avoirdupois weight—that is in a pound canister there are 7,000 grains.

Originally individual hand loaders measured their powder charges with a simple dip or scoop measure. The shotgun dip measures were made adjustable, and were graduated in drams and eighths of a dram, and they also could be used for measuring shot, being additionally graduated for ounces and eighths of an ounce of shot. The scoop of a size or adjustment that would just hold the correct amount of powder was dipped into a wide-mouthed container holding the powder until the scoop was full to overflowing, care being taken to dip it to the same depth in the pile of powder each time. Then the powder was struck off level with the top of the scoop with a card, and the level full scoop of powder was poured into the cartridge case through a funnel. This method, however, is not nearly accurate enough for modern powders, and is entirely obsolete.

Powder charges are now weighed on accurate balances or scales that are arranged to weigh by grains, and which are accurate to within one-tenth of a grain. Or else they are measured by mechanical powder measures which are adjustable to throw the correct charge. Generally speaking from one-half to one and a half minutes is required to weigh a single powder charge to within $\frac{1}{10}$ grain on a measure or scale, and this is too slow except for experimental work or where extreme accuracy is required. In factory cartridges the charges are thrown with a mechanical measure as the scale is entirely too slow for quantity loading.

Hand operated mechanical measures will throw from twenty to thirty charges per minute, but they are not so accurate as balances or scales. When properly used there is a slight variation in the weight of consecutive charges thrown amounting to about .3 grain with finely grained powder, to .7 grain for the coarser powders with large tubular grains. These are the maximum variations, but ninety per cent of the charges thrown will not vary more than half this amount. Such variations amount to little in terms of accuracy, velocity and pressure, and unless extreme accuracy is desired there is little need for the tedious weighing of each charge, unless one is using maximum charges close to the safety limit, in which case each charge should be accurately weighed.

The small mechanical powder measures manufactured for individual use are graduated in grains which are correct only for black powder. Tables are furnished to translate these graduations into grains weight of all makes of smokeless powder. For example: if one wishes to throw 30 grains weight of du Pont No. 4064 powder the table will indicate that he should set the graduations at 25 grains. The measure will then throw 30 grains weight of No. 4064, or very close thereto.

This method of adjusting the measure is not accurate enough for very fine work, or when throwing charges approaching the maximum. A far better method is to first set the measure as above, and then verify the setting by first throwing charges on the pan of the balance or scale, verifying the setting of the measure, and making any needed small correction in adjustment before starting to throw the charges into the cartridge cases.

The methods of weighing and measuring powder are described in complete detail in the handbooks on reloading already referred to, and with these as a guide a careful person cannot go wrong if he will take the precaution of checking the setting twice.

Burning and Pressures. The various types of smokeless powder are manufactured in the form of minute grains which vary in their form and size. Some are tubular in form, like small gray-black cylinders with a hole through the center, some like small round discs with or without a hole in the center, some saucer shaped, some in small square flakes, and others rough and shapeless and of only fairly uniform size. The object of these different forms and sizes of grains is to cause the powder to ignite and burn at a certain desired rate as required in the cartridges for which that powder is designed.

Powder must not burn too rapidly or violently. The gas must give a gradual pressure rather than a sudden severe blow. The British Text Book of Small Arms likens proper burning to the force necessary to open a partly closed door. If the force be applied slowly the door will open properly, but if applied with great suddenness the force may shatter the panel of the door without causing it to open. This can best be illustrated by Figure 78.

The powder chamber in a properly designed cartridge case is of such size that it will just contain the powder charge which fills it completely to the base of the bullet; or it may be of slightly larger size so that the powder fills it only half or three quarters full. If the powder were to ignite and burn completely in this chamber an extremely high and dangerous pressure would arise and the gun might burst. So the powder is so designed as to composition and granulation that a charge of it which fills or partly fills the chamber will result in the powder starting to burn slowly, and not reach its peak of pressure until the bullet has started forward slightly up the bore. As the bullet starts forward the chamber begins to be enlarged

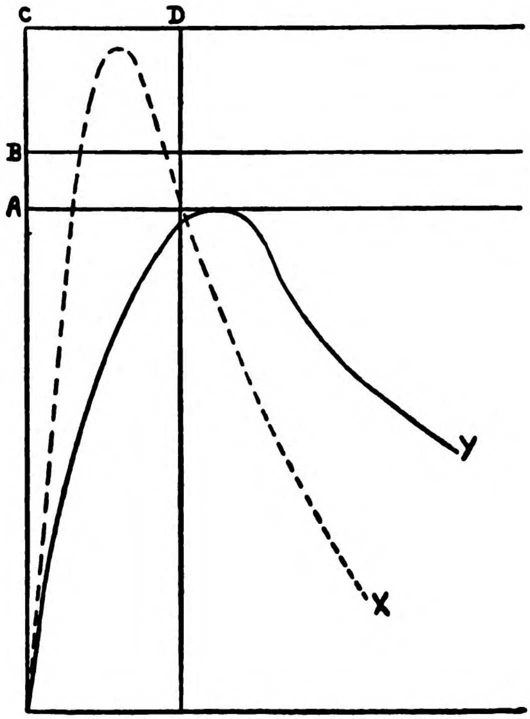

FIGURE 78

giving more room for the gases to continue their expansion, and thus keeping the pressure within proper limits. The line A represents the normal pressure limit of the gun, B the margin of safety, and the space C-D the time necessary for the bullet to start forward. The pressure curve Y is that of a normal full load. Obviously this load is correct. We could use it with perfect safety and without any injury to the gun. But if we were to use the same bullet with a much larger charge of the same powder, or the same weight of a finer grained and faster burning powder, or in a case having a smaller powder chamber, or even if we were to use this same powder charge but with a heavier or much tighter bullet; the picture would change and the pressure curve would be more like X because the powder burns faster or throws off more gas. Thus the pressure passes the safety limit before the bullet has had time to move forward and increase the space in which the powder is burning. The breech action probably lets go.

It will therefore be seen how necessary it is that we use a powder that is designed for the cartridge we are loading, that we load a proper amount of it, and that we insure the proper conditions of cartridge and bullet. Then the powder will burn with a safe and even pressure, uniform velocity and a minimum of fouling, and fine accuracy will result.

Too low a pressure is likewise undesirable. This may be caused by using the wrong powder, or too little of the right powder, or too light or too small a bullet for the powder charge. The powder grains under this much lowered pressure may not burn completely, the primer may not even ignite it fully, the velocity will be low and irregular, the fouling will be excessive, and the fouling may even become corrosive. In some cases there may be so little pressure that the bullet may not even leave the bore, but may stick at some point ahead of the breech or up towards the muzzle. The shooter might not notice this because there would be some report and some recoil, and he might load and fire another cartridge. When this occurs the air between the two bullets is compressed so forcibly as to cause the barrel to bulge or burst just behind the stuck bullet. Tables of charges for various powders and cartridges give both a maximum and minimum charge. It is just as important that the charge should not be decreased below the minimum as that the maximum should not be exceeded.

Progressive Burning Powders. We have already seen that the rate of burning of the powder is controlled to some extent by the size and shape of the powder grains. Pistol and shotgun powders, and a few rifle powders that are required to burn rapidly have small grains in the shape of thin discs and flakes. These ignite all over, present the maximum burning surface from the start, therefore the volume of the gas and the pressure rises quickly. As the grains burn they decrease in size, there is less burning surface, and so the pressure and the amount of gas thrown off drop quickly. There is a quick push, but the push on the bullet is not continued far up the bore. This condition is ideal for pistols which have very short barrels, and for shotguns which likewise have short barrels in proportion to the size of their bores, and also have barrels that thin out towards the muzzle to such an extent they will not stand heavy muzzle pressures.

Rifles on the other hand have long barrels with respect to the diameter of the bore, and with them we desire high velocity to give us flatter trajectory and increased killing power. Therefore the grains of rifle powder are usually made in the form of small cylinders perforated through the center and called "tubular" grains. As the outside and ends of the cylinders burn they get smaller, and throw off less gas. But as the inside of the hole burns that surface gets larger and increasingly more gas is thrown off until the grain is consumed. The net result of the burnings of the four surfaces is that the grain burns slower than a flat grain, and the pressure is more sustained. We can thus obtain a higher velocity with a pressure that does not exceed the safety limit.

Our powder manufacturers have always tried to make rifle powders that would continue to give off a considerable volume of gas even after the pressure had reached its peak. Marked progress in this respect was made early in this century by coating the outside of the powder grains with a substance that burned more slowly than pure nitrocellulose. After World War I these experiments had made such strides that the manufacturers were able to produce powders which had a much longer sustained pressure than former powders. These powders are called **progressive burning powders,** and the older powders which do not have these properties to such an extent are now called **regular burning powders.**

Progressive burning powders have two advantages; they enable us to obtain higher velocities within the pressure limit, and normal velocities with lower pressures. As an illustration let us take the .30-06 service cartridge loaded with a 150 grain jacketed bullet. At the time of World War I it was loaded with a regular burning nitrocellulose powder known as Pyro D.G., which gave the bullet a muzzle velocity of 2,700 f.s., with a breech pressure of 48,000 pounds per square inch. With this powder it was not practical to increase the velocity because 48,000 pounds was the maximum pressure set by specification requirements. With the modern progressive powders suitable for this cartridge that are now available we can obtain a muzzle velocity of about 3,050 f.s. and still keep our pressures down to 48,000 pounds. Or we can obtain the old standard velocity of 2,700 f.s. with a pressure of only about 35,000 pounds.

The general adoption of these progressive powders about 1922 to 1925 to replace the older regular burning powders permitted our cartridge manufacturers to increase the velocities of almost all rifle cartridges at that time. For example the .30-30 W.C.F. cartridge with 170 grain bullet was increased in velocity from 1,960 to 2,200 f.s.

Figure 79 shows a graph indicating in general the pressure curve of a progressive as compared with a regular powder. Note the slower rise to the pressure peak, and the slower falling off of pressure after the peak for the progressive powder.

This graph also shows that high velocities do not necessarily depend on high pressures. A certain amount of pressure is of course necessary, but the degree to which that pressure is sustained is also a contributing factor. We might for example, either through ignorance or carelessness, load a charge of quick burning pistol or shotgun powder, instead of the proper kind of rifle powder, in a large rifle cartridge. The terrifically high pressure resulting would likely blow out the base of the case, and the escaping gas would probably wreck the breech mechanism of the rifle, but the bullet would leave the muzzle with a relatively low muzzle velocity.

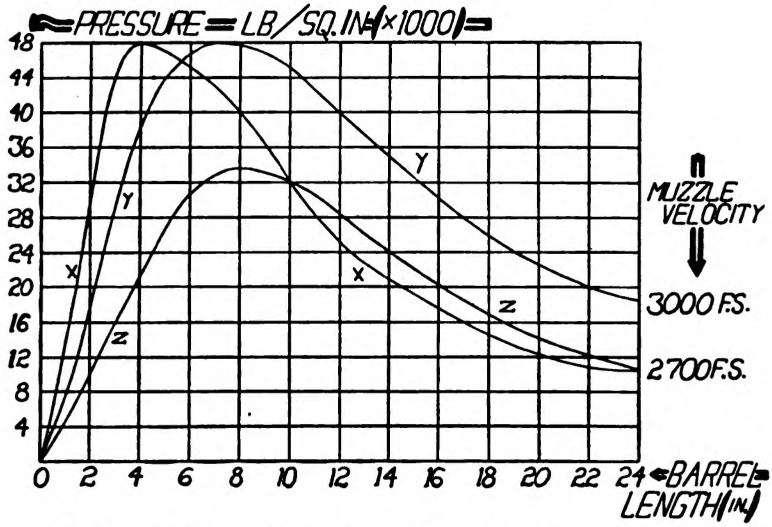

FIGURE 79. PRESSURE CURVES WITH REGULAR AND PROGRESSIVE BURNING POWDERS

X—Regular burning powder at its maximum permissible pressure gives M.V. 2700 f.s.

Y—Progressive burning powder at the same maximum permissible pressure gives M.V. 3050 f.s.

Z—A lower charge of progressive burning powder gives M.V. 2700 f.s. with very low pressure.

Primers used. The selection of the proper primer to use with various rifle and pistol powders is an important matter. In general, six sizes and types of rifle and pistol primers are at present manufactured in the United States:

1. Large size rifle primers of the stronger type, diameter .210″, for the larger military and magnum cartridges having cases with considerable powder capacity.
2. Large size rifle primers of the moderate type, diameter .210″, for the moderate and smaller center fire rifle cartridges.

3. Large size pistol primers, diameter .210", for the larger sizes of pistol and revolver cartridges.

   All three of the above primers will fit fairly well in all American rifle and pistol cases having the large size primer pocket.
4. Frankford Arsenal pistol primer, No. 70., diameter .204", which will fit only the .45 Colt Auto Pistol case of Frankford Arsenal make.
5. Small size rifle primers, diameter .175", for the smaller sizes of rifle cartridges such as .22 Hornet, .25-20, .32-20, etc.
6. Small size pistol primers, diameter .175", for the smaller sizes of pistol and revolver cartridges.

   The two small size primers, 5 and 6 above, will fit fairly well in all makes of American rifle and pistol cases having small size primer pockets.

A few years ago all of these sizes and types of primers were made loaded with both chlorate non-mercuric and chlorate mercuric priming mixtures as well as with non-corrosive non-mercuric priming mixtures. At present, however, it is believed that they are loaded only with the non-corrosive non-mercuric mixtures; except that the Frankford Arsenal No. 70 priming mixture, chlorate non-mercuric is still loaded in primers in sizes 1 and 4 by the Ordnance Department.

The handbooks of the makers of reloading tools already mentioned contain tables showing the correct size of primer to be used with each caliber of cartridge and type of powder, but the matter goes a little further than that.

The tables of powder charges are all predicated on the use of the modern non-corrosive non-mercuric primers *except* in the case of the .30-06 cartridge, where the charges are based on the use of the Frankford Arsenal No. 70 large size, chlorate non-mercuric primer. The new non-mercuric non-corrosive primers develop a higher order of ignition and give higher pressures to an equal charge of powder than do the older chlorate primers. Therefore, in the case of the charges given for the .30-06 cartridge, if we used a non-corrosive non-mercuric primer we would get a very high and perhaps dangerous pressure. So the rule is to reduce the powder charge 3 to 5 grains in weight when using any load that has been calculated on the basis of the old chlorate primers when we use the newer non-corrosive non-mercuric primers. This is most important.

Next the question arises whether to use the more powerful large size rifle primers (No. 1 above) or the moderate large size rifle primers (No. 2 above). If the powerful primer be used in one of the smaller rifle cartridges it will probably over-ignite the powder, give high pressure, variations in velocity, and poor accuracy. On the other hand if the moderate strength primer be used in many of the larger cartridges it will not ignite the powder properly, there may be misfires and hangfires, an increase in the fouling, and the accuracy will not be good. The dividing line seems to be about at the .250-3000 Savage, .257 Roberts, and .35 Remington Auto cartridges. Generally speaking either primer can be used in such cartridges. In certain loads in these cartridges and others closely approximating their size, sometimes No. 1, and sometimes No. 2 primer will give the best results, and indeed there may be considerable difference in the results given by these two types of primers.

For the same reason, and in a much more exaggerated form, rifle primers should never be used in pistol cartridges, nor vice-versa, except as below.

The new du Pont Sporting Rifle Powder No. 4759, so far as our experience goes to date, seems to be particularly sensitive to over-ignition. It will not produce good results, as a rule, with the powerful rifle size large primer (No. 1 above), but it does give fine results with the moderate large size primer (No. 2 above) or with the large size pistol primer (No. 3 above) in rifle cartridges.

Nitro-glycerin vs. Nitro-cellulose Powders. There have been many arguments in the past as to whether it is best to use nitroglycerin or nitrocellulose powders. Ten years ago, as a rule, slightly better accuracy could be obtained with the former than with the latter powders, but the former gave slightly more erosion, and in some cases rifle barrels wore out faster when nitroglycerin powders were used. It was sometimes a matter as to whether the shooter wished the very finest accuracy, or the longest accuracy life from his barrel.

Nitroglycerin powders do develop hotter gases than the nitrocellulose types, and where heavy charges are used the accuracy life of the barrel is relatively shorter. However, with moderate charges to develop those velocities that were normal before the introduction of progressive burning powders there was not much difference in the barrel life with the two types.

In many cases erosion has been an unnecessary bugbear with riflemen, and is important only in machine guns or when heavy loads in magnum cartridges or loads to obtain the very highest velocities in high intensity cartridges are used. Erosion tests are not a good indication of the life of an average rifle barrel because, to economize in time and labor, such tests are conducted very rapidly. Usually one hundred rounds are fired as rapidly as possible, after which the barrel is cooled by pouring water through it before proceeding further. After every five hundred rounds an accuracy test is made. Erosion progresses very fast when firing rapidly because of the greater heat. It progresses very much more slowly when a military rifle is fired normally, in quick bursts never to exceed ten rounds, with time for cooling in between, and much of the firing slow fire at one minute per shot. As the hunter fires the rifle, almost always only one or two shots from a cold bore, it is doubtful if much erosion takes place.

Today, however, the picture has changed somewhat. The more modern progressive burning nitrocellulose powders now give just as good accuracy as the older nitroglycerin powders. The constant demand is for more and more velocity. To try to attain these higher velocities with nitroglycerin powders almost always results in fast erosion. It is thought that nitroglycerin powders will gradually cease to be used where the highest velocities are desired, but they still remain excellent propellants for low and moderate velocity loads.

The matter of erosion will be considered in detail in Volume II under Interior Ballistics.

Mixed Foulings. It has been claimed by some rifle shooters that if a barrel be fired and fouled with cartridges containing a certain rifle powder, and then without cleaning it be fired with cartridges containing a radically different powder, that the mixing of the fouling of the two powders may prove highly corrosive to the bore. The writer has never found anything to sustain this contention.

Of course if one load is fired with a chlorate primer there may be enough potassium chloride left in the bore to cause after-corrosion; but such a tendency can be eliminated by water cleaning.

There is one case, however, where foulings should not be mixed. The fouling of all slow burning rifle powders except the most modern is rather sticky and tenacious in its nature. Before the introduction of the new series of du Pont I.M.R. powders this fouling was difficult to remove, and to expedite cleaning most shooters used a brass bristle brush to loosen it up. At that time it was found that if a shooter attempted to fire cartridges loaded with reduced loads of fast burning powder and lead alloy bullets through the bore of a rifle containing this sticky fouling of fully charged cartridges, that the accuracy was very poor with the reduced loads, and much leading occurred. Therefore well informed shooters always cleaned the bores of their rifles thoroughly after firing full charges in them before they attempted to use reduced loads loaded with lead alloy bullets. This procedure is not so important today because the fouling deposited by the new series of I.M.R. powders is neither sticky nor tenacious.

What Constitutes a Good Smokeless Powder? In a cartridge for which the powder is designed the normal or desired velocity should be obtained without excessive pressure and with uniform pressure. With selected components and in a normal barrel and weighed powder charges the velocity should be uniform from shot to shot;

certainly the maximum variation plus and minus, should not be over 15 f.s. These results, that is perfect ignition, should occur when existing good primers of the proper type are used. The powder should produce a minimum of smoke and muzzle flash. The fouling should not be excessive, sticky, or tenacious. A minimum of fouling is desirable. The powder should be consumed, or nearly consumed in the length of barrel for which it was designed. The powder fouling, when mixed with the primer fouling, should not be corrosive. The powder should be non-hygroscopic—that is it should not absorb moisture from the air. The granulation should be such that it can be measured with a permissible degree of accuracy in mechanical measures. It should not generate great heat nor cause excessive erosion. It should not change its characteristics dangerously when exposed for short intervals to maximum high and low climatic temperatures. It should be stable—that is when stored either in cartridges or in bulk under proper conditions it should not change its characteristics for many years.

Precautions. Although the following precautions are contained in works on hand loading it is thought best to mention them here.

When handling powder do not smoke, or have any open flame, such as a kerosene lamp or candle in the same room.

In looking up a charge of a certain powder for a certain cartridge and bullet in the handbook, check it at least twice to see that you have made no mistake. Take no man's word for a certain charge, particularly over the telephone, unless you know that he has checked it twice and is not quoting from memory.

In setting the weights or graduations on balances, scales, or powder measures, check these three times to see that no mistake has been made. It is here that there is the greatest chance for an error.

Immediately after charging the cartridge cases with powder, and before seating the bullets, inspect each cartridge case visually to see that it contains the correct amount of powder. This can be seen by looking into the mouth of the case in a good light, when the powder should be seen filling each case to the correct height.

After the bullets have been seated (or the powder wads in the case of shotgun shells) immediately pour all of the powder out of the measure into the canister, and screw the stopper down tight. Then you can light your pipe.

Never, never, never attempt to seat a primer in a case or cartridge that contains powder.

Storage of Powder. When a canister of smokeless powder is opened the odor of ether will be very noticeable. If the canister be left open, or be kept in a very warm place for a long time these volatiles will evaporate, changing the burning characteristics of the powder. Keep the stoppers of the canisters screwed down tight except when actually loading the powder.

Store the canisters in a fairly dry place where the temperature does not exceed 90 degrees except for very short periods. In the summer an attic is a bad place as it may become excessively hot for long periods. A cellar is a good place provided it is not so damp as to rust the canisters. Powder should always be kept under lock and key to prevent meddling by children or others. Smokeless powder ordinarily stored in canisters is not dangerous in the sense that it might explode in the case of a fire. When only slightly confined it burns slowly instead of exploding. Black powder in a canister will, however, explode dangerously in a fire.

Smokeless powder, either in cartridges or in canisters, that has been stored for a very long period of years under high temperature, as in a hot storehouse in the tropics, may deteriorate to such an extent as to make it worthless and a fire hazard, but it will not explode. Under these conditions the powder may fume and give off smoke. If in cartridges it may "pop" the bullets out of the cases, or it may swell a canister slightly. Then it may ignite spontaneously and cause a fire. Such a deterioration is almost unheard of in the United States, but it has been known to occur in the tropics under conditions of very long and hot storage.

Modern powders do not get more dangerous with age. Rather they tend to get weaker.

When shooting on a very hot summer day do not expose cartridges to the direct rays of the sun where they will get very hot, nor have them in a closed metal box in the sun. The heat would temporarily increase the rate of burning and tend to high pressures and irregular shooting. Keep the cartridges in the shade. For the same reason do not leave a cartridge in an extremely hot rifle for a long time. No trouble has been known to occur when a loaded cartridge is carried in a rifle in the hot sun for a day provided the rifle does not get too hot to handle with the bare hands. After such short exposures to heat the powder returns to its normal condition after it has cooled off, and no damage has been done.

Rifle and Pistol Powders

Within the space available in this work it would be impossible to give a complete description of all rifle and pistol powders. The following short comments on the canister powders that are now available to hand loaders will indicate the different kinds and types and the use for which they are best suited.

The Hercules Rifle and Pistol Powders are the oldest powders now in regular use. They are double base or nitroglycerin powders of the regular burning type.

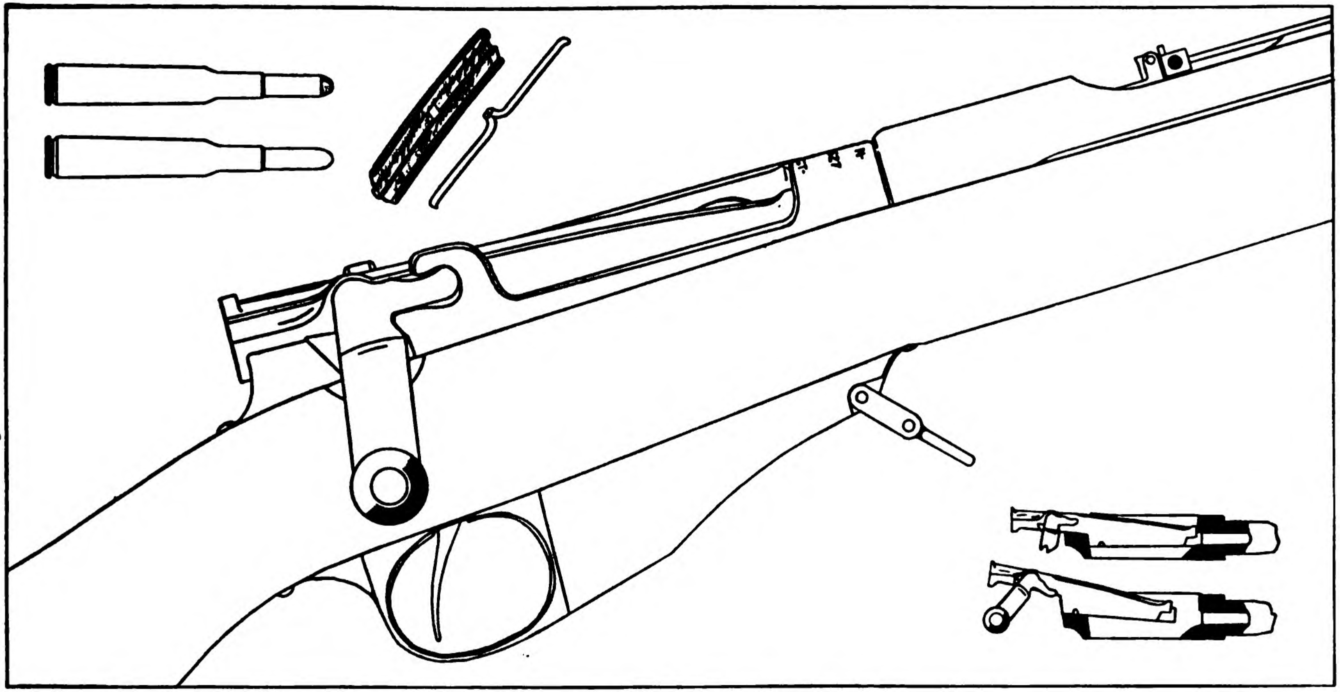

FIGURE 80. THE 6 MM LEE U.S. NAVY RIFLE

A short-lived rifle, adopted by the U.S. Navy around 1895, also marketed in sporting models by the Winchester Company for some years. The rifle was not any too satisfactory, nor was the 6 mm cartridge at the time of its development as it was several years ahead of its time. Drawing above shows the 6 mm Lee cartridge and the details of its clip, it was the first clip loading rifle in any of our services. Lower sketches show details of bolt locking.

Hercules Sharpshooter Powder No. 1. A fine grained dense nitroglycerin powder. The grains are perforated black discs about .08″ in diameter and .015″ thick. This is one of the oldest of our existing rifle powders and was designed for use in the older and larger black powder rifle cartridges, particularly the .45-70 U.S. Government, to replace black powder, and to give about normal black powder velocities at pressures that would be well within the safety limit of black powder rifles. It also performs very well in small and medium bottle-necked cartridges for reduced and moderate loads. It burns at its best at around 30,000 pounds pressure, but it will also burn well in very reduced loads at extremely light pressures, and in some few cases it has been used successfully in loadings that approach 40,000 pounds. In its heavier loadings it should be used only with jacketed bullets as in large charges its gases are very hot and liable to melt the bases of unprotected lead alloy bullets.

Hercules Lightning Powder No. 1. A large grained dense nitroglycerin powder. Black perforated discs about .08″ in diameter and .02″ thick. It is a very flexible powder designed for medium size high power hunting cartridges such as .25-35, .30-30, .32 Special, and .303 Savage. It has also been used successfully in medium loads in cartridges as large as the .30-06 with both full jacketed and gas check bullets, and the writer has also used it with good results in the small .25-20 cartridge. It is somewhat quicker burning than HiVel, but not as fast as Sharpshooter. It burns well at pressures between 20,000 and 50,000 pounds, and requires a low weight of charge to develop its velocities. At one time Hercules made a larger grained Lightning powder known as Lightning No. 2, but it has now been discontinued. If a canister is labeled simply "Hercules Lightning Powder" it contains No. 1.

Hercules Unique Powder. A very fine grained, dense, nitroglycerin powder made in black discs about .06″ diameter and .005″ thick. It is a fast burning powder and has been used chiefly in revolver cartridges, for reduced and midrange loads in military size cartridges, and for standard loads in small cartridges such as the .25-20. It will burn well at pressures from about 6,000 to 35,000 pounds. It permits quite high velocities to be obtained in certain revolver cartridges.

Hercules HiVel Powder No. 2. This is a dense, double base rifle powder with a nitroglycerin content of about fifteen per cent. The black tubular grains have a length of about .085″ and a diameter of .04″. It is the slowest burning of the Hercules double base powders, and was designed for use in the .30-06 and other military cartridges of similar size. It burns well at pressures from 20,000 to 50,000 pounds. For a given velocity it requires a lower weight of charge than any of the regular burning single base powders, and is therefore a very economical powder to use. As a rule it is suitable only for use with metal jacketed bullets. In the .30-06 cartridge it gives considerably better accuracy than any of the single base regular burning powders, and was invariably used in the loading of the super-accurate Palma Match ammunition. The .30-06 International Match Load intended for 300 meter shooting under Olympic rules should also be mentioned. This consisted of the 173 grain M1 boat tailed bullet, the Frankford Arsenal No. 70 primer, and 36.4 grains of HiVel No. 2 powder. The muzzle velocity was 2,200 f.s., and the pressure only 28,500 pounds. This is the most accurate short and mid range load ever developed for the .30-06 rifle and our international teams won many matches with it when competing against the best foreign marksmen and material. HiVel No. 2, although an old powder, is still most excellent when one desires fine accuracy at old standard velocities in the .30-06 cartridge. But when an attempt is made to attain much higher velocities in this and similar cartridges it will be found rather erosive as compared with the most modern single base progressive powders.

Hercules No. 2400 Powder. This is a very fine grained dense type of powder rather similar in composition to HiVel. The black discs have a diameter of about .03" and a thickness of .015-inch. It was designed particularly for the .22 Hornet cartridge, and is the best powder for use in it. It is also suitable for the .25-20 W.C.F. cartridge. It has been used to some extent in cartridges as large as the .30-06 for moderate velocities with very light bullets, and for magnum loads in revolver cartridges. It is very fast in its burning.

Hercules Bullseye Powder No. 2. A fine grained pistol powder of very quick burning type. Black discs about .04" in diameter and .005" thick. This has been a standard pistol and revolver powder for many years, and has proved most excellent for this use. It will burn satisfactorily in a barrel as short as two inches, and does superbly in six and eight inch barrels. It measures very accurately in mechanical powder measures. To burn it correctly in revolver cartridges the bullets should be firmly crimped. The weight required to give normal velocities is extremely small, and it is easily possible to get two charges in one cartridge, which must be guarded against in loading as this would give extremely high and very dangerous pressures. A very small charge of this powder can also be used in cartridges like the .30-40 Krag and .30-06 U.S. with very light bullets or buckshot for gallery loads, but the muzzle of the rifle must be elevated before each shot to settle the powder charge around the primer end of the case so that the powder will ignite properly.

E. I. du Pont de Nemours and Company in recent years have generally confined their manufacture of rifle powders to the single base nitrocellulose type. Starting about 1934 they brought out a new series of single base, progressive burning, flashless Improved Military Rifle Powders in canister lots. These started with number 3031, and so far have been manufactured to include number 4350. They have obsoleted all the older rifle powders which are no longer made. While this series was developed from previous progressive powders, it presents many advantages over the older ones. The powders comprised in it have more flexibility, are exceptionally well ignited by the recent non-corrosive primers, and yet are ignited well by the older types of chlorate primers. In proper charges they give very uniform velocity, much less fouling than previous powders, and the fouling is not sticky so that as a usual thing the brass brush is not necessary for cleaning. When used with recent non-corrosive primers the fouling is absolutely non-corrosive. Incorporated in them is a flash inhibitor which greatly reduces muzzle blast. When copper or gilding metal jacketed bullets are used there is almost an entire absence of any metal fouling in the bore. The erosion is noticeably less for a given charge or velocity than with any previous powders. And finally, with them the American rifleman has been able to obtain a degree of accuracy in many cartridges that has never before been approached. These powders are described below in the order of their burning, beginning with the fastest. All have black, tubular grains.

Du Pont I.M.R. No. 4227 Powder. Length and diameter of grains both about .025-inch. This is the fastest burning of this series of powders, and was designed for the .22 Hornet and .25-20 cartridges, but it has also been found to be excellent for such small cased cartridges as the .32, .38, and .44 W.C.F., in which the old black powder velocities can be exceeded to a considerable extent. For example, in the .44-40 W.C.F. cartridge 29 grains of this powder gives M.V. 1890 f.s. with a 200 grain jacketed bullet in a 24 inch barrel. This load would be quite dangerous in a revolver, but the pressure is well within the safety limit of the Winchester rifle. It is one of the two powders that give fine results in the .22-3000 Lovell, and .22-3000 Donaldson 2-R cartridges, and in these two it is well adapted to quantity loading because the maximum charge does not quite fill the case to the base of the bullet, and being fine grained there is little variation in the charges thrown with mechanical powder measures.

Du Pont I.M.R. No. 4198 Powder. Length of grain about .085", diameter .025-inch. This is a fast burning powder of very excellent flexibility. It was designed primarily for use in such cartridges as the .22 Savage High Power and the .25-35 W.C.F. It has many other uses, however, in developing normal or slightly under normal velocities in much larger cartridges, either with gas-check or metal jacketed bullets. One rather remarkable instance in which it performs well is in the very large .45-90 black powder cartridge in which a velocity of 2215 f.s. can be obtained with the 300 grain metal cased bullet, or 1980 f.s. with the 405 grain metal cased bullet with pressures that are permissible in the old Winchester Model 1886 rifle. The standard black powder velocity in this cartridge with 300 grain bullet was only 1480 f.s. So far as we have determined to date it gives maximum velocity and maximum accuracy in the .22-3000 Donaldson 2-R cartridge with 45 to 55 grain metal cased bullets. The charge to accomplish these results in this cartridge is 17 grains. If this charge be thrown into this case from a mechanical measure it will fill the case to overflowing, so it must be poured in slowly, only a few grains at a time, through a long necked funnel, when the grains will settle compactly against each other and just fill the case to the mouth. Then when the bullet is seated it compresses the powder column about .22-inch. This is one of the very few instances where it is safe to compress a dense rifle powder. This charge should be used only in rifles having strong actions, and both rifle and cases should be in good condition. But when these conditions obtain the charge is safe, reliable, and extremely accurate. No. 4198 is not, however, the powder to use in the larger bottle necked cartridges with fairly heavy bullets when maximum velocities are desired, much more speed and better results being obtained with one of the following slower burning powders.

Du Pont I.M.R. No. 3031 Powder. Length of grain about .085-inch, diameter .035-inch. This is probably the most flexible of any of this series of powders. It gives excellent results in practically all modern bottle necked cartridges from the .25-35 W.C.F. to the .30-06 and .35 Winchester, although with the heavier bullets in the larger of these cartridges it is excelled by the slower burning powders listed below. In some of the larger straight cased cartridges such as the .405 Winchester, and the .45-70 Government, it is the best of all this series.

Du Pont I.M.R. No. 4320 Powder. Length of grain about .043-inch, diameter .035-inch. The writer considers this medium slow burning powder to be the best to use with all but the very heaviest metal cased bullets in the medium and large size bottle necked cartridges. It gives maximum velocities with 55 grain bullets in the .22 Varminter, with 87 grain bullets in the .250-3000 Savage, with 100 grain bullets in the .257 Roberts, with 100 and possibly 130 grain bullets in the .270 Winchester, and with 150 and possibly 180 grain bullets in the .30-06 cartridge. In fact the writer has used it almost exclusively in all these calibers. It has never seemed to the writer that there was much if any difference between it and 4064 powder, except that the grains of 4320 are slightly smaller and the charges thrown from the measure are slightly more uniform in weight. So far as the writer knows the most accurate heavy load for the .220 Swift cartridge is 39 grains of this 4320 powder with the 55 grain Sisk Express, or the 55 grain Wotkyns-Morse 8-S bullet. In the .30-06 at distances beyond 500 yards he has never seen any accuracy equal to that obtained with selected 173 grain M1 boat tailed bullets and 51 grains of this powder and the F.A. No. 70 primer, the muzzle velocity being 2860 f.s.

Du Pont I.M.R. No. 4084 Powder. Length of grain about .085-inch, diameter .036-inch. This powder is quite similar to 4320 described above and probably equal in efficiency in all respects. It is supposed to be slower burning than 4320, and undoubtedly is, but the writer can see little if any difference. Due to the rather large size of its grains the charges should be weighed and not measured when maximum loads are used or extreme accuracy is desired.

Du Pont I.M.R. No. 4350 Powder. Length of grains about .088-inch, diameter .038-inch. This is the slowest burning of this series of powders, and is particularly adapted to obtaining the highest velocities with heavy bullets in the larger military and sporting cartridges, and for the .300 and .375 H. & H. Magnum cartridges. In the larger .25 calibers with 100 and 117 grain bullets, in the .270 Winchester with 150 grain bullets, and in the .30-06 with 220 grain bullets higher velocities can be obtained with it than with any other powder, and still keep within safe pressure limits. It has also been used to some extent in the .22 Varminter and .220 Swift cartridges with heavy bullets, and in some of these instances with most excellent accuracy. When we take a bullet like the 65 grain in the .220 Swift and with this powder speed it up to M.V. 3550 f.s., we get a flatter trajectory over 300 yards and at greater distances than we do with a lighter bullet at far higher velocity. No. 4350 is the newest of this series of powders. It did not appear until just before the present war, and hand loaders have had relatively little experience with it, but it presents many possibilities for future experiment.

Du Pont Sporting Rifle Powder No. 4759. Black tubular grains about .06-inch long and .03-inch diameter. This new powder is not, strictly speaking, included in the above series as it is a sporting and not a military powder. It is made by the extrusion process, and is intended for reduced and mid range loads with lead, gas-check, and metal cased bullets in rifle cartridges only. It is not recommended for use in revolver or pistol cartridges. In general it performs in a similar manner to the old and now obsolete du Pont No. 80 powder, but it will develop higher velocities than No. 80 with lower pressure and less fouling. In moderately light charges which do not nearly fill the powder capacity of the case the position of the charge in the case, whether it be settled in the primer end or up towards the base of the bullet, does not appear to affect the velocity appreciably. With

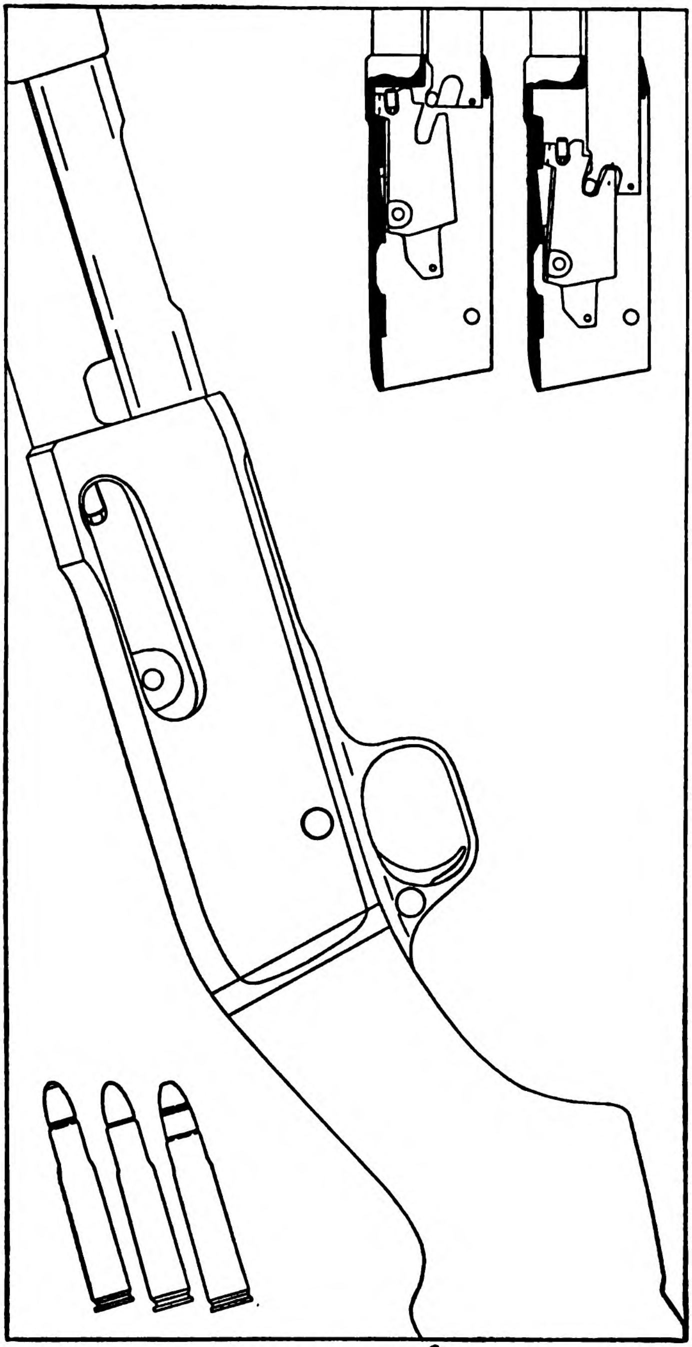

FIGURE 81. THE REMINGTON SLIDE-ACTION SPORTER

A modern version of a slide-action sporting rifle, chambered for the ".30/30 series" of cartridges. A very handy and popular rifle. Upper sketches show three of the cartridges adapted for use in this rifle; the .30 Remington, .32 Remington and .35 Remington cartridges, all rimless cases. Lower sketches show method of locking the action, by means of a single lug close to the cartridge head.

light and moderate weight bullets in most of the bottle necked cartridges from the .22-3000 Lovell and the 2-R to the .30-06 and the .348 Winchester it gives exceptionally fine accuracy with moderate velocities. In the .22 Varminter cartridge, for example, a charge of 20 grains will give M.V. 2820 f.s. with 50 grain bullet, and most remarkable accuracy, and the erosion is probably nil, so one could fire hundreds of rounds without decreasing the life of his barrel. A similar load will work finely in the .220 Swift, which cartridge as a rule does not handle reduced loads well. The writer has also found this powder to be superior to all others for moderate loads with gas check bullets in the .257 Roberts, .270 Winchester, and .30-06 cartridges. Two weeks before this was written, with the 169 grain Bond hollow point, gas check bullet Number 311870, and 18 grains of 4750 powder and Winchester No. 115 primer in a light .30-06 sporting rifle (M.V. 1430 f.s.) he obtained a 5-shot group at 100 yards having an extreme spread of only .42-inch, and followed that by another 5-shot group which increased the spread to only 1.10-inches for the ten shots. The bullet was sized to .311-inch, seated to just touch the lands, and the insides of the case necks were polished.

Du Pont Pistol Powder No. 5. This is a fine grained nitrocellulose powder intended for use in pistol and revolver cartridges. The grains are gray in color and disc shaped, measuring about .035-inch in diameter and .01-inch thick. It has been used to a great extent for the service loading of the .45 Colt Auto-cartridge, and is also excellent for all other pistol and revolver cartridges in loads that produce standard velocities. It burns well at pressures from 6,000 to 15,000 pounds. Above 15,000 pounds pressure it is liable to become erratic and perhaps dangerous, and is therefore not adapted to obtaining high velocities in hand gun cartridges.

Du Pont Pistol Powder No. 6. This is a multi-base quick burning powder for use in revolver and pistol cartridges. It is slightly faster burning than No. 5, and requires a slightly smaller weight of charge, but slightly more bulk to produce the same velocities. Some hand loaders are of the opinion that it gives slightly better accuracy than No. 5.

Western Cartridge Company "Ball" Powder. In 1941 the Western Cartridge Company at their powder mills began the manufacture of a new type of powder known as "Ball" powder from the small spherical pellets in which it is formed. This nitrocellulose powder is manufactured by an entirely new process which bids fair to revolutionize small arms powder manufacture. Particularly by this process powder can be produced in large quantities in only three days, whereas the other common processes of manufacture of smokeless powder require about fifteen days.

Ball powder was developed by the Technical Department of the

Western Cartridge Company headed by Dr. Fred Olsen, who, before he joined the Western organization, was chemical co-ordinator of the Ordnance Department of the Army stationed at Picatinny Arsenal. Until its invention smokeless powder was handled dry during many of its manufacturing processes, and was reduced to pellets, tubes, or grains mechanically by forcing the nitrocellulose "dough" through a "macaroni" machine and chopping the strands into grains of the desired sizes.

In the manufacture of ball powder the nitrocellulose is immersed in ten times its bulk in water, and reduced to a pure liquid by various chemicals including ethyl acetate. Being lighter than water, the gelatinized nitrocellulose rises to the top of the water as a creamy lacquer. By stirring the mixture the lacquer acts in the water very much as olive oil does in vinegar, and forms into globules—the tiny ball powder pellets. Other chemicals are added to the mixture to prevent the balls from reuniting with each other when the stirring is stopped. By controlling the speed of stirring the powder balls can be made into a great variety of sizes suitable for a wide range of cartridges.

One important advantage of this method of manufacture, in addition to its speed, is that it only requires a plant and facilities than can be assembled anywhere by local boilermakers. One plant for the making of ball powder was completed in England in four months.

Ball powder has been used almost exclusively for loading the Cartridge, Carbine, Caliber .30, M1 used in the Winchester Carbine adopted by the Army, and literally billions of cartridges so loaded have been manufactured. Up to the present writing the entire production of ball powder has gone into military ammunition, and it has not as yet been offered to individuals in canister lots.

Rim Fire Powders. A number of very small grained smokeless powders are manufactured exclusively for use in rim fire cartridges, particularly those of .22 caliber. These powders are suitable for this one use only, and are sold exclusively to the loading companies. They have never been offered in canister lots as hand loading or reloading of rim fire cartridges is impossible for the average individual. These smokeless powders, together with non-corrosive priming, have completely solved all fouling and corrosion difficulties in rim fire ammunition.

Another rim fire powder, much used in the past in .22 rim-fire cartridges, and still loaded by Winchester in their super-accurate E.Z.X.S. .22 Long Rifle match ammunition is *Lesmok*. It is a semi-smokeless powder consisting of 85 per cent black powder and 15 per cent gun-cotton. It is extremely accurate in .22 caliber cartridges and due to that quality has made an enviable reputation. It has, however, two disadvantages. Its fouling is not strictly non-corrosive, and it is extremely dangerous to manufacture. The super-fine accuracy that it gives is much appreciated in competitive small bore rifle shooting, but manufacturing difficulties may lead to its obsolescence at some future date.

Shotgun Powders

Powders designed for use in shotgun shells must burn at a much more rapid rate that rifle powders because of the nature of the projectile and the gun. The individual pellets of shot are smaller than the bore of the gun, and they and the wads are not suited by nature or composition to form a good gas seal against the inside of the barrel. The powder must therefore impart its energy to the composite projectile as quickly as practical without the elements of time and gas pressure being great enough to burst through the wad seal into the shot charge. Also the peak pressure must be exerted quickly near the breech of the shotgun where the barrel walls are relatively thick and strong, and must then drop considerably so it will not burst the thinner walls of the forward portion of the barrel. The burning rate must also be carefully adjusted so that it will produce the required velocity to the shot charge, according to the weight of the shot, size of the pellets, and bore of the gun. Too high velocity gives poor patterns and prohibitive recoil; while too low velocity gives poor penetration and killing power, and increases the lead necessary to hit flying birds.

The first propellant shotgun powder was **Black Powder.** It was followed by **Bulk Smokeless Powder,** then by **Dense Smokeless,** and finally by **Dense Progressive Burning Powder.**

Black Powder, as we now look back on it, was rather unsatisfactory in that its burning rate could only be varied within the narrow limits of the grain size and to some extent the mechanical composition of the powder.

Bulk Smokeless Powders met with immediate favor from the explosive industry because the burning characteristics could be more carefully controlled over a wider range of burning speeds. These early powders were designated as "bulk" powders because the same volume of the powder developed approximately the same amount of energy as did black powders. That is to say, if a certain shell took a charge of three drams of black powder, the same measure that was used to measure each charge of black powder could also be used to measure a three dram charge of the bulk smokeless powder, and each charge would give approximately the same velocity.

Vast quantities of bulk shotgun powders have been used in the past for the factory loading of shotgun shells, but of late years they have gone out of use almost entirely for factory loading. These bulk powders consisted essentially of incompletely colloided nitrocellulose fibers, the grains being somewhat irregular in shape and rather soft and porous. Usually they are of a yellow color, but a dye is sometimes used to give them a distinctive hue. The objection to these powders is that their moisture content, and hence rate of burning, is considerably influenced by changes in temperature and humidity. The paper shotgun shells are not hermetically sealed, therefore the powders gave varying results according to climatic conditions.

The existing bulk powders are known as du Pont Shotgun Smokeless and Hercules E.C. Shotgun. As the loading of them is very simple and safe, they are well adapted to hand loading by individuals, but they cannot quite equal the performance of modern powders, particularly the more recent powders that are furnished to the loading companies to meet their exact specifications.

Dense Powders. As an improvement over the bulk powders, the powder companies developed a new type of completely colloided powders which are called "dense" powders because equivalent ballistics are obtained with about one-third less of the volume required for black and bulk powders. As a rule these powders are loaded in high base shells so that the powder will occupy the proper amount of space in the shell to make the loaded column of powder, wads, and shot come to the specified length or height in order that the loaded shell shall be of the right overall length for the standard chamber of the gun. Dense powders, as distinguished from dense progressive burning powders, are generally used to give standard field, skeet, and trap velocities, and are not well suited to developing higher velocities with heavy shot charges.

Dense Progressive Burning Powders are designed to give slightly higher velocities with slightly larger charges of shot than can be obtained satisfactorily with bulk or dense powders. Their rate of burning is such that they give more of a push than a blow to the charge of shot, with a little longer sustained pressure peak. For a given velocity they develop lower pressures than other powders, therefore a slightly increased charge of shot can be used without the pressure being excessive. And likewise the push on the shot being more gradual, a slightly higher velocity can be given to the shot without opening up the pattern. They are not flexible powders, and burn correctly only when the loading conditions are quite exact. If they were used to give a lighter charge of shot a much higher velocity the patterns would probably be very ragged. The term "High Velocity" or "Super Speed" in connection with these progressive burning powders is perhaps slightly misleading because the velocities are actually only about 15 to 70 feet per second higher than the field, skeet, and trap velocities obtained with bulk and dense powders.

It is possible to control the manufacture of these dense and progressive burning powders to give the exact burning speeds required for any combination of components of primer, shell, wads, shot, and crimp, and it is now the general custom of the powder makers to "tailor make" each lot of powder to a specific gauge, load, shell, and shot size as required by the loading companies.

While the powder manufacturer is able to modify the burning rate of modern dense powders by varying the size or shape of the grains or the chemical composition of the mixture from which the powder is produced, the ballistic properties of the loaded round can also be altered by such seemingly unimportant details as the size and density of the shot pellets, the number and toughness of the wads, the strength of the crimp, the rigidity of the material from which the shell itself is made, or the ductility of the metal base of the shell, to say nothing of the burning characteristics of the primer.

The effect of each of these details on the ballistics is discussed in Volume II of this work under Shotgun Ballistics. It is the present practice for the loading companies to manufacture the components of the loaded round, designing each item in a manner which they feel will best perform its functions. The cumulative ballistic effect of modification of components is offset by modifying the burning characteristics of the powder used for loading in order to give the maximum performance in each of the great variety of shotgun gauges and loads from the small and popular .410 up to the new magnum loads for the 12 and 10 gauge shotguns. Shooters of today demand the highest possible performance as to velocity, pattern, pressure, and killing effect, whether for use in the field for game or against clay birds for trap or skeet shooting.

It is no longer possible for the amateur or expert to cut open a shot shell and tell by visual inspection the grade of a particular brand of powder with which the shell was loaded. It is an easy matter, however, to distinguish the various brands from each other since they differ materially in granulation and grain size. Hercules Red Dot Powder, for example, is made up of small black circular discs of regular shape with a liberal sprinkling of red grains. Du Pont MX Powder is of irregular grains, shaped like small hard pellets which are dark in color. Western Minimax grains are hard and spherical, and vary in size although each grain is in the form of a near-perfect ball.

The special "tailor made" powders are not sold to the public who would not be able to control their burning with the exact primer, shell, wads, wad pressure, weight and size of shot, and crimp that each requires to perform as designed. The powder companies do, however, sell canister lots of certain shotgun powders to hand loaders who can utilize them safely provided the simple directions are carefully followed. These powders are listed and described below, and the exact amount of each to use in each gauge of shell, and with varying weights of shot are given in the Ideal Handbook before referred to. Besides loading just the right amount of these powders, no more and no less, it is also necessary that the over-powder wads be forced down in the shell with the specified amount of pressure in order that the powder shall burn correctly.

Du Pont Smokeless Shotgun Powder. The oldest smokeless powder now in common use. A true bulk powder that can be loaded dram for dram with black powder. The grains are yellow. Its best burning pressure is around 9,000 pounds. It is noted for giving rather light recoil, perhaps because its recoil, dram for dram, is usually compared with that of black powder. It should be loaded in low base cases because of the space it takes up. The pressure on the wads should be about thirty to fifty pounds. It is a safe powder for the amateur to use.

Hercules E.C. Shotgun Powder. This powder is almost identical with du Pont Smokeless Shotgun above, and the same remarks will apply. The grains are an orange color.

Du Pont M.X. Shotgun Powder. This is a dense, progressive burning powder. The grains are in the shape of irregular, hard, greenish-black pellets. It should be loaded in high base shells, and the setting of the powder measure should be checked with scales. Dip or scoop measures should not be used. Also this powder should not be used for loading shells for older guns with twist or Damascus barrels. The loading pressures should be: 10 gauge, 86 pounds; 12 gauge, 78 pounds; 16 gauge, 63 pounds; 20 gauge, 55 pounds; 28 gauge, 43 pounds; .410 bore, 25 pounds.

Hercules Red Dot Shotgun Powder. A dense, progressive burning powder made in disc shaped grains about .06-inch in diameter and .003-inch thick. The grains are generally black, but some show red dots, hence the name. Low base shells should be used for the heavier loads, but some of the lighter charges can be loaded in high base shells. The setting of the powder measure should be checked on scales, and dip and scoop measures should not be used. Do not use in guns having twist or Damascus barrels. The loading pressures are: 10 and 12 gauge, 78 pounds; 16 to 28 gauge, 62 pounds; .410 bore, 64 pounds.

Hercules Infallible Shotgun Powder. This is a dense powder intended for field, trap, and skeet loads, and not for high velocity heavy shot loads. The setting of the powder measure should be very carefully checked by scales, and it should not be loaded by dip or scoop measures. High base shells should be used. Do not compress the powder heavily; twenty-five pounds pressure is ample.

Du Pont Oval Shotgun Powder. This is a dense, progressive burning powder for high velocity heavy loads only. It does not burn well unless the full recommended charges be used. Check the powder measure setting with scales, and do not use dip or scoop measures. Do not use in old guns having twist or Damascus barrels. The loading pressure should be the same as for du Pont M.X. powder above.

Hercules Herco Shotgun Powder. The remarks above for du Pont Oval powder will apply equally with this powder, except that the loading pressures should be the same as for Hercules Red Dot powder. It should be loaded in low base shells.

CHAPTER XI

Ammunition

Bullets

FROM a ballistic point of view the bullet is the most important ammunition component. As to its shape and sectional density depends its ability to overcome air resistance and fly to a considerable distance. On its perfection of form depends that gyroscopic stability on which accuracy of flight is based. On its weight, construction,

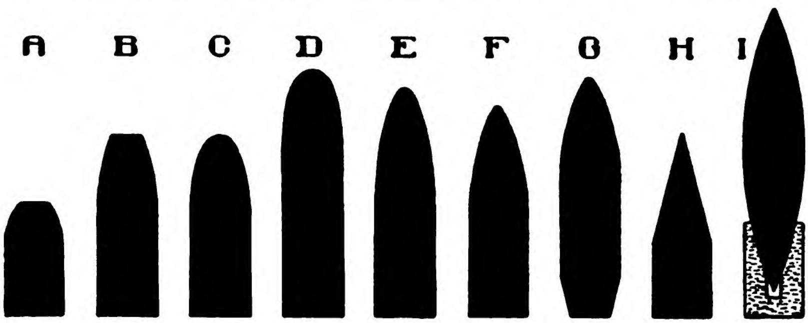

Figure 82. Typical Bullet Forms

All bullets have been drawn to same caliber in order to make the comparison of forms easier.

A—Short, flat point. B—Medium, flat point. C—Medium, round nose. D—Long, round nose. E—Medium long, sharp point. F—Medium, sharp point. G—Sharp point, boat-tailed. H—Pencil point, Wotkyns-Morse 8S. I—Stream line with sabot.

When the stream-lined bullet is fired the rear point of the bullet sets back very tight into the sabot, the hollow in the sabot permitting this wedging setback. The bullet is thus so tight in the sabot that it revolves with the sabot as though the two were a solid bullet. But as soon as the bullet leaves the bore the pressure is released and the sabot springs back and its sides spring outward, releasing the bullet cleanly from the sabot. The bullet, being heavier, continues on its course, while the sabot soon falls to the ground, although the sabot itself forms a dangerous missile as it will sometimes fly several hundred yards.

and velocity depend its ability to cause damage or its killing power.

Bullets are classified in a number of ways. As to their shape they are divided roughly into spherical and conical, and the latter into short, medium, long, sharp pointed, round pointed, hollow pointed, flat base, boat tailed, and stream lined. See Figure 82. As to their composition and construction they may be classified into lead alloy with or without copper gas checks, and metal cased, and the latter into full jacketed, expanding, soft point, hollow point, armor-piercing, tracer and incendiary. All of these types have their own particular spheres of usefulness.

Spherical or round bullets, except in their application to shotguns, are almost obsolete. In flight a round bullet meets so much air resistance, and is so poorly shaped to overcome that resistance that both its accurate range and its extreme range are very short. Our early flint lock, muzzle-loading Pennsylvania rifles which fired round lead bullets exclusively, did not have sustained accuracy sufficient to surely hit a man or deer beyond about 150 to 200 yards, although they would shoot almost into one hole at 50 yards, and when the barrel of the rifle was elevated to a high angle the bullet would scarcely carry a thousand yards. Round bullets were made of lead almost exclusively, and their present use in rifles and pistols is confined to short range gallery loads. All modern bullets are conical, that is more or less cylindrical in shape, their length being greater than their diameter, and they are usually more or less pointed in front, and sometimes pointed or tapered at the rear.

Lead Bullets

All bullets for rifles and pistols were formerly made of lead, usually alloyed with a small percentage of tin or antimony, and in older days quick-silver (mercury), to harden them. Today as a usual thing only the bullets for rim fire cartridges and for center fire revolver cartridges are made wholly of a lead alloy, although this metal is also almost universally employed for the cores of metal cased bullets. Lead is the only metal which will economically give bullets the weight which is necessary within the limitation of their size.

Lead bullets are usually made by casting them in a bullet mould. See Figure 83. The lead is first melted in a pot, and is then alloyed with the proper proportions of tin and antimony. The molten alloy is then poured into the pre-heated mould with a special dipper. It hardens therein in a few seconds, at which time the mould is opened, and the bullet drops out onto a soft material so it will not be injured by its fall. The exact technique of bullet casting is given in the Ideal Handbook already referred to. Some bullet moulds are constructed with six or more cavities for quantity production.

Some large ammunition factories extrude the lead alloy into a wire under heavy pressure. The wire is then cut into slugs of the proper length, and these slugs are formed in dies under pressure to the exact form and size for the completed bullets.

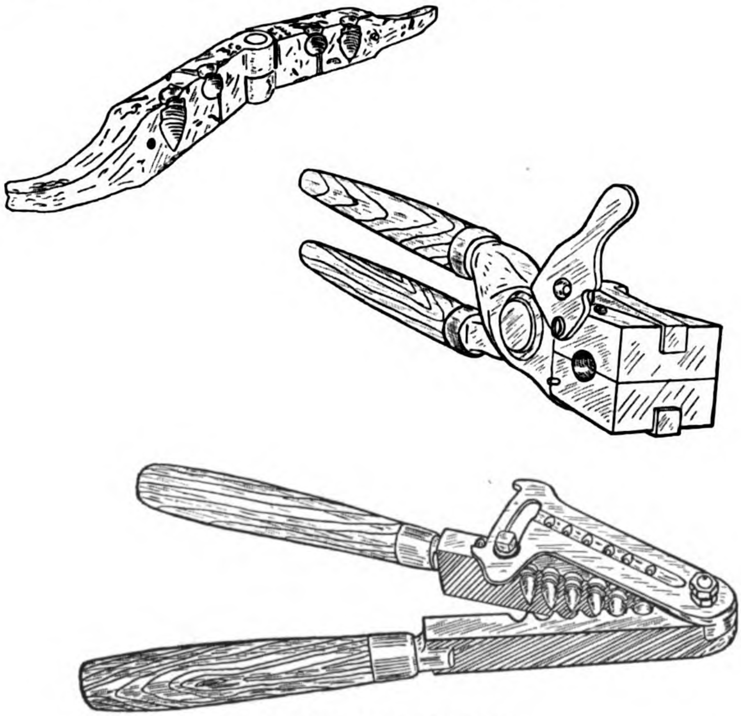

FIGURE 83. BULLET MOULDS

Top sketch is an old "Colts Patent" mould, as furnished with the early cap-and-ball Colt revolver. Obviously this specimen has seen much use; somebody having "vented" the cavity for casting round balls in order that the air might escape and a more perfect ball result.

Middle is a modern Ideal mould, as made and sold today.

Bottom is what is known as an "Armory" mould, for the casting of one certain bullet in quantities. These are made to cast from four to ten bullets at a time, generally all bored for the same bullet.

After the bullets have been cast or formed they are put through a sizing and lubricating press which sizes them accurately to the exact diameter required, and presses lubricating grease into their grooves. Or the mould may be made to cast the bullet the exact size, and they are then stood base down in a pan, and melted lubricant is poured around them. When the lubricant cools they are then cut out of the "cake" by means of a headless cartridge case which scrapes off all excess lubricant except that in the grooves of the bullet. The lead bullet is then ready for loading into the cartridge. Cartridge cases intended for lead bullets are very slightly bevelled or chamfered at the mouth so that when the bullet is seated the mouth of the case will not scrape or cut the sides of the relatively soft bullet. Figure 84 shows a number of typical lead alloy bullets, both old and modern.

As will be noticed from the illustrations, lead bullets are usually formed with a number of grooves or cannelures formed on their sides, which are filled with a heavy lubricating grease or wax. Such lubricant is necessary with lead bullets to prevent particles of lead from adhering to the surface of the bore and "leading the barrel."

The exact diameter of the bullet is quite important. In the days of black powder bullets were usually made the exact diameter of the bore—that is groove diameter—or slightly smaller, down to as much as .005-inch below groove diameter. The exact size was determined by experiment and was predicated on shooting the rifle dirty, that is not cleaning the bore between shots. With black powder, when the bore is not cleaned between shots (on all but the very dampest days) it fouls badly, and the fouling forms a hard cake in the bore over which the bullet has to pass. If the bullet was too large it was badly deformed by this cake, and did not shoot with much resemblance of accuracy. If smaller it was not so much deformed, and the average accuracy was better. In black powder days, using the best rifles, and shooting with the bullets seated in the cartridge case (i.e.

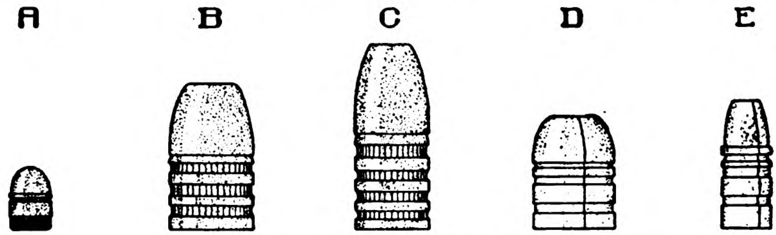

FIGURE 84. TYPES OF LEAD BULLETS

Lead bullets are sold separately and supplied in standard factory loaded ammunition by the various loading companies, but they can also readily be cast by hand by individuals. Factory lead bullets are usually made from slugs cut from presized lead coils, and the slugs then swaged into shape and caliber under heavy pressure. Lubrication grooves, or cannelures, are then rolled into the bullets by means of knurling heads, and these heads form distinctive patterns around the bullet.

A factory made lead bullet can generally always be told by its having knurled grooves rolled into it, and further by the fact that its base is often slightly cupped by the action of having been forced into the forming die. Also, factory bullets are generally tumbled in a rumbling barrel after manufacture, and this tumbling process dulls their color greatly.

ordinary breech loading) and not cleaning the bore between shots; it was quite common to have the first five of ten shots make a group with an extreme spread of four or five inches at 100 yards. Then the fouling began to accumulate and cake seriously in the bore, and soon it might take a foot circle to hold five or ten consecutive shots.

The fouling of modern smokeless powders is much less in bulk than that of black powder, and it does not cake in the bore in the same manner, so that the bore remains in nearly uniform condition from shot to shot, and offers little or no increased resistance to the passage of successive bullets. Thus when smokeless powder is used it has been found that lead bullets should measure exactly the groove diameter of the bore, or may often with advantage be .001 to .005-inch larger than groove diameter. If the bullet be smaller than groove diameter the hot powder gases are liable to rush past the bullet, between the bullet and the sides of the bore, before the bullet has upset to completely fill the bore, and melt streaks up the sides of the bullet, thus deforming it so it does not shoot accurately. With large bullets the neck of the case is sized so that the inside of the neck is the exact diameter of the bullet.

It used to be thought that the quick gas generation by black powder gave a severe blow to the base of the bullet and thus at once upset the bullet to fill the bore completely and hence bullets for use with black powder could be made slightly smaller than groove diameter because they would at once upset to that diameter anyhow. That smokeless powder gave more of a shove than a blow, did not upset the bullet so completely, and hence bullets for use with smokeless powder had to be larger to shut off all escape of gas past them at the start.

This contention is hardly substantiated in view of our present knowledge of what happens when the rifle is fired. When gas pressure, either black or smokeless, begins to rise, first of all the cartridge case, including its neck, expands to the full limit of the cham-

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Individual make of hand cast bullets can always be told by the vertical line left in the opposite sides of each bullet where the halves of the mould met, also by the fact that they carry plain grooves (not knurled) cast into the bullet as it was moulded, and by the further fact that these cast bullets always have a shiny and much brighter look than the dull factory lead bullet. See D and E.

A—The 30 grain .22 Short lead bullet as turned out by an ammunition company.

B—The 300 grain .45/60 Winchester rifle bullet, factory made.

C—The 255 grain .38/55 lead bullet, factory made.

D—A .44 caliber revolver bullet, cast by individual shooter, in a bullet mould.

E—The 86 grain .25/20 rifle bullet, as hand cast.

ber. The bullet, being heavy and having considerable inertia, has not started forward appreciably at this instant, and some gas rushes in between the expanded case neck and the sides of the bullet, and a small portion of this gas leaks past the bullet. (In a spark photograph taken of the muzzle of a rifle at the instant of firing this slight puff of gas which has leaked past the bullet can be seen emerging from the bore *ahead* of the bullet.) The bullet, more or less surrounded by gas, then starts forward into the leade and up the bore. As the bullet encounters the resistance of the lands the gas pressure on its flat base is sufficient to then upset the bullet completely to fill the bore and shut off all, or nearly all further escape of gas past it. It is now thought that the superior accuracy obtained with full size or slightly oversized lead bullets and smokeless powder is due to the bullet occupying a larger portion of the space between case neck and bullet sides so there is not so much room for gas to rush in initially between neck and bullet, and because its larger size insures that the bullet will seal the bore quicker. That is the larger bullet passes from the case, through the leade, into the rifling with minimum deformity. At any rate, under best conditions, groups with an extreme spread of 1.5 to 2.0-inches at 100 yards are quite common with slightly oversized lead bullets and smokeless powder, and such groups can be continued almost indefinitely without cleaning the bore. With black powder, shooting bullets from the case, and counting only those shots before the powder fouling begins to cake, or cleaning the bore after every shot, it was extremely seldom that a group smaller than four inches was obtained with lubricated lead bullets.

The **hardness of the lead bullet**, that is the proportion of lead or antimony or both used in alloying it, is important. In muzzle loading days bullets were usually cast of pure lead, although occasionally a rifleman would use a small amount of tin or in some cases quicksilver (mercury) to harden the bullet to give it deeper penetration. But today almost all lead bullets are alloyed more or less. In the breech loading black powder days the alloy of bullets was almost a fetish with our more skillful riflemen. They found that the least change in amount of tin used in casting the bullets often made all the difference between fine and mediocre accuracy, probably because of its relationship to getting the bullet into the rifling with the minimum of deformity. Today, as a rule, the higher the velocity with which the bullet is fired, or the quicker the twist of the rifling, the harder must be the alloy to prevent the bullet from slightly "skidding" when it enters the rifling, with consequent deformation. Common alloys in black powder days were one part by weight of tin to twenty parts of lead, or one tin to sixteen lead. Such alloys are still common practice with revolver bullets. With higher velocities and smokeless powder, and in the quicker twists employed in modern rifles, much harder alloys are used. Also it is now rather common practice to alloy with antimony instead of tin as antimony is cheaper and has a higher melting point than tin, and so the antimony alloy is less liable to be fused by the hot smokeless gases. Alloys of one part antimony to twenty lead, or one to ten are commonly used by the factories. Some tin is, however, desirable when bullets are cast in moulds as it causes the bullets to run smoother through the mould, and a typical modern alloy used by riflemen for casting bullets to be fired from high velocity rifles with quick twist of rifling is 90 parts of lead, 5 of tin, and 5 of antimony, all by weight.

Referring again to Figure 84 showing some typical lead bullets. The manufacturers of reloading tools who furnish the bullet moulds, usually designate their moulds and bullets by a number of six figures. The first three figures are usually the diameter in thousandths of an inch to which that bullet is intended to be sized after it is cast. Usually the mould will cast its bullets several thousandths of an inch larger than this diameter so they can be sized down exactly in the sizing and lubricating tool. The last two or three figures sometimes indicate the weight of the bullet in grains, or sometimes are merely arbitrary figures assigned for identification. Different manufacturers use different series of numbers, so it is the usual practice to precede the number by the name of the maker, as "Ideal 308241."

Flat point bullets were a necessity in most repeating rifles having tubular magazines, and still are. In such a magazine the nose of one bullet presses against the primer of the cartridge forward of it in the magazine. If the bullets were made with sharp points the point of the bullet might puncture the primer of the cartridge ahead of it when the rifle recoiled, and cause that cartridge to explode in the magazine. Also, particularly with lead bullets, a flat point bullet will expand more than a round nose or pointed bullet when it strikes a substance, and hence these flat point bullets expanded better on game and killed better.

3118 (Figure 85) for the .32-20 black powder cartridge and weighing about 115 grains is quite typical of the early, short, light weight, flat point bullets for use in low velocity, repeating, tubular magazine rifles having a slow twist of rifling, such as the .32-20, .38-40, and .44-40. These short cartridges required short bullets to make them short in overall length. Also the short cases would not contain enough powder to propel a heavier, longer bullet at the required velocity. Such short bullets, fired at low velocities, and in slow twists, were often cast of pure lead.

319247 is the old standard bullet for the .32-40 black powder cartridge, and weighs 165 grains. The standard muzzle velocity with

40 grains of black powder was 1,385 f.s. in a 30 inch barrel. The bullet was cast one part of tin to sixteen parts of lead, the rifling being one turn in sixteen inches. The bullet was sized to .319-inch, while the groove diameter of most .32-40 barrels was about .3205-inch. In other words we here have a bullet smaller than groove diameter, predicated on shooting black powder without cleaning the bore as previously discussed. The resulting accuracy in this, and similar cases, was nothing to set the world afire. The .32-40 rifle made its reputation for accuracy not with this standard bullet and black powder load, but with special bullets seated in the bore ahead of the case, or muzzle loaded bullets, or a larger bullet like 321232 with smokeless powder. This standard bullet in the standard cartridge did, however, kill deer quite well.

Medium long bullets like the above 319247, or still longer bullets required a quick twist of rifling to rotate them fast so that they would fly with point to the front. Rifles with slower twists such as the .32-20 would not shoot these medium long bullets accurately.

31949 is a sharp pointed bullet for the .32-40 to be used for shooting birds or small animals without destroying meat or pelts, which a flat pointed bullet like 319247 would usually do. Moulds could be furnished to cast the bullet in any of the weights shown.

457125 is the standard 500 grain bullet for the old .45-70 U.S. Government black powder cartridge used in the Springfield Model 1873 rifle. With 70 grains of black powder the muzzle velocity was 1,179 f.s., and when shooting at 200 yards the trajectory height at 100 yards was 14.36 inches. The alloy was 1 to 16, tin and lead.

456122 is the famous hollow point Gould express bullet for the .45-70 and other .45 caliber cartridges. It weighed 330 grains and was much preferred by deer hunters because it had a flatter trajectory and lighter recoil than heavier bullets like 457125. In the .45-70 with 70 grains of black powder the velocity was 1338 f.s. and the 200 yard trajectory height was 12.66 inches. This is one of a number of so called "express" bullets that were made with hollow points to cause them to expand so as to give greater killing power, and to lighten them so they could be fired with a higher velocity and flatter trajectory. This was a very popular bullet for deer in black powder days, but it did not have sufficient penetration for elk and grizzly bear because of its light weight and the excessive expansion caused by the hollow point.

308206 weighing 125 grains was designed by Horace Kephart, a prominent rifleman, woodsman, and historian of forty years ago. It was the first lead bullet to be used successfully in small bore, high power rifles having deep rifling and a quick twist. Mr. Kephart's idea in designing it was to have two wide bands which would surely hold the rifling without skidding, a wide lubricating groove between the two bands, and also a lubricating groove ahead of the first band. The ogive or curve of point of the bullet rode on top of the lands, and the grease in the first groove lubricated the bore before any lead cut into the rifling. The square edge of the first band also acted as a dirt scraper, and scraped the fouling out of the bore ahead of the bullet. These principles have been used in almost all successful lead bullets that followed this one. Mr. Kephart used this bullet, sized to .311-inch, most successfully in his .30-40 Winchester and Remington rifles with a charge of low pressure smokeless powder to give a muzzle velocity of about 1,300 f.s., it being designed for small game shooting and economical target practice up to 200 yards. The writer also used this bullet with good results in his .30-30 and .30-40 rifles between 1901 and 1906.

308241 was designed as an improvement over 308206, to be used for the same purpose in all .30 caliber rifles. It is still being used, and has proved very popular among target riflemen and for gallery use in National Guard armories. Loaded with low pressure smokeless powder to give about M.V. 1300 f.s., it will often group in as small as 2 inches in ordinary military rifles at 100 yards, and has the reputation of "shooting into four inches all day long."

321232 was designed specially for the .32 Winchester Special and .32-40 rifles, and embodies some of the ideas of the Kephart bullet. It is sized to .321-inch and is therefore a tight fit in these bores which usually have a groove diameter of about .3205-inch. Seated to project far enough out of the case so that the first band touches the lands, without crimp, and at about M.V. 1,400 f.s., it has been the most successful bullet to be used seated in the case in these .32 caliber rifles, far excelling 319247. It should be cast of 1 to 10, tin and lead, and weighs about 170 grains.

308403 is a 172 grain bullet designed by Mr. H. M. Pope for fine target shooting at 100 yards in .30 caliber military rifles. The mould was made to cast the bullet exact size and the bullet was not intended to be sized. The diameter of the first four bands from the point was .301-inch to ride snugly on top of the lands, fifth band .303-inch, sixth band .305-inch, and the last broad base band was .315-inch. The bullet was seated in the expanded case with the fingers, the mouth of the case extending only half way up the base band. Almost the entire bullet was therefore seated in the rifling ahead of the case, the bullet being centered in the bore by the tops of the lands, and only cutting into the lands very slightly before discharge. The propellant was 12 to 15 grains of du Pont No. 80 powder in the .30-06 case. Probably today 14 grains of du Pont No. 4759 powder would give even better results. This is probably the most accurate unprotected base lead bullet ever used in .30 caliber rifles. The indoor Metropolitan Championship in New York City,

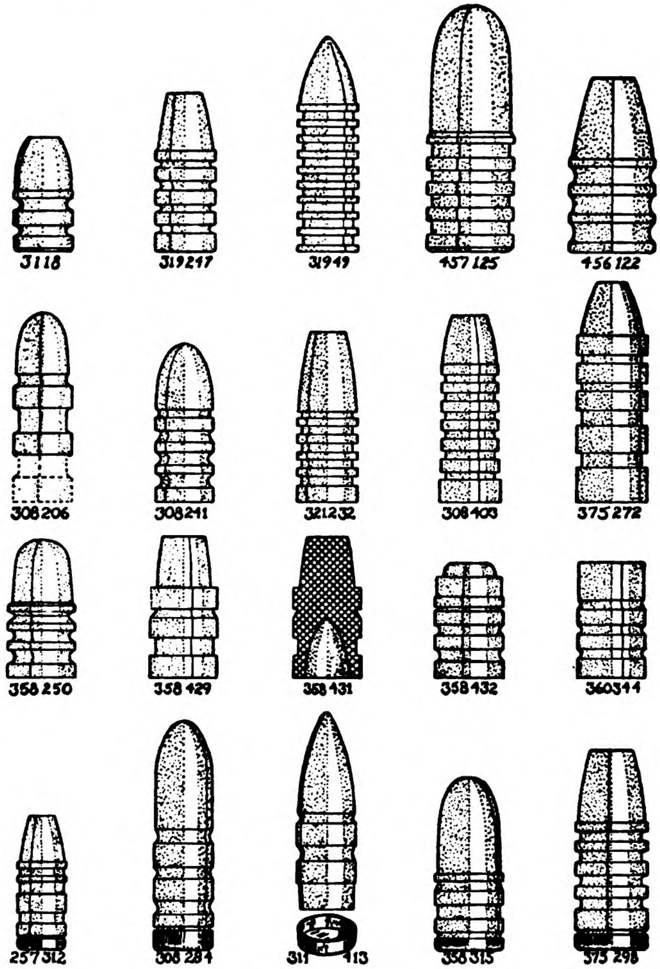

FIGURE 85. REPRESENTATIVE LEAD BULLETS
Top Row—Older designs for black powder rifles.
Second Row—Modern bullets for smokeless powder.
Third Row—Lead bullets for revolvers.
Bottom Row—Gas Check bullets for higher velocities.

calling for 100 shots at 100 yards has been won with it a number of times. Of course it is purely a target bullet, as it is so lightly seated in the case, with all the lubricating grooves exposed, that it would be quite impractical in the field.

375272 was designed by Dr. W. G. Hudson for 200 yard Schuetzen target shooting in .38-55 rifles. It was designed particularly to get away from the recoil of black powder and the inconvenience of muzzle loading, and yet obtain fine accuracy. The design is similar in principle to the Pope bullet above. The mould cast the bullet the exact size to be used without resizing. The three upper bands measure .372-inch to ride on the top of the lands and center the bullet in the bore, and the two base bands were cast .382-inch to fit tightly to the bottom of the grooves. The bullet weighed 304 grains. The bore was specially throated ahead of the chamber to be an exact push fit for the bullet, and the bullet, for each shot, was seated ahead of the case with a schuetzen bullet seater. The powder charge consisted of 7 grains weight of Hercules Sharpshooter powder and 16 grains of du Pont No. 1 smokeless powder (an old low pressure powder), put in the case in the order named, and a blotting paper wad was seated on top of this powder charge with about two pounds pressure. Another successful charge consisted of 18 grains weight of Sharpshooter powder, a quantity of the cereal known as "Cream of Wheat" equal in bulk to 10 grains of black powder, and a blotting paper wad put in the shell in the order named with about 2 pounds pressure on the wad. The cereal which was recommended by Mr. J. H. Keough is for the purpose of protecting the base of the bullet against the heat of the large charge of Sharpshooter powder, and the amount named should not be exceeded. This is a hot load, and rather hard on the barrel. These loads grouped in about three inches at 200 yards, and Dr. Hudson won many matches with them including the world's record of 99 out of a possible 100 on the Standard American target at 200 yards for the Championship of America at Amburster Park in 1910. He said: "Since developing these loads I have several times gone back to my fine old muzzle loading outfits and black powder, and while they seem to shoot well, there was something slow about them in comparison, and my daily average has been markedly less; so that while I still preserve my old muzzle loading outfits for the sake of pleasant memories connected with them, I have come to the conclusion that in the matter of high scores it is hard to beat this .38 caliber smokeless load, and I shall continue to use it until I get something better."

The writer believes that generally speaking this bullet and load represent the best accuracy ever obtained with lead bullets and breech loading. It did not quite equal the accuracy obtained with lead bullets and muzzle loading in Pope rifles with which there is ample evidence that the average (not selected) accuracy at 200 yards was a 2½ inch spread. Note that with the Hudson load the bullet was first seated in the special throat ahead of the chamber with a bullet seater, and the case containing the powder charge was afterwards seated in the chamber behind the bullet.

This maximum accuracy obtained with lead bullets, both breech and muzzle loading, should be compared with that now obtainable with selected metal cased bullets seated in the neck of the case in the standard manner, particularly in such cartridges as the .22 Varminter and .220 Swift. In rifles using these cartridges the writer has seen dozens and dozens of 10-shot groups fired at 200 yards which had an extreme spread of 1.60-inches or less, as compared with 3 inches for the Hudson load and 2½ inches for the Pope muzzle loaders. The writer is aware that this is in direct contradiction to the many statements of Mr. N. H. Roberts contained in his work "The Muzzle Loading, Cap Lock Rifle" to the effect that modern rifles have never equalled the old muzzle loaders in accuracy. A careful study of Mr. Roberts' work will show that he bases his contention on a few fortunate groups obtained with the muzzle loaders over a long period of years, and not on average groups or average performance. But even if we base it on fortunate groups the modern rifle will still have the best of it, for the writer has seen many fortunate groups obtained with modern rifles and loads which will equal or excel any of the fortunate muzzle loading groups shown in Mr. Roberts' book, except only the 200 yard 10-shot group measuring .70-inch shot by Mr. C. W. Rowland of Boulder, Colorado with a .32-40 Pope muzzle loading rifle fired from a bench rest.

Added to the superior accuracy of modern rifles and their ammunition, is also the very much superior wind bucking qualities and the flatter trajectory which certainly must be included in a definition of practical accuracy because they are so important in surely hitting a small object at a distance.

The fact remains therefore that metal cased bullets at their best are slightly more accurate than lead bullets at their best, probably because the former are harder and better resist any slight deformities which might be acquired when passing through the bore of the rifle. Also the metal cased bullet is formed and rectified in a solid die that is accurately ground, while the lead bullet is cast in a mould which is divided in halves, and the two halves do not always form a perfect circle. Accuracy in the last analysis depends on perfect delivery into the air of a perfect gyroscope.

Revolver Bullets

358250 is the standard bullet for the .38 Smith and Wesson Special cartridge. It weighs about 156 grains. Revolver bullets are usually cast 1 to 10 tin and lead, and should never be softer than 1 to 20. This bullet shoots with very excellent accuracy in revolvers, but due to its round point it is not noted for its killing or stopping power.

358429 is a flat point bullet designed by Mr. Elmer Keith to give better killing power in the .38 Smith and Wesson Special cartridge.

It weighs about 173 grains. At velocities permissible in revolvers and pistols, hollow point and other special bullets cannot be relied on to expand on impact unless they are made very light with a very large cavity and given all the velocity that their light weight and the strength of the weapon will permit. In such case the light weight and weak construction of the bullet results in decreased penetration and increased killing power is not obtained. Therefore in revolvers and pistols the heavy bullet with flat point gives the best stopping power.

358431 is the same Keith bullet with a hollow base to lighten it to about 150 grains so that higher velocities can be obtained within the limit of permissible pressure.

358432 and 360344 are wad cutter bullets, also for the .38 Smith and Wesson Special cartridge. Wad cutter bullets are preferred by a majority of the best revolver shooters for target shooting because they cut a large, clean hole in the paper target, thus giving the maximum scoring value, and a hole through the target that is so distinct that its value can be determined from the firing point when the target is viewed through the spotting telescope. These bullets, flat in front with practically no point, shoot with just about the same accuracy as conventional pointed bullets up to 50 yards, but beyond that distance their accuracy is not as good as with pointed bullets.

Gas Check Bullets

High velocity, and incidentally flat trajectory cannot be obtained to any degree with plain lead bullets and smokeless powder because the hot gases given off by the larger powder charges needed to obtain such higher velocity would melt the unprotected bases of these bullets before they left the bore, and thus destroy accuracy.

To prevent this melting of the base, lead bullets intended to be fired at higher velocities have their bases protected with small copper cups called gas checks. The bullet is cast with a slightly tapering base, and the copper gas check is then pressed tightly on this base, the cup remaining on the bullet when it is fired. Figure 85 shows five of these typical gas check bullets.

As a general rule the plain, unprotected base bullet can not be given a muzzle velocity in a rifle exceeding about 1500 f.s. without danger of melting its base. At that velocity the trajectory and the wind bucking ability of the bullet restrict its useful range to about 200 yards, unless it is a very heavy bullet similar to 457125.

Gas check bullets, on the other hand, can be shot with heavier powder charges capable of giving velocities from 1,800 to 2,200 f.s., and indeed in some special cases as high as 2,600 f.s. At these veloci-ties these bullets are quite suitable for economical target shooting up to 500 or 600 yards, and in some instances this increased power makes the heavier of these bullets suitable for the shooting of game such as deer, particularly when the bullet has a flat or hollow point. Also, as a rule, just as good accuracy has been obtained at all distances with gas check bullets as with plain base bullets. Like plain base bullets, gas check bullets should be slightly larger in diameter than the groove diameter of the barrel—about .001-inch larger for .22 and .25 caliber bullets, and about .003-inch larger for .30 caliber and above.

Gas check bullets fill a velocity gap midway between plain lead bullets and metal cased bullets. The reason for their design is that it is easy for the shooter to mould these bullets himself and to affix the gas checks which he can purchase at a very moderate price, whereas metal cased bullets have to be purchased ready made from the manufacturers and are relatively expensive.

257312 is a small gas check bullet weighing about 85 grains that performs quite well in .25-20, .25-35, .250-3000, and .257 Roberts rifles. In the .25-20 a charge of 8.7 grains of Hercules Sharpshooter powder will give a velocity of 1780 f.s. In the .250-3000 Savage rifle 15.5 grains of Hercules No. 2400 powder gives about M.V. 2,100 f.s.

308284 is a bullet weighing about 207 grains that has been used for many years with excellent results in .30-40 and .30-06 rifles. It has been extremely popular in the National Guard for both short and mid range shooting up to 600 yards. Properly loaded it is easily capable of making possible scores on the 20-inch bullseye at 500 yards. In the .30-40 cartridge the popular load has been 21 grains of Hercules Lightning powder, giving M.V. 1800 f.s., while in the .30-06 25 grains of the same powder gives 1900 f.s.

311413 is the very popular Squibb gas check bullet weighing 169 grains which is now used more than any other cast bullet in .30-06 rifles. It gives fine accuracy up to 500 yards with a charge of 22 grains of Hercules Lightning or 24 grains of No. 2400 powder, the velocity being about 1900 to 1950 f.s. The same powder charges will also shoot well in the .30-40 cartridge, giving slightly higher velocities. This bullet has a sharp point and can therefore be used successfully in hunting rifles for the shooting of grouse, ducks, and small animals without injuring meat or pelts. For such use the powder charge might be 16 to 18 grains of du Pont No. 4759 powder with one of the medium strength primers.

358315 is a 200 grain gas check bullet for use in the .35 Remington and .35 Winchester rifles, and is particularly indicated for economical target practice in these calibers. If it were made with a flat point it would probably kill deer very neatly.

375296 is for use in the older .38-55 rifles which have been so popular in past years among deer hunters. It weighs about 280 grains. A charge of 22.3 grains of Hercules Lightning powder in the .38-55 will give M.V. 1640 f.s. with far better accuracy and better killing power than the old standard black powder cartridge which shot a 255 grain bullet at M.V. 1285 f.s. and was the load which made its reputation as a deer killer.

To show the capabilities of gas check bullets as well as some of the intricate technique of using them; due to the inability to obtain metal cased bullets during the present war, the writer has been using gas check bullets almost exclusively in his .257 Roberts, .270 Winchester, and .30-06 rifles for target practice. Many hundreds of rounds have been fired each year, and frequent tests for accuracy have been made from bench rest with telescope sights.

In the .257 Roberts rifle, groove diameter .2565-inch, twist 10 inches, the Bond gas check bullet No. 257720 weighing 71 grains sized to .258-inch has been used. The powder charge was 14 grains weight of du Pont No. 4759 powder.

In the .270 Winchester rifle, groove diameter .278-inch, twist 10 inches, the Bond gas check bullet No. 280780 weighing 109 grains and sized to .280-inch has been used with a powder charge of 16 grains of du Pont No. 4759 powder.

In the .30-06 rifles, groove diameter .308-inch, and twist 10 inches the Bond gas check bullet No. 311890, sized to .311-inch and cast with a hollow point has been used with 18 grains of du Pont No. 4759 powder.

In all three loads above: Bullets were cast of an alloy of 90-5-5, lead, tin, and antimony, and were lubricated with Ideal lubricant. Cases were all chamfered at the mouth and necks only were resized, and then expanded so that the inside of the neck was exactly the diameter of the bullet. The inside of the necks of all cases were slightly polished with steel wool wrapped around a brass bristle brush. Bullets were seated projecting from the mouth of the case so that the ogive of the bullet was very slightly engraved by the lands when the cartridge was seated in the chamber. The Winchester No. 115 or Remington No. 2½ non-corrosive, non-mercuric primers were used. The fouling in all cases was very slight, hardly noticeable, much less than with any other cartridge the writer has ever fired.

All of these loads *averaged* just about 1.5 inches extreme spread for ten shot groups fired at 100 yards from bench rest. Many much smaller groups have been obtained including the .42 inch 5 shot group shown in Figure 86. Besides the accuracy tests made by the writer in his own rifles these loads have been fired in other pieces by other riflemen, and practically always with excellent results, so they are not merely special loads adapted to only one individual rifle. For target practice they are accurate enough to do justice to the highest degree of marksmanship that any individual is capable of. A cartridge cannot be too accurate for target practice for no individual can develop a degree of accuracy in excess of that of which his tools are capable.

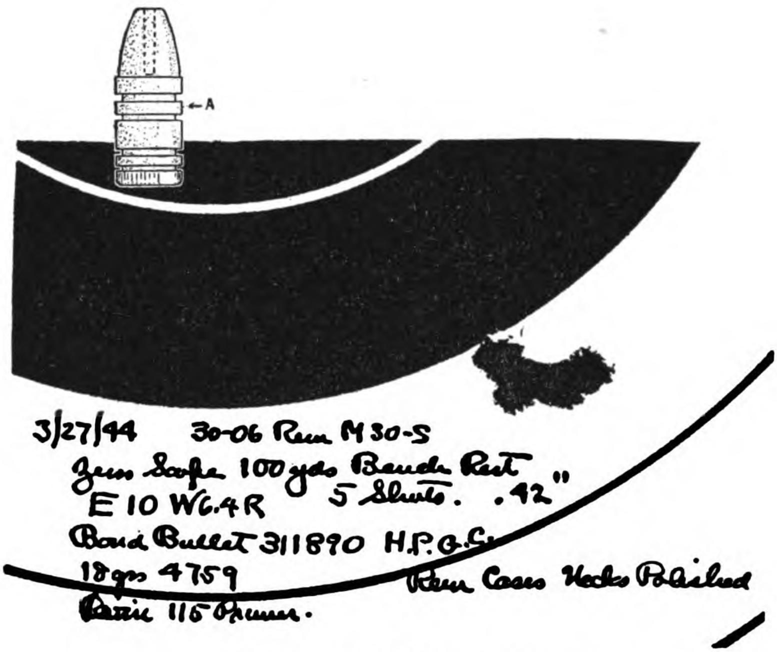

FIGURE 86. GAS CHECK BULLET ACCURACY

The above target shows five consecutive shots at 100 yards, fired by the writer from bench rest with Bond-Loverin Bullet No. 311890, actual weight 161 grains, in .30-06 Remington Model .30-S Rifle. Bullet was cast with a hollow point from 90-5-5 alloy, sized to .311-inch, and seated in case to point A which caused the first band to be slightly marked by the lands. Ideal lubricant. Remington cases were chamfered at the mouth, necks only resized, expanded to .311-inch, and the inside of the necks were slightly polished with steel wool. Winchester No. 115 primers. 18 grains du Pont No. 4759 powder. The extreme spread of the group, center to center of bullet holes, is .42-inch.

The writer does not believe in publishing fortunate groups as they give an erroneous impression, but could not resist showing this one. With the above load fourteen 10-shot groups have been fired from a heavy barrelled Springfield rifle, six from a Springfield sporting rifle with medium weight barrel, and four from a Remington Model 30-S rifle with light weight barrel, all at 100 yards from bench rest. The average extreme spread for all twenty-four 10-shot groups is 1.52 inches. Bullets cast without hollow point did not show quite such fine accuracy.

Economy in Shooting

The chief reason today for the use of lead and gas check bullets in center fire rifles is economy—economy in the cost of ammunition and in barrel life. The greatest economy is obtained when the shooter reloads the fired cases he has on hand, and does not charge for his labor. Real economy begins to appear only when first savings have paid the cost of the reloading tools. Factory loaded rifle cartridges are expensive, particularly in the larger sizes, and metal cased bullets before the war cost from $1.00 to $3.00 per hundred. In figuring the cost of reloading with lead or gas check bullets, the following were approximately the prices of materials in 1940.

Lead, tin, and antimony alloy	$0.20 per lb.
Gas checks	2.00 per 1,000
Primers	3.80 per 1,000
Powder	from $1.60 to 2.00 per lb.

Prices F.O.B. Dealer.

The frictional wear on the barrel and erosion are practically nil, except with the very heaviest gas check loads where an accuracy life of 20,000 to 40,000 rounds may be estimated.

Lead bullets will not shoot accurately in rifle barrels that are pitted, rusted, or much eroded, or in bores which contain the heavy, sticky fouling of older smokeless powders, or the caking of black powder. In such barrels lead bullets are liable to "lead" the bore, that is deposit flakes of lead on its surface. For best results with lead and gas check bullets the bore should be in good condition, and clean to start with. When the above conditions are favorable, results with lead bullets depend upon the skill and care bestowed in preparing the ammunition.

Copper Plated Lead Bullets

In recent years many lead bullets for use in rim fire cartridges, and in revolver cartridges have been electroplated outside with copper. The process was first introduced so as to avoid having to lubricate the lead bullet. Rim fire bullets in particular are outside lubricated, that is covered with wax on that portion of the bullet which projects outside of the case, and this lubricant is more or less of a nuisance. The lubricant is liable to be rubbed off the bullet in handling, and also it picks up dirt and grit and carries it into the bore unless carefully handled. A copper plated lead bullet does not have to be lubricated to prevent its leading the bore, and also it can be fired at slightly higher velocities than a plain lead bullet without leading and without its base being melted by the powder gases. Such copper plated bullets, sometimes called "Lubaloy

Coated" are very common in the high velocity .22 caliber rim fire cartridges.

These bullets are not, however, a complete success. As a rule in .22 rim fire cartridges they are not quite as accurate as the plain lead lubricated bullets. They can be made slightly more accurate by lubricating them, and this is often done. But even lubrication does not make them quite as accurate as the lubricated lead bullets. They also cause more frictional wear in the bore, so that roughly a rifle barrel for the .22 Long Rifle cartridge will wear out in perhaps 50,000 rounds if used with these copper plated bullets, whereas the barrel life with lubricated lead bullets is probably in excess of 250,000 rounds.

In .22 rim fire hunting rifles, however, where the very finest accuracy is not so much in demand, these copper plated bullets are more useful and popular. It is here quite desirable to be able to carry cartridges loose in the pocket. This can be done without detriment with copper plated bullets, but with lubricated bullets the lubricant would rub off or pick up dirt in the pocket.

Metal Cased Bullets

With the introduction of high pressure smokeless powder and the increase of muzzle velocities of rifles from about 1300-1500 to 1900-2300 f.s., it was found that plain lead alloy bullets would not give satisfactory results. The powder gas melted the base and sides of the bullets, and the bullets skidded in the rifling. Bullets made en-

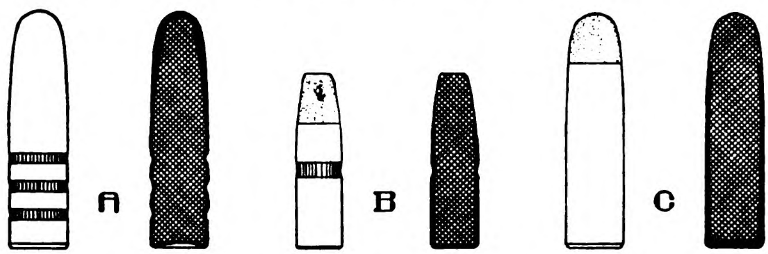

Figure 87. Early American Metal Cased Bullets, 1898-1908

A—The .30/40 Krag service bullet, as loaded into ammunition of the Spanish-American and Philippine Insurrection periods. The provisions of the Hague Convention were observed by making the forward portion of the bullet jacket extra heavy, as shown above, this to prevent any upsettage upon impact. Three heavily knurled grooves helped fix the jacket to the bullet core and at this period it was the practice to lubricate metal cased bullets, all three grooves being filled with lubricant.

B—A W. R. A. factory .25/35 soft point bullet of the 1900 period. Note excessive exposure of lead forming the soft point tip of this bullet; this was a feature of these early soft point bullets which were fired at around tirely of harder metal were too light; that is they did not have the sectional density to maintain their velocity and carry to long distances. It was clearly desirable to retain lead as the major bullet metal so as to give weight, but to cover the lead with a harder jacket which would resist melting and hold the rifling. The two metals which proved most successful at the start were **soft steel** and **cupro-nickel,** the latter being an alloy of about 60 per cent copper and 40 per cent nickel, and often called "German Silver." On the continent of Europe soft steel was preferred, but England and the United States started off with cupro-nickel for early bullet jackets. The thin jacket or outer metal case was about .002 to .003-inch thick, and was filled with a lead core.

Cupro-nickel was rather expensive, and in the United States ammunition manufacturers soon found that they could substitute **gilding metal** for it, which reduced the cost. Gilding metal is an *alloy* of copper with five to ten per cent of zinc. So while cupro-nickel continued to be prescribed for the jackets of military bullets, U.S. manufacturers quickly came to use gilding metal for sporting bullets to be used at slightly lower velocities and in sporting rifles with slower twists of rifling. The gilding metal was usually thinly plated with tin to prevent its tarnishing, and it was difficult to tell the two metals apart unless the jacket was scratched with a file when the copper color would show if the jacket was of gilding metal. These metals were used for all bullet jackets in the United States until after World War I. Only a few jackets of mild steel were produced experimentally in the United States, and the term "steel jacketed bullet" is a misnomer when applied to American ammunition manufactured prior to World War II.

These jackets were and are made in much the same way that brass cartridge cases are manufactured. A small disk or cup is stamped out of thin sheet metal, and then is elongated and drawn out with punches and dies into a ferrule shaped jacket of approximately the finished shape and size. There are two general types of metal cased bullets. The **full jacketed** bullet, termed a **solid** bullet in England, and a **ball cartridge bullet** in our military service, is the type generally used for military purposes, or where deep penetration instead

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M.V. 2,000 f.s. This long exposure of the naked lead furthered spreading of the bullet's tip, a feature which was much advertised at the time; later on it was learned that too much spreading was not advisable as the bullet lacked penetration; then we commenced to get bullets with much less lead exposed at the tip.

C—A .30/40 soft point 220 grain bullet of the 1900 period. This also had an extreme exposure of lead at the tip; it made a splendid bullet for deer but lacked penetration on heavier game. The bullet jacket was of copper, tinned lightly.

of expansion is desired. The jacket covers the point and sides of the lead core, and is closed over its base. The jacket is formed with a point, and is open at the rear end, and the lead alloy core is inserted into the jacket from the rear, the open rear end of the jacket then being slightly closed over the base. See Figure 87.

The **expanding, soft point, or hollow point** bullet employs a jacket which is open at the front end, the rear end of the jacket being completely closed in to form a flat base. The lead core is inserted into this jacket from its front end, and the bullet is then formed in a die, the front open portion of the jacket being drawn in to conform to the shape of the final point of the bullet. See Figure 88. The soft exposed lead at the point of the bullet expands on striking an object such as a game animal, and the bullet "mushrooms" to about double

FIGURE 88. EARLY METAL CASED BULLETS

Here are shown some of the earliest factory-made metal cased bullets placed on the American market for sporting use. They have a core of soft lead covered with a jacket of thin copper, which was then tinned. These are all typical "Express" bullets.

A—A .45 caliber 295 grain jacketed bullet sold by the U. M. C. Company for use in the .45/90 Winchester rifle. Packed 25 bullets to the box, which was labeled "Geigers Patent, Oct. 21, 84." Note that this bullet carries four grooves, only two of which are knurled. Case was crimped into forward groove. The manufacturers favored a number of grooves in those early days, intended to help lock the copper jacket to the lead core. The bases of these early bullets were not as smooth looking as present-day ones, as these jackets puckered badly when folded over into the core; this fault was corrected in later years and we now have metal cased bullets with clean and very accurately made bases.

B—A factory-made lead bullet, made in the '90s and sold for use in the .45/90 rifle, which was a very popular caliber in those days. Note the wide cavity in the point of this bullet; the drug store cowboys of that period used to recommend that a .22 blank cartridge be inserted into this cavity when hunting large or dangerous game which trick undoubtedly introduced some element of danger into their shooting.

C—A .45 caliber, 245 grain "Mushroom Grooved Bullet" as the label on the box had it, made for use in the .45/90 Winchester rifle and sold by the Union Metallic Cartridge Company under Tweedies Patent, Aug. 16, 1892. This bullet was furnished with lubrication in all three of the knurled grooves. Note extreme depth to which cavity was drilled.

its original diameter, causing a more serious wound than does the full jacketed bullet, and giving increased killing power.

The jacket metal which thus surrounds the bullet is rather thin, generally from .002-inch thick for early sporting bullets to be fired in slow twist sporting rifles at relatively low velocities, to about .0035-inch thick for the military bullets and bullets intended for much higher velocities in quick twist rifles. The core is of lead, usually alloyed with a small percentage of antimony, and in practice is usually extruded under high pressure in the form of a wire which is then cut into slugs of the required length, and these slugs are then formed into the shaped bullet core in dies.

When a metal cased bullet is fired through a rifled bore the lands press into the bullet in much the same manner as they press into a lead bullet, and they hold the bullet securely so that it is forced to follow the rifling and rotate with the twist. The lands also do a certain amount of "cutting" into the jacket, and the jacket must be of sufficient thickness so the lands will not cut through the jacket and rupture it in the bore. However, the jacket does not have to be quite as thick as might be supposed to prevent cutting through. In our .30-06 military bullets a thickness of the side walls of the jacket of .0035-inch seems to be sufficient despite the fact that the lands stand .004-inch above the bottoms of the grooves, or even .005-inch in the case of the .30-06 Model 1917 rifle.

When metal cased bullets were first introduced older American riflemen were very critical of them. They spoke of the "mechanical cruelty" of forcing a hard, unlubricated bullet through a rifled bore. They thought that the friction resulting would soon wear out the rifling, that the hard bullet would not expand to seal the bore, and that gas cutting would occur. Indeed, after the first few months of use they could point to the condition of the bores to prove their point. We now know that what they called "gas cutting" was erosion of the surface of the bore caused by the hot powder gases, and the roughened condition of the forward portion of the bore was due to corrosion caused by the chlorate primer, and not by the wear of the metal cased bullets.

Frictional wear with bullets cased with cupro-nickel or gilding metal does occur, but is not serious. If we had this wear alone to contend with rifle barrels of good steel would remain in satisfactory condition for from 20,000 to 40,000 rounds. Rather it is the breech erosion of the powder gas which wears out modern rifle barrels, and this has been decreased considerably by the use of modern powders.

Since metal cased bullets were first introduced we have learned a great deal about their construction, design, and use, and there has been marked improvement in them. At the start these bullets were never made larger in diameter than the groove diameter of the barrel. Thus the early .30 caliber rifles were produced with a minimum groove diameter of .308-inch, and with a permissible tolerance up to .310-inch, and the bullets for these were made with a diameter of from about .307-inch to .308-inch. An effort was made to hold both bullets and groove diameters to .308-inch, but still it was possible to be using a .307 bullet in a .310 bore. Gradually, however, we learned that better results in accuracy and barrel life were obtained where the diameter of the bullet was very slightly larger than the groove diameter of the barrel. With this knowledge also came ability to hold the manufacture of both barrels and bullets to much closer tolerances with improved precision machinery. As a result .30 caliber barrels are now held to a tolerance of .308 to .309-inch for groove diameter, and as a matter of fact it is now rare to find a good barrel of peace time manufacture that has a groove diameter in excess of .3084-inch. For such barrels we now prefer to hold our metal cased bullets to a diameter between .3084 and .3087-inch. The bullet fit in other first class bolt action rifles and ammunition runs about the same in proportion, but in the case of lever action rifles and their ammunition, where the breech mechanism is not quite so strong, bullets seldom exceed groove diameter so as to avoid high pressures.

In England, however, the usual practice has been just diametrically opposite. Their .303 Short Model Lee-Enfield rifle has a groove diameter of .311-inch, and they prefer to make their bullets to measure about .3095-inch. Their theory is that when the lands press into such a bullet they displace enough metal to swell out into the grooves and exactly fill the grooves and seal the bore gas tight, and any more would simply add to friction and heating. In this connection it may be said that their practice is to make their lead cores very much softer than we do, therefore their bullets probably expand more in the bore and do form a satisfactory gas dam. However, our ordnance engineers and riflemen think that our present practice results in better accuracy and longer barrel life than the English practice. It is difficult, however, to draw an exact comparison because until very recent years British powders have been much more erosive, and British primers much more corrosive than ours.

The accuracy of any bullet depends upon its being so uniformly made that it forms a perfect gyroscope. Particularly must it center of gravity coincide with its center of form. If it does not, then while in the bore the bullet will of necessity be compelled to rotate around its center of form, but the instant it leaves the muzzle it will begin to rotate around its center of gravity, and the result will be that the bullet flies with an air spiral and its accuracy of flight is reduced accordingly. This matter has been discussed fully by Dr. F. W. Mann in his work "The Bullet's Flight." Now the jacket being of very much lighter metal than the lead core, if the jacket be thicker on one side than another, the bullet will be manifestly unbalanced, and its center of gravity will not conform to its center of form. The same will occur if the bullet is in the least irregular in shape, if its point is not uniform, or it is not truly round. In drawing bullet jackets it is a very easy matter for the dies and punches to get slightly out of alignment and make the jackets as much as .001-inch or more thicker on one side than the other. The machine operator must be very skillful, and must be constantly inspecting the production of jackets with a dial micrometer, and stop his machine and make adjustments when necessary in order to produce perfect jackets.

Of course such critical inspection increases the cost of the bullets, and it is not done to such an extent with the more ordinary hunting bullets as with those bullets used in cartridges preferred by those skilled riflemen who can appreciate and demand the most accurate ammunition. In the manufacture of hundreds of thousands of bullets for the ordinary .30-30 cartridge, for example, one operator may be assigned to three or four bullet machines, and he will not have time to make very frequent inspections and adjustments. But in making Palma Match bullets for the .30-06 cartridge the most skillful operator in the shop has but one bullet machine in his care. In addition to the difference in accuracy given by the two bullets, this explains why we can purchase .30-30 bullets for about $1.50 a hundred, while fine target bullets cost $3.50 to $4.00 for a like amount. The more expensive bullets will also be more uniform in weight than the cheaper ones.

There is also something intangible in the manufacture of extremely accurate bullets. It is the practice of some factories who produce fine match ammunition to continually, all day long, send small samples of the bullets from the bullet machines to the testing range where they are immediately loaded into cartridges and fired for accuracy. During the hours when a machine is producing exceedingly accurate bullets, those bullets are set aside for assembly into match ammunition, and when the production is not quite so good it goes into ordinary commercial ammunition.

Of course "ordinary commercial ammunition" also has a standard of accuracy which it must come up to to be accepted by the factory inspectors, and it must be said that this standard is constantly rising. The writer has conducted accuracy tests with many makes and calibers of commercial ammunition over many years on his own ranges. The gradual improvement in accuracy and reliability has been very evident, and as a matter of interest it has been particularly marked during the period from 1937 on. In some calibers, in very recent years, the ordinary run of the mine commercial cartridges now approach the accuracy of special match ammunition.

Factory ammunition is manufactured in lots. One lot may contain one particular lot of powder, bullets, primers, or cases, and another other lots of these components, and the resulting accuracy of the lots may differ slightly, although both may be up to the standard for that ammunition. Also one particular lot may differ from day to day of manufacture, or even from hour to hour as tools wear slightly or get a little out of adjustment. All this explains why one may purchase several boxes of ammunition one day, and then several boxes of what appears to be identically the same ammunition several months later, and find that there is a marked difference in the performance of the two purchases.

The metal of which the bullet jackets are made also has its bearing on accuracy. It should be neither too hard nor too soft. Hardness can be controlled by annealing or working the jacket metal, but there is something intangible here too. The writer can well remember that over a long period of years a number of brass manufacturers furnished jacket metal to a certain ammunition manufacturer of identical chemical and physical properties, but the product of one of these manufacturers invariably made more accurate bullets than that of the others.

This matter of accuracy has been dwelt on at length in this chapter because it has been found that the bullet is by far the most important item that goes into securing fine accuracy, more important even than the rifle, particularly since precision machinery has enabled rifle makers to produce weapons gaging so close to the ideal standards. Among a number of bullets of various designs and makes, all of which we might say are excellently fabricated, some may give the finest kind of accuracy, and some may be merely good or mediocre. Three examples will suffice to illustrate the point. In high intensity .22 caliber rifles like those excellently made for the .22-3000 Donaldson 2R, .22 Varminter, and .220 Swift cartridges, as a general rule the very finest accuracy has been obtained with Wotkyns-Morse 8S bullets, none others quite equalling it, although certain Sisk bullets nearly do so.

In the .257 Roberts rifles with barrels cut with a 10 inch twist a large number of riflemen have found that the most accurate bullet to date is the 117 grain soft point boat-tailed bullet for the .25 Remington Auto cartridge that is made by the Western Cartridge Company. This bullet is not very much in demand, and it may well be that all that hand-loading riflemen have used have been made from just one lot, and that lot a particularly fortunate one, and it may be that production after the war will not equal the original lot. However, the fact remains that to date this bullet has given the most superior accuracy in this rifle.

In .30-06 rifles with groove diameters running around .308-inch, a great many riflemen have found that, excepting the special Palma Match bullets and the 172 grain Government boat-tail National Match bullets, the very finest accuracy is obtained from the 172 grain open point, pointed, .30-06 bullet made by the Western Tool & Copper Works. And so it goes, but of course we do not know what post-war manufacture will bring forth.

Cupro-nickel as a jacket material is now almost a thing of the past. It served excellently as a jacket material for the .30-40 Krag cartridge when velocities were only 1960 to 2100 f.s. It continued to be the standard jacket material for bullets for the .30-06 cartridge up until about 1922, but in this cartridge with muzzle velocities of 2700 f.s., and also in some other cartridges with velocities of 2300 f.s. and over, it gave continual trouble in the form of metal fouling in the bore. The cupro-nickel would be deposited in the bore in smears and lumps, some of them three or four thousandths of an inch thick, mostly on top of the lands, and mostly in the muzzle half of the bore. Often as little firing as ten rounds slow fire would result in a heavy deposit. It deposited faster and to a greater extent in rough bores than in smooth bores, and in rapid fire than in slow fire, but no bore was smooth enough to be immune. When the bore was cleaned in the ordinary manner, and examined from the muzzle in a good light, this fouling could be clearly seen adhering to the top of the lands in spots and smears, and often in the grooves as well, appearing like bright metal.

This metal fouling interfered with the best accuracy. Also in those days chlorate primers were used exclusively, and the metal fouling imprisoned the chloride under and through it, and often when this metal fouling was removed the surface of the bore under where it had been would be found to be badly pitted. The only successful way of removing this cupro-nickel fouling was to cork up the chamber of the barrel and pour the bore full of a special ammonia solution which dissolved the cupro-nickel in about half an hour, without damaging the steel. A number of precautions had to be taken in the use of this solution, details of which will be found in Volume II of this work.

Experiments at this time showed that this metal fouling did not occur with bullets jacketed with gilding metal, or at least it does not occur to an undesirable extent. Gilding metal does give some copper fouling, but only in the form of an extremely thin wash on the surface of the steel, hardly more than a color, and it practically never accumulates in thickness. When the cleaned bore is examined from the muzzle in a good light this fouling can be seen, looking as though the bore had been very slightly copper plated, which indeed it has. It has never been found that this wash of copper did any harm, or caused any bad effect on accuracy, and the practice is now to disregard it entirely and not try to remove it. Indeed there is some reason to think that in a small degree this copper plating may prevent the rusting of the steel. It must not be confused with the heavy, lumpy, flaky silver colored metal fouling typical of a bore that has had cupro-nickel jackets fired through it.

Gilding metal has therefore become the almost universal metal for the jackets of metal cased bullets manufactured in the United States. Generally its alloy is of ninety per cent copper and ten per cent zinc, although an alloy of 95-5 is frequently used for automatic pistol bullets, and for bullets for very low powered rifle cartridges. The Western Cartridge Company use a small percentage of tin in their alloy and call it **Lubaloy.** This is done partly because, theoretically at least, the tin lends a little anti-friction property to the alloy, and partly because of its advertising value. Certainly Lubaloy is an excellent jacket material. In England a similar alloy, copied from the Western, is called **Nobaloy.**

Gilding metal as a jacket material has been a complete success. Not only has it eliminated metal fouling, but accuracy life of barrels seems to be longer with it, cleaning is simplified, and accuracy superior to anything before known has been obtained. Probably the increase in accuracy has not been due entirely to the jacket—most of it has resulted from better bullet construction, and improvements in powders and primers—but at least gilding metal has not been detrimental.

One year Frankford Arsenal tried the experiment of electro-plating the jackets very heavily with tin. Very excellent accuracy resulted, but the experiment was not a success for two reasons. First, the bullet soldered itself very firmly to the neck of the case, and if the cartridge was fired in a very tightly necked chamber, or if the neck of the chamber was heavily greased, so that the neck of the case could not expand to normal chamber walls, and free the bullet from the case, an extremely high breech pressure was set up, and the head of the case often blew out and wrecked the rifle. Second, the bullet heavily plated the bore with tin, and this tin alloyed with the steel of the barrel, and the resulting steel-tin alloy, with its lowered melting point, washed out very rapidly so the life of the barrel was extremely short. Such jackets were therefore abandoned. Gilding metal jackets are sometimes washed slightly with tin to prevent tarnishing. The coating is so thin that it probably does little harm, but it is of little help except to make the bullets look attractive.

As stated in a previous chapter, **mild steel**, tin or copper plated to prevent rusting, has been used for bullet jackets in time of war when copper is in heavy demand for other war materials. Good jackets can be made with it, and the bullets shoot accurately, but cause more frictional wear in the bore than gilding metal. Steel jackets can always be told by touching them with a magnet.

Long, Round Nose, Military Bullets. The small bore, high power rifle, in calibers from 6 mm to 8 mm, was a military development, and their extended use for sporting purposes did not occur until they had been in use in the British army for some few years. Thus the original metal cased bullets were all made full jacketed for military purposes. One exception was in the French army where a solid bullet made of gilding metal and known as the "Balle D," was used in the 8mm Lebel rifle. These military bullets were all made long-heavy, 220 grains in .30 caliber, 175 grains in 7mm, and 160 grains in 6.5 mm calibers, so they would overcome air resistance and fly well for long range rifle and machine gun fire. At this time sharp pointed jacketed bullets had not been introduced, and all military bullets were formed with a more or less round point. A long, full jacketed, round or flat point bullet has the property of penetrating deeply into substances such as wood or flesh and bone, and moreover penetrates fairly straight through these substances in the direction in which it is fired. It does not ordinarily expand to any extent, and usually merely drills a small round hole. In war on men and animals it often wounded instead of killing outright, but this was believed to be a military advantage as a wounded man is more of a care to the enemy than a dead one.

In their campaigns against the fanatical natives of the North-west frontier of India at the close of the last century the English army found that their long .303 Lee-Enfield bullet of 215 grains, a full jacketed or "solid" bullet with round point, did not stop the rushes of these natives. They would sometimes receive two or three bullets throught the body and still come on and continue to fight. So the English made some of these bullets expanding by grinding off the nose of the bullet jacket. Such bullets were called **"Dum-Dums."** The use of dum-dum or otherwise expanding bullets was later prohibited in civilized warfare by one of the Hague Conventions, but the name has remained a popular one with the newspapers to this day.

This long, round nosed military bullet was not satisfactory for big game shooting because it did not kill reliably or humanely, but such bullets still have two uses in sport. With them a hunter can shoot through small game such as wild turkeys, and kill the game well, but without destroying meat or blowing the game to pieces, as the bullet usually only drills a small hole. They are also used by some hunters in Africa for brain shots on elephant. An elephant can best be killed by a brain shot, but the brain is a very small mark, and it takes the accuracy favored by a light rifle with light recoil to hit it. What is needed is a bullet that will penetrate deeply and straight. The size of the bullet for this shot makes no particular difference, and many professional African elephant hunters have used successfully .256, .276, and .303 caliber rifles with these full jacketed or "solid" bullets. The hunter must be cool and experienced to make a brain shot tell, this bullet being very ineffective for any other shot on large game. On special order the Western Cartridge Company have been loading .30-06 cartridges with a 220 grain full jacketed bullet, having a thick jacket and a slightly flattened point for elephant shooting.

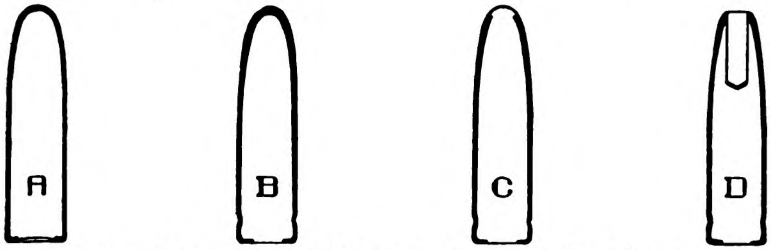

FIGURE 89. ORIGIN AND HISTORY OF THE DUM DUM BULLET

Our press and the sporting publications frequently speak of the "dum-dum bullet" and the history of this projectile is of considerable interest. This word and type of bullet were coined by the British in the '90s, during which time they were engaged in the development of their present .303 rifle and cartridge, one of the pioneer small bore weapons of that day.

A—Illustrates construction of the first metal cased bullet for use in the .303 British rifle, known as the Mark I bullet. It weighed 215 grains and was of typical construction; lead core and jacket of thin metal. Cordite powder was used by the British as a propellent and this has always been a particularly hot burning powder; this fact together with the elementary construction of their first metal cased bullet gave the British considerable trouble from the cores being blown out of the bullet jackets, so much so that this Mark I bullet was of brief duration and life. Note relatively thin jacket and the short turnover of jacket at the bullet base.

B—The British profited by their experience from blown jackets and promptly developed the Mark II bullet, having a much thicker jacket covering its nose and with a wider turnover of jacket at the base, plus a cannelure being added to help hold the assembly together. This ended all trouble from the bullet coming apart, but it introduced a new problem and a most serious one. The bullet lacked shocking or killing powers. At this time the British Army was engaged in extensive punitive expeditions on the Northwest Frontier of India, fighting against Afghan and Pathan tribesmen. It soon developed that such a full jacketed bullet was of no practical effect against these primitive natives as, unless shot through the heart or brain, they kept right on fighting. The story has it that in this emergency the British Ordnance force stationed at their arsenal at Dum Dum, India took this Mark II ammunition and ground off the jacket from the tip of each cartridge, turning it into a most effective man-stopper.

C—Profiting from this experience, a Captain Bertie-Clay, stationed at the Dum Dum Arsenal, invented and patented a new type of bullet, shown

Sharp Pointed Military Bullets. About 1905 the German army introduced an innovation in military bullets for small bore rifles by reducing the weight of their 236 grain 8 mm bullet to 154 grains and forming it with a very sharp point. They called this bullet a **"spitzer."** Being of such light weight it could be given a very high velocity, about 2825 f.s. in the 8 mm, and this, together with its sharp point, resulted in a very flat trajectory over mid ranges. With the rifle sighted for 500 yards and aimed at a man's belt, the trajectory was such that it would not strike above the man's head at mid-distance, and dropping slightly beyond 500 yards it would still strike the enemy in the legs at 600 yards. This was a great advantage for military purposes. Other nations were not slow to adopt this light, sharp point bullet. The United States adopted it in 150 grains at M.V. 2,700 f.s. in their Ball Cartridge, Caliber .30, Model 1906. This bullet will be commented on more fully further along in this chapter under the heading Bullet Forms.

These sharp pointed bullets were made in full jacketed type, and their points were formed on an ogive of six or eight diameters. See Figure 90. Contrary to what had been expected they did not show greatly increased penetration as compared with the former long, heavy, round nosed military bullets. On striking substances such as wood, dirt, flesh, or bone, their sharp points seemed to turn over slightly, and the bullet "dived" off at more or less of an angle, and often turned over sideways, not penetrating in the direction in which fired. When it turned sideways it met much resistance. In flesh it often caused ghastly wounds, and as a result in warfare many were the complaints that the enemy were using dum-dum bullets. It behaved the same way when tried on big game, sometimes killing splendidly, but not reliably, because sometimes it would penetrate point to the

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as **C.** This was merely a metal jacketed bullet open at both ends. It alone is the true "Dum Dum bullet," but the name struck the popular fancy and has remained in use until this day, being generally applied to any soft nosed or expanding bullet. This original Dum Dum bullet suffered the same fate as would be expected from a jacketed projectile open at both ends, and so much trouble was experienced from blown jackets that its use was soon abandoned. This was about 1896.

D—Here is shown the famous Mark IV bullet for the .303 British cartridge. It was developed in an effort to produce a bullet which would effectively disable an enemy when struck in a non-vital part of the body. It too quickly came to an end through core blow-outs but was also promptly outlawed by the provisions of the Hague Convention which met shortly after its introduction and forbid the use of any type of expanding or explosive bullet. The effects of this provision against expanding bullets were widespread and are to be seen in the construction of our own .30/40 Krag bullets of this same period. See bullet **A** in Figure 87.

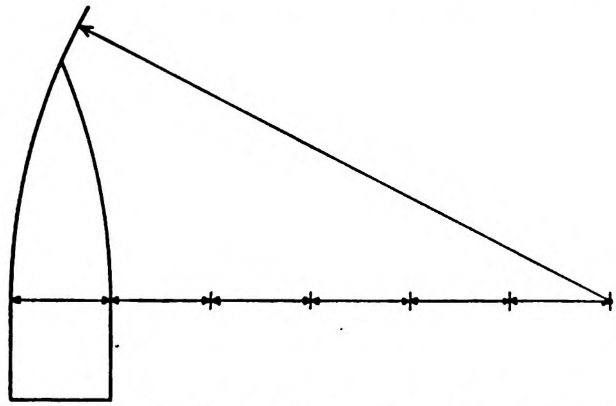

FIGURE 90. BULLET OGIVE ON A RADIUS OF SIX DIAMETERS

front and cleanly, when it made only a very small hole. Shortly after its introduction Mr. Stewart Edward White tried this 150 grain full jacketed pointed bullet on African game. It often killed very well, but he had some failures. In one instance, shooting at an antelope, the bullet struck the shoulder squarely, was deflected downward, struck the breast bone, then a leg bone, was further deflected down to the ground, ricochetted there, and finally struck the ground 50 feet in front of Mr. White. But for strictly military purposes it was a great success, and now practically all military bullets are formed with a very sharp point.

These sharp pointed, full jacketed military bullets have their use in sport. Their tendency to turn over when penetrating depends on high velocity. Loaded to a muzzle velocity of 1300 to 1500 f.s. they will penetrate very cleanly, and can be used for shooting small birds and smaller fur bearing animals. The writer has used hundreds of them for this purpose.

In addition to full jacketed bullets, other bullets known as armor-piercing, tracer, and incendiary are used for strictly military purposes.

The Armor-piercing Bullet is a pointed, flat base bullet with a gilding metal jacket. The core is of pointed, boat-tailed shape and is made of hardened tungsten chrome steel. The steel core is slightly shorter than the assembled bullet, and the space inside the jacket and in front of the core is filled with lead, while the space in rear of the boat-tail core has a gilding metal base filler cup. See Figure 91. This bullet is intended for use against airplanes, tanks, armored vehicles, and pill boxes. For identification the Caliber .30 Armor-piercing Bullet has a blackened tip, blackened for about ¼-inch from the point.

Tracer Bullets. These bullets, when fired, emit a bright red flame from their base, thereby showing the gunner by the trace of flame the path as well as the striking point of the bullet, the flame continuing to burn and trace for about 600 yards. They are loaded into cartridges so as to give the same trajectory over 600 yards (for .30 caliber) as the standard ball and armor piercing cartridges. While tracer cartridges are intended primarily for machine gun use, they can often be used to advantage in rifles for signal and incendiary purposes, target designation, and verification of range estimation. Tracer bullets for the .45 Automatic Pistol are also made for signal-

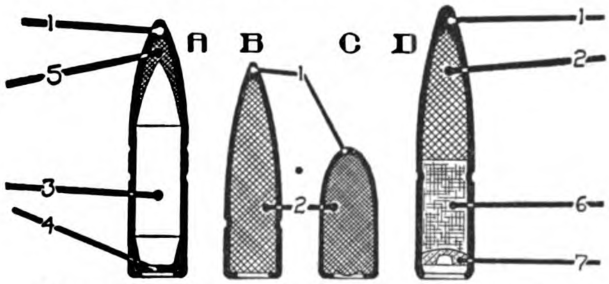

FIGURE 91. U.S. SERVICE BULLETS, CALIBER .30

A—Armor-piercing bullet.
B—150 grain service bullet, for M2 cartridge.
C—Carbine bullet, 110 grains.
D—Tracer bullet for .30 caliber cartridge.

1 indicates jacket (gilding metal). 2 is slug, (lead and antimony composition). 3 is a.p. core of tungsten-chrome steel. 4 is the special base filler to a.p. bullet, made of gilding metal; 5 is the point filler, of lead. 6 is special tracer composition with an igniter composition shown as 7.

ling purposes. In machine guns for use on airplanes and tanks it is customary to load them into the belts alternately with armor-piercing cartridges, so the sheaf of fire can be plainly seen by day or night, and can be reliably brought to bear on the target.

The Caliber .30 U.S. tracer bullet has a gilding metal jacket, the standard service sharp point, and a flat base. Its overall length is 1.45 inch, being longer than any other Caliber .30 bullet. The forward half of the bullet contains a lead core, but the hollow formed by the jacket walls in rear of the lead core is filled with the tracer mixture. In rear of the tracer mixture is a small amount of igniter mixture. The base of the bullet is left open, that is, it is not covered to any extent by the jacket. When the bullet is fired the hot flame of the propellant powder ignites the igniter mixture, which in turn reliably ignites the tracer mixture almost as soon as the bullet has left the bore. As the bullet flies the tracer mixture continues to burn with an intensely bright red flame, thus clearly showing the path of the bullet from muzzle to target by day or night. Tracer bullets have the point of the bullet colored red for identification. See Figure 91.

Tracer cartridges are used only in military service, and are never sold to individuals. Should an individual obtain one or more of these cartridges he should at once return them to military control, or else dispose of them by throwing them into a deep river or lake, as they are exceedingly dangerous to have around. They should never be "monkeyed" with, and particularly no attempt should be made to unload them for examination, as they might ignite and cause exceedingly serious burns or a fire. They should also never be fired on an ordinary rifle range as they would almost certainly set fire to anything they struck. Incidentally, their use in a fine rifle would be more or less detrimental to it as the fouling is very difficult to remove, and extended use will result in metal fouling the bore. The ingredients used in the tracer and igniter mixtures are confidential.

Incendiary Bullets are similar in construction to tracer bullets, but the composition contained in the cavity burns fiercely on impact with a very hot flame which will quite reliably ignite anything that the bullet strikes. For identification purposes the incendiary bullet has a light blue tip. The same precautions should be observed as with tracer cartridges.

Expanding Bullets

Much ingenuity has been exercised in constructing small caliber, metal cased bullets so that they will expand reliably and kill well when used for sporting purposes on big game. The first of these bullets made for the .30-30 and .30-40 cartridges were what are called **"soft point"** bullets. The jacket is formed with its opening at the point, from which end the lead core is inserted. The jacket is short so that a portion of the core, the soft point, is left exposed at the point of the bullet. See Figure 92. On striking game this soft point expands or upsets, the point of the bullet thus "mushrooms" and expands to about twice its original diameter, causing a much larger wound than a full jacketed bullet, and killing better and more humanely.

The first of these soft point bullets made in the United States were designed for killing deer, which are relatively small, soft bodied, small boned, easily killed animals. The soft core of these bullets was exposed for almost ¼-inch back from the point of the bullet. They performed excellently on deer and other animals of about that size and build. Soon after penetrating the skin the bullet expanded. Sometimes it held together in the form of a perfect mushroom. At other times the bullet disrupted, the core left the jacket, and sometimes the core itself split into a number of pieces. But practically always the bullet or its particles tore a hole about three inches in diameter through the animal's body, sometimes penetrating clear through, and sometimes remaining inside the body, disrupting all tissue in its course, and killing quickly and humanely. If the bullet penetrated all the way through the deer it often made an exit hole in the skin on the opposite side large enough to stick one's fist into.

But such easily expanding bullets did not kill well on much larger and tougher animals such as elk, moose, and large bear. The bullet expanded too much or flew to pieces too quickly on these larger animals, and it sometimes expended all its energy on their large bones, failing to penetrate deeply to the vital organs. So presently the ammunition companies gave the hunters heavier bullets with less lead exposed at the point, and with thicker jackets for use on these heavier animals. But conversely these heavier, harder to expand bullets did not always mushroom on the softer bodies of deer, but might penetrate cleanly with only a small hole, and not kill reliably on these smaller animals. From then on until very recently hunters were supposed to select their cartridges according to the game they desired to hunt, using light and easily expanding bullets for deer and sheep, and heavier, harder bullets for larger game, just as the shotgun shooter uses shells loaded with different sizes of shot for different sized birds. Many hunters failed to recognize this, and often used the wrong bullets, and blamed the ammunition for their failures.

This condition did not please the ammunition companies who naturally disliked to have any of their cartridges declared unsatisfactory, and they have constantly endeavored to make bullets which would perform well on any American big game, irrespective of size. Bullets with hollow points, that is a hole more or less deep, drilled or formed in the point, were tried. They were quite effective, but perhaps not quite as good as a soft point properly exposed for the sized game to be hunted. One of these **hollow point bullets** in particular performed very well on all sizes of big game, this being the .30 caliber, 180 grain, open point, boat tail, expanding bullet made by the Western Cartridge Company. See Figure 92. This semi-pointed bullet had a cavity in the point about ¼-inch deep. Opposite the bottom of the cavity a cannelure was rolled in the jacket to slightly weaken it at this point. The forward quarter inch of the bullet was supposed to expand or turn over, and the jacket was supposed to rupture at the cannelure, but to cease its rupturing at this point, thus causing the rear remainder of the bullet to hold together well for deep penetration. The bullet usually acted much in this manner, and when the point disrupted or expanded, the remaining heavy base of the bullet more or less turned over, and penetrating more or less sideways, caused a large and almost always quickly fatal wound. The writer shot grizzly bear, moose, caribou, sheep, goats, and many deer with this bullet, and it never failed to kill well.

About 1924 a demand arose for a **sharp pointed expanding bullet.** The sharp pointed bullet, as will be seen later, overcomes the resistance of the air much better than round or flat point bullets, the bullet loses less of its velocity as it flies to longer distances, and consequently has a flatter trajectory, and also more remaining energy at all ranges. If it could just be made to expand reliably it would be the ideal form for a game bullet because of flatter trajectory and longer sustained killing power.

Except when the bullet travels at an extremely high velocity it is not practical to make a pointed bullet with a soft point because the sharp lead point is almost sure to be deformed in handling. At extremely high velocities such as pertain with the ultra high intensity .22 caliber rifles, we can make a pointed bullet with just barely a small pin point of lead exposed at the point so it is in no danger of being deformed, and yet this pin point is sufficient of an exposure to cause the bullet to upset at very high velocity. See the Wotkyns-Morse 8S bullet in Figure 82. But such a bullet would not expand very reliably at muzzle velocities under about 2600 f.s.

The Winchester Repeating Arms Company solved this problem by producing their Pointed Expanding Bullet (see Figure 92) in which the sharp soft point is covered with an extremely thin point jacket of gilding metal, the jacket covering the point only of the bullet for about $\frac{1}{10}$ inch back from the point and extending only a little distance down inside the main jacket so as to make it secure. The thin tip jacket collapses and does not restrict the expansion of the lead point under it. The Remington Arms Company, on the other hand, made their core with a hollow point, and the core extended to within only about $\frac{1}{8}$ inch of the point of the bullet. In front of the core is a bronze tip, with its front point forming the sharp point of the bullet, and its base in the form of a wedge slightly entering the hollow in the lead core. When this bullet struck the bronze point was forced back and into the hollow in the lead core, and thus expanded the lead core.

Both of these bullets acted very well, although perhaps there was a tendency for them to fly to pieces a little more than was desirable, particularly at high velocities, and not penetrate quite as deeply on the largest game as desirable. So the ammunition companies decided to experiment further. Not only were they in search of a more efficient bullet for all game, but each of them also wished a radially new bullet which they could advertise with glaring headlines and thus increase their sale of ammunition—good business. Their ballistic engineers were also influenced by the fact that their investigations seemed to show that the most efficient expanding bullets had been those with simple soft points. Two courses were open to them. Either they could endeavor to perfect a bullet that would perform well on all big game, irrespective of size; or they could print on their 20 round ammunition cartons the kind of animals that particular soft point bullet was designed to kill, and thus educate the public to the use of the proper bullet. They chose the former course which was probably the wiser one.

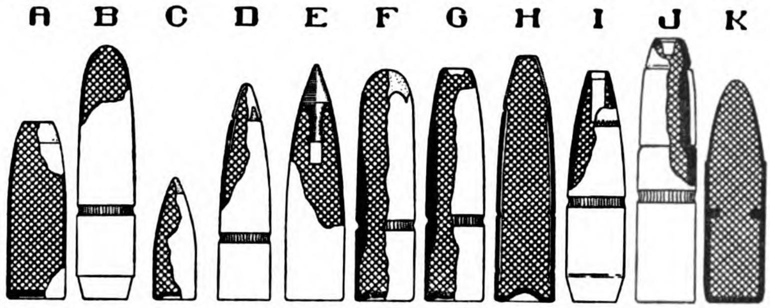

FIGURE 92. METAL CASED EXPANDING BULLETS

A—Typical soft point bullet with flat point and full exposure for the .30-30 series of cartridges. Excellent expansion on deer at M.V. 2,000 to 2,200 f.s. At higher velocities it expands too quickly and flies to pieces. In .30 caliber it weighs about 170 grains.

B—The .30-06 caliber, 220 grain soft point boat tailed bullet made by the Western Cartridge Co. A very celebrated bullet for big game. Stewart Edward White found it the very best bullet for African game and killed many lions with it. M.V. 2,300 f.s. in .30-06 caliber. Not reliable on deer as it does not always expand on their soft bodies.

C—The .25 caliber 87 grain bullet for the .250-3000 Savage cartridge. A sharp point bullet with little lead exposed and a thick jacket. Performs quite well on deer, and so little lead is exposed that points do not deform much in handling. A bullet of similar construction, if intended for ultra high velocity cartridges of .22 caliber (3,600 f.s. and over) should have even less lead in proportion exposed at the point or it will fly to pieces prematurely.

D—The 130 grain .270 caliber Winchester Pointed Expanding bullet. The jacket is very thick at the base. At M.V. 3,160 f.s. this is a most excellent killing bullet on all American big game and quite accurate. Other Winchester Pointed Expanding bullets of similar construction do not seem to be quite so accurate, possibly because their jackets are not so thick at the base.

E—Remington Bronze Point bullet, 130 caliber, 180 grains. The bronze point acts as a wedge on impact and causes excellent expansion, and at the same time prevents deformation of the sharp point.

In 1933 the Peters Cartridge Company introduced their **belted bullet.** In .30 caliber for the .30-06 cartridge this bullet weighed 225 grains, and was loaded to a muzzle velocity of 2350 f.s. (advertised as 2400 f.s.); a very powerful cartridge. It was a round nose builet with a shallow hollow point, but was unique in having a broad, thick band or belt of gilding metal surrounding the outside of the jacket about 1/5 inch below the point, the band being about half an inch wide, and appearing very much like a ring on a finger. The shallow hollow point invariably expanded at once and mushroomed well on any animal, but the thick belt held the major portion of the bullet below it intact, and this rear portion by reason of its weight drove well into the vitals on the largest game. On a hind quarter shot it would even drive well up into the chest cavity on our largest game. It practically never failed on any game when it was properly directed, and it proved to be unusually accurate as well. Many of our older hunters think it was the most reliable ex-

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F and G—Remington Core Lokt bullets, soft point and open point. .30 caliber, 180 grains. Note extremely thick jacket over the middle portion of the core, which prevents disintergration of the center and base of the bullet when the thinner jacketed point and ogive expand. Accurate and are making a very enviable reputation for killing power.

H—The Winchester Silvertip bullet. .30 caliber, 180 grains. The point is jacketed with cupro-nickel (silver color) and this thin jacket extends down inside the thicker gilding metal jacket almost to the base of the core.

I—The famous Western open point boat tail bullet. .30 caliber, 180 grains. The cannelure on the ogive of the jacket just even with the bottom of the hollow point is supposed to weaken the jacket there, causing easy expansion but limiting the disruption of the jacket to this cannelure, thus preventing the base of the bullet from going to pieces. A very successful game bullet.

J—The Peters Belted bullet. .30 caliber, 225 grains, loaded in .30-06 to M.V. 2,400 f.s. A thick gilding metal belt surrounds the forward portion of the jacket just in rear of the point as shown, and effectively prevents disintegration of any of the bullet other than the hollow tip. The hollow tip would expand even on deer. Extremely accurate and experienced Alaskan hunters thought it killed more reliably than any other .30 caliber bullet. Discontinued due to high cost of manufacture.

K—A German sporting bullet of D.W.M. make, known as their "H" bullet. A heavy band or shoulder inside the middle of the jacket prevented the base of the bullet from flying to pieces. Bullet weight—12.7g., DWM No. 554.

As is clear from all of these types, the effort has been made to construct expanding game bullets so that the point will mushroom easily, but the heavy base of the bullet will remain intact to give deep penetration, and penetration through heavy bones.

panding bullet that has ever been produced in .30 caliber. See Figure 92.

But this bullet was very expensive to manufacture, and there was no profit in its sale. Therefore the Remington Arms Company, who, together with the Peters Cartridge Company, had been acquired by E. I. du Pont de Nemours & Company, decided to introduce a new game bullet which was a simplification of the Peters belted bullet. Instead of the expensive belt or band they very greatly thickened the gilding metal jacket at the same point, and they made these bullets with either a soft point or a hollow point so hunters could choose either they wished. The front end of the soft point bullet was made with little scollops around its diameter, apparently with the idea of causing equal expansion and mushrooming on all sides of the bullet. This bullet Remington termed **the Core Lokt.** It was introduced just before World War II, and we do not as yet have sufficient reports on it from the game fields to make any positive statement as to its performance, but all reports so far have been extremely favorable. Of course, nothing that we can do to a light .25 caliber bullet is going to make it into an effective projectile for the killing of the largest game. But in .30 caliber these Core Lokt bullets of 180 grains at M.V. 2700 f.s., or in 220 grains at M.V. 2300 f.s., will probably prove most effective on all species of American big game irrespective of size. These bullets also seem to shoot with fine accuracy, and the only drawback is the round point which does not overcome the resistance of the air well.

The Winchester and Western combine have likewise recently introduced a new game bullet in their effort to produce a projectile which would perform satisfactorily on all American big game. This is known as **the Silvertip bullet.** The lead core is inclosed in two jackets. That covering the bullet nose, and extending down inside the main jacket nearly to the base, is made of thin cupro-nickel, and is supposed to prevent premature expansion while the bullet is penetrating the hide and outer muscles and bone. At first, on striking, the bullet diameter increases very little, expansion of the soft core being controlled and gradual. Then as deeper penetration nears the vital organs, the cupro-nickel (silver colored) jacket bursts open, and the bullet expands rapidly to approximately twice its original diameter, exerting its energy where it has its most deadly effect. This recently introduced bullet also has not yet been sufficiently used to present any positive statement as to its effectiveness. We do, however, have one reliable report on it (Mr. Jack O'Connor) indicating that in .270 Winchester, 130 grains weight, it penetrated deeper than the 130 grain Winchester Pointed Expanding bullet, and killed excellently. If it excels this latter bullet it must be splendid, because in .270 caliber this older 130 grain pointed expanding bullet was probably the most successful bullet for all but the very heaviest game that American hunters have ever used. See Sketch H of Figure 92.

A demand, in fact a very insistent demand, remains for a thoroughly reliable and extremely accurate pointed expanding bullet that will perform well on either deer or much larger game. As an indication in this direction the writer is of the opinion that the most successful pointed expanding bullet yet produced is the above 130 grain, .270 Winchester Pointed Expanding. Its jacket was very thick at the base and lower sides. It has made a tremendous reputation in the game fields for quick kills. Of course it is probably a little light for the heaviest game, but it should have been tried in .30 caliber with a weight of 180 grains. The standard 180 grain .30 caliber Pointed Expanding bullet does not have a jacket thickness at base and lower sides in the same proportion as does the .270 caliber 130 grain bullet.

Bullet Forms

So far we have considered the construction of the bullet almost exclusively. We must now take up another detail which is quite as important—the bullet's form or shape. The most common forms of bullets are shown in Figure 82.

For the purpose of comparison of forms a bullet may be likened to an arrow, a ball of light cotton, and a boat. If we shoot or otherwise propel an arrow at a certain speed, say 100 feet per second, it will travel quite a distance because it has great sectional density; that is it has great weight in proportion to the sectional area of its diameter. It overcomes the resistance of the air well. On the other hand if we throw or otherwise propelled a large ball of light cotton of the same weight as the arrow at the same initial velocity it would probably not fly further than 5 to 15 yards because it has such a low sectional density, is so large in diameter with respect to its weight and encounters greater air resistance which quickly slows down its velocity so it soon falls to the earth.

So too with a boat. A bullet shaped like the short, flat point bullet shown in Figure 82 would be like a scow. It would be almost impossible to drive it through the water with any speed unless we used a great amount of power, and as soon as that power ceased to be applied it would slow down very quickly and come to a standstill. The hulls of racing yachts, on the other hand are shaped much like the pointed, boat-tail bullet also shown in Figure 82. They are long and narrow, and they have a pointed bow and tapering stern. They have greater sectional density and their shape is such that they slide through the water easily, not encountering much resistance. In the same way a bullet of this form flies through the air easily, it overcomes the resistance or does not have so much resistance to overcome; it does not lose its initial velocity so rapidly as the blunter or shorter bullet, and with the same starting velocity it will fly to a much greater distance.

Many of us find it difficult to visualize the effect of air resistance. As we walk through air it does not seem to offer much resistance because we walk at such slow speed. But if we try to run against a stiff wind we do begin to feel the resistance of the air. A wind velocity as high as 160 miles per hour has been observed in a hurricane. Hurricanes often do tremendous damage and some very queer things have been known to occur in them, such as straws blown through the trunks of large trees. Well, the little bullet of the .22 Long Rifle cartridge starts off at a muzzle velocity of 1100 feet per second which is just the same as though it encountered a hurricane blowing at 752 miles per hour! The .30-06 bullet starts off at 2700 feet per second, and at once meets a hurricane of 1841 miles per hour, and the .220 Swift bullet starting at M.V. 4140 f.s. meets 2823 miles per hour which is not exactly a gentle breeze, and must offer quite some resistance. So you begin to get a better idea of what air resistance a bullet has to fight its way through.

The **ballistic efficiency** of a bullet is expressed by its ability to overcome this air resistance, or to fly through the air with the least resistance, which is the same thing. Ballistic efficiency depends upon two factors; the sectional density of the bullet, and its form. It will be well at the start to know how to determine sectional density and thereby be able to compare this property in various bullets. The formula for determining sectional density is (W/d^2) .7854. That is divide the weight of the bullet expressed in pounds by the square of the diameter of the bullet, and multiply the result by .7854. To determine the weight of the bullet in pounds we divide its weight in grains by 7000.

With regard to the form of the bullet; with sharp pointed bullets the curve of the point is designated in terms of bullet diameters of the radius on which the point is formed. This is explained by Figure 90, which shows a bullet with ogive or curve of point formed on a radius of six diameters. This radius is used in determining the form factor. If, however, the bullet has a round or flat point, other form factors are used, depending on the exact form of the point. Ballistic tables contain exact outlines of many different forms of points with the form factor for each, so the factor for any bullet can be obtained by comparing it with its outline. We will give the tables in the following volume.

The sectional density and the form factor together determine the **ballistic coefficient** of the bullet. All of these matters will be discussed fully in Volume II of this work in the chapters dealing with exterior ballistics. We will therefore confine ourselves here to a few pertinent remarks relative to the various forms of bullets shown in Figure 82.

The **short, blunt, flat point bullet** is typical of the older bullets used in short cartridges of low velocity such as the .32-20, .38-40, and .44-40 so popular for repeating rifles seventy years ago. It is also typical of modern revolver bullets. The bullet has low sectional density and a blunt point. It is thus essentially a short range bullet as it loses its velocity very rapidly. Being low in sectional density and having a short bearing in the bore, it does not set up much pressure in the bore, and hence it could be given a fairly high muzzle velocity in the short cartridge cases containing a small amount of powder in which it was originally loaded. The relatively low pressures developed were in keeping with the relatively weak rifles in which these older short cartridges were employed. By constructing such a short, light bullet with a thick metal jacket it is possible to give it a very high muzzle velocity within the pressure limitations because the bore resistance is light. An example is the Remington Hi-Speed .30-06 cartridge loaded with a light bullet of this type weighing 110 grains which is given the very high muzzle velocity of 3380 f.s. in a 24 inch barrel. The short range trajectory is very flat, but at longer ranges the bullet falls off fast in velocity due to its being unable to overcome the air resistance well, the trajectory becomes very curved, and it is essentially a short range bullet despite its very high muzzle velocity. Likewise this bullet, irrespective of its construction, lacks ability to penetrate deeply in wood or other materials for exactly the same reason that it lacks ability to penetrate well through the air.

The **medium length flat and round nose bullets** shown in Figure 82 are typical of many of the older black powder cartridges such as the .25-20-86, .32-40-165, .38-55-255, and .40-70-330, and also of nearly all the bullets used in earlier and many modern high power cartridges such as the .30-30, .303 Savage, .32 Special, .33 W.C.F., .348 W.C.F., .35 Remington, and .35 Winchester. They have enough length and sectional density to retain a fair degree of velocity and penetration to moderate distances. In the older black powder cartridges, in which they were given a muzzle velocity from 1300 to 1400 f.s., they retained sufficient velocity, energy, penetration, and ability to mushroom, and had a sufficiently flat trajectory to make them effective game bullets up to about 150 yards. In high power cartridges with initial velocities from 1960 to 2300 f.s. these properties are retained so as to make such bullets effective to about 200 to 250 yards. Under the best conditions they would shoot accurately enough for good target shooting at known distances up to 500 or 600 yards. They may thus be called short range game bullets and mid range target bullets. Due to their moderate weight they cause only medium resistance in the bore and therefore fairly high velocities can be given to them in lever and pump action rifles without exceeding the pressure limit of such weapons. The older soft point, metal cased bullets of this type, such as those made for the .30-30, .303 Savage, and .32 Special cartridges, have rather thin jackets, and if such bullets are loaded into large capacity cases, and an effort is made to obtain high velocities with them, their jackets are liable to rupture in the bore. As an example, the ordinary .30-30 bullets of 160 to 170 grains cannot be given a velocity much greater than 2500 f.s. in the .30-06 cartridge without danger of rupturing. When a bullet ruptures, that is its jacket splits or cuts in the bore, it more or less flies to pieces when it leaves the muzzle, and does not strike the target. Many of these bullets also have a crimping cannelure in the jacket about half way between the point and the base, and when given very high velocity, if the bullet is a full jacketed one, the jacket is liable to part or rupture at this cannelure. The front half of the jacket and the core may shoot out of the barrel, but the rear half of the jacket may remain in the bore, causing an obstruction, and the next shot may cause a bulge in the barrel at the point of the obstruction, or a deep ring in the bore there, or the barrel may even burst.

The **long, heavy, round nose bullet** shown in Figure 82 is typical of the bullets used in high power military rifles of forty years ago, such as the .30-40 Krag, 220 grains, .303 British 215 grains, 7 mm Mauser 175 grains and .256 Mannlicher 160 grains. Also such heavy bullets are today much used for heavy game in sporting rifles. They were made long and heavy so as to give them the sectional density to make them effective at 1,000 yards at velocities around 1960 to 2300 f.s. in rifles, and for much longer distances in machine guns. For such velocities they required cases of fairly large powder capacity, such as those of the above cartridges. In these cartridges such velocities could be obtained with pressures not to exceed 40,000 pounds. In target shooting such bullets were capable of accurate work up to 1,000 yards, and the recoil in the above rifles, weighing about 9 pounds, was moderate. Such bullets when made in expanding type give very excellent killing effect on the largest American big game, and also on all moderate sized African game at moderate distances, that is to about 300 to 350 yards. These long bullets have the sectional density and remaining energy sufficient to smash through flesh and bone into deep seated vitals. In fact in their respective calibers it is doubtful if such bullets will ever be equalled from the standpoint of killing power alone. Even the small .256 or 6.5 mm Mannlicher bullet of 160 grains when fired at M.V. 2,300 f.s. has made a tremendous reputation the world over in the hands of British sportsmen on all moderate sized game, and our .30-40-220 Krag at M.V. 1,960 f.s. was eminently satisfactory for all American game. The sure hitting range of these heavy bullets is, however, limited by their trajectory. In 220 grains weight they cannot be given velocities in excess of 2,100 f.s. in the Krag cartridge, or 2,375 f.s. in the .30-06 cartridge, and this means trajectories such that it is a matter of luck to hit at estimated distances in excess of 300 yards. In the .300 H. & H. Magnum cartridge the 220 grain bullet can be given M.V. 2,700 f.s., and this would extend its sure hitting range to nearly 400 yards, but the recoil is such that it requires about a ten pound rifle and a strong man to shoot it with the fine accuracy necessary to hit at such a distance.

The **length** that any bullet can be given depends on a number of factors. It cannot be so long that the velocity it can be given, with permissible pressure, will not be sufficient to maintain its stability in a given twist of rifling. It must not be so long that when seated in the case to permissible depth it will increase the normal overall length of the cartridge, so that the cartridge will not operate through the magazine in a repeating weapon. And finally, the length of a bullet is limited between the point where its ogive touches the lands of the rifling, and the rear end of the neck of a bottle necked case below which the base of the bullet should not extend.

The ideal caliber for a long range rifle has often been said to be .280 or 7 mm. This is because this is the largest bore in which a bullet of the best ballistic coefficient (which in .280 caliber figures out to be a bullet of about 180 grains) can be fired in a 9 or 10 pound rifle without objectionable recoil.

Our .30-06 Springfield and Garand service cartridge (Ball Cartridge, Caliber .30, M2) contains a metal cased, **sharp point, flat base bullet** of 150 grains, and the muzzle velocity is 2,800 f.s. This has been our service cartridge since 1940. At M.V. 2700 f.s. this was also our service bullet from 1906 to about 1925 (Ball Cartridge, Caliber .30, Model 1906). Likewise a 154 grain bullet of the same shape is used in the 7.9 mm cartridge of the German Mauser service rifle at M.V. 2,800 f.s. Such light, sharp pointed bullets, sometimes called "spitzer" bullets, are very efficient projectiles at these initial velocities for military rifles and machine guns. In the rifle they give excellent accuracy to 1,000 yards at least, and exceedingly flat trajectory over 600 yards. In machine guns the sheaf of fire can be well controlled up to about 2,500 yards. In rifles of military weight (9 pounds) the recoil at the above velocities is moderate. For medium sized game pointed expanding bullets of the above weight and velocity are very killing up to about 250 to 300 yards. If the 150 grain bullet be given a muzzle velocity of 3,000 f.s., which can be done in the .30-06 cartridge with modern powders, the bullet seems to have a real explosive effect on deer, and kills almost instantaneously when it enters the chest or abdominal cavities. However, due to their relatively light weight, these bullets sometimes do not carry their destructive effect quite deep enough on larger, tougher animals.

In .22 caliber these light weight, pointed, expanding, bullets, weighing about 45 grains, and fired at about M.V. 2,500 f.s. or over kill instantly in all body shots on woodchucks, prairie dogs, jack

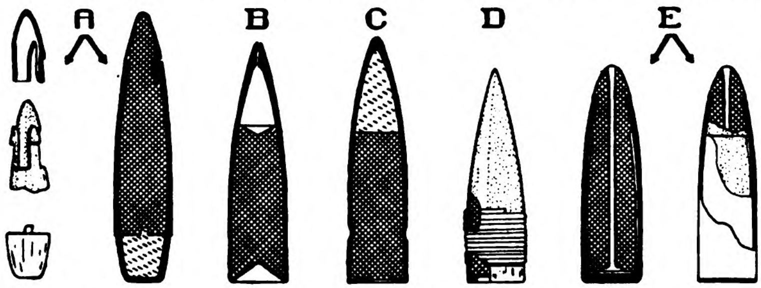

FIGURE 93. VARIATIONS FROM STANDARD BULLET DESIGN

Here are the details of some different types and designs of modern metal cased bullets, developed and tried out during the past two or three decades. All the examples shown are of .30 caliber projectiles, for use in standard American and British rifles.

A—Showing design and construction of a sporting and target bullet designed by the late Col. John Caswell, a noted African big game hunter of the 1st World War period. He intended this peculiar design to imitate the action and flight of a feathered arrow shaft, with heavy head forward and light parts to rear, and so designed his bullet; the base portion is filled with an aluminum pellet, as shown. Point is of patented expanding construction. Under actual tests, this bullet developed most favourable accuracy at short ranges but after traveling some hundreds of yards became erratic in flight and went off at unaccountable tangents.

B—A special target bullet developed by the late Sir Charles Ross for use in his .303 Ross rifle on the target range. This projectile has a hollow point, together with a coned hollow base, latter is solid with core inserted from point end, then point is formed by spinning the jacket walls together; sketch shows the seam. Jacket was of soft steel, tinned. This bullet developed high accuracy at long range.

C—The British 174 grain service Mark VII bullet, as loaded during the 1st World War. Forward portion of its bullet core is formed of aluminum, rear portion of lead. This construction gives a high ballistic co-efficient with superior ranging power, and the British cartridge is a very fine one in this respect.

D—Here is a fine flop, which was hung on the rifle shooting public just prior to the 1st World War—the famous "wire wound bullet" which was designed and marketed by a firm located in California. This freak conrabbits, etc. If the bullet be increased in weight to 55 grains, and be given a muzzle velocity of 3,500 f.s. or over (.22 Varminter and .220 Swift) they will likewise kill well on coyotes and wolves, and when the bullet enters the chest or abdominal cavity and explodes they will also often kill deer instantly. But the velocity is not sustained enough beyond 200 yards to cause such good kills on deer. The .25 caliber 100 grain expanding bullet at M.V. 2900 f.s. is likewise very effective on deer up to but not much beyond 200 yards.

If we lengthen this sharp point bullet, thus increasing its weight to about 180 grains in .30 caliber, or 130 grains in .270 caliber, or 117 grains in .25 caliber, we quite materially increase its ranging ability, its killing power, and sometimes its accuracy, and we also usually decrease the amount it is deflected by cross-winds, provided we give the bullet an appropriate velocity. While the 150 grain pointed bullet at M.V. 2,700 to 2,800 f.s. has proved to be a very satisfactory bullet for target shooting up to 1,000 yards, the 180 grain bullet at the same velocities is very noticeably superior to it in accuracy and wind bucking qualities. Not all of this increase in accuracy has been due to increase in weight, however, for practically all 150 grain bullets used in target shooting have been standard service bullets, while most of the 180 grain bullets so used have been manufactured in a very precise manner for expert long range target shooting. Whenever we consider the accuracy of any particular type, form, or weight of bullet we must also take into consideration the precision with which that particular bullet is manufactured. But the fact remains that the very finest long range accuracy in the world has been obtained with 180 grain pointed, full jacketed bullets of .30 and .280 caliber at about M.V. 2,700 to 2,800 f.s.

The chief reason why a light bullet (150 grains in .30 caliber) is

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sisted of a plain alloy bullet having its base protected by a heavy cup, or gas check, of copper, above which was wound several turns of insulated copper wire having its ends cast into the lead core. The windings were then well lubricated. Upon being fired, these windings naturally unwrapped and from then on the chief feature of this bullet came from the musical notes given forth as the wire tore loose. It was utterly worthless for any practical use when fired from a high velocity rifle.

E—This is a famous and well designed hunting bullet that had considerable merit. It is the late Chas. Newton's famous "insulated core" bullet, in .30 caliber. Drawing shows details of construction; it had a plain jacket of gilding metal and the lead core was protected for most of its length by a wrapping of heavy paper. Jacket was quite heavy, as shown. A light finishing nail ran the length of this assembly and prevented a too-rapid break-up of the bullet upon impact and also prevented deformation of the soft lead point from handling and when loaded into the magazine of the rifle.

preferred to a heavier bullet (180 grains) for military purposes is because of the heavier recoil given by the latter bullet. Secondary considerations are the weight of the ammunition, the erosion and wear on weapons, and the cost. To give a satisfactorily flat trajectory over 600 yards (which is now considered about the limit of aimed rifle fire in war) both bullets must be given a muzzle velocity of at least 2,700 f.s. For many good reasons the weight of the military rifle is limited to about 9 pounds. While a seasoned rifleman would not consider that a 180 grain bullet at M.V. 2,700 f.s. gave an objectionable recoil in a 9 pound rifle, yet the fact remains that its recoil, as compared with that given by a 150 grain bullet, is a very material factor in the time, effort, and ammunition required to develop a high standard of marksmanship among large bodies of troops. In the United States service the fact that the 150 grain bullet operated better in our Garand semi-automatic rifle than the 180 or 172 grain bullets was also another factor in the decision to go back to the 150 grain bullet about 1940.

In England the details that have influenced the weight and form of their military bullets have been slightly different. The original British small bore military rifle dating back to about 1893 was the .303 Lee-Enfield. Its original service cartridge fired a long, round nose bullet of 215 grains at M.V. 2,000 f.s. For certain very impelling reasons England has never been able to discard the Lee-Enfield rifle for one with a stronger breech closure to handle a heavier cartridge. Improvements in their service cartridge have thus had a pressure limitation of about 40,000 pounds, and have also been limited to the .303 case. When the advantages of a pointed bullet became evident they adopted a 174 grain bullet with a sharp point (Mark VII bullet) loaded to a muzzle velocity of 2,450 f.s., and have retained it ever since. This is a very excellent military cartridge, of fine accuracy, and moderate recoil and erosion, although it suffers somewhat by not having quite as flat a trajectory over 600 yards as might be desired.

Modern Forms. Taking all forms of projectiles—bullets, boats, automobiles, rockets, and airplanes—we find that all that are most efficiently designed for flight are more or less tapered at both front and rear. Those that are designed for relatively low velocity flight are tapered more at the rear than at the front. But that which is designed for the fastest flight of all, the bullet, is tapered sharply in front. The racing car and airplane both have rather blunt points, but considerable and long taper to the rear. Both are designed to fly at relatively low velocity. An airplane speed of 300 miles per hour is only 423 feet per second. But a bullet starting at 2,000 f.s. or over is preferably given a very sharp point. The demarcation velocity, where rear taper becomes more important than front taper, is apparently the velocity of sound—1100 f.s.—or slightly over.

Airplanes and racing cars contain engines which continually maintain their velocity, but a bullet receives all its propelling energy at the start only from the expanding powder gas, and as it flies its velocity constantly decreases until soon it falls off to 1100 f.s. or under, where a rear taper would be much more advantageous to its remaining flight than a sharp point. The velocity of our 150 grain service bullet, starting off at 2,800 f.s., is reduced to the velocity of sound when it has travelled about 1,200 yards. Therefore, for travel beyond 1200 yards it would be an advantage if this bullet were also tapered to the rear, that is, had a boat tail.

Boat Tailed Bullets

This brings us to the consideration of the boat tailed bullet. See its typical form in Figure 82. In World War I very considerable tactical use was made of "barrage fire" from machine guns at long and extreme ranges, sometimes exceeding 3,000 yards. Many guns could put down a sheaf of fire at long distances through which opposing troops could not pass, or only pass with numerous casualties. Or a barrage might be laid down on a very distant road, thus denying its use to the enemy. The United States entered World War I with machine guns shooting our service rifle cartridge, the Ball Cartridge, Caliber .30, Model 1906, shooting a 150 grain pointed, flat base bullet at M.V. 2,700 f.s. This cartridge had an extreme range of about 3,400 yards, and in machine guns its sheaf of fire could be controlled only to about 2,500 yards. This cartridge was entirely outranged by the machine gun cartridges of our enemies.

To determine the form of bullet which would be most effective at long ranges in machine guns the Ordnance Department of the Army at once established a testing station at Daytona Beach, Florida. There a long, flat, sandy beach was washed clean and smooth by each high tide, and at low tides bullets fired over it would show clearly by their impact on the clean beach where they had struck, and thus their range at each angle of elevation, their extreme range, and the extent and density of their sheaf or pattern at each range. Briefly it was there discovered that the most effective bullet we could fire in our .30-06 cartridge, within its pressure limitation, was one of about 170 to 175 grains, sharp pointed, and also with a taper or boat tail at its rear end. The greater the slope of the boat tail the greater the ranging ability of the bullet. But the amount of rear taper had to be limited to about one caliber, or .30-inch, in order to leave a long enough bearing of the bullet in the rifling. Within this limit a taper of 12 degrees was about the limit of effectiveness, but 9 degrees was almost as effective. A 172 grain bullet with a 9 degree boat tail .30-inch long could be given M.V. 2,700 f.s. within the pressure limit of 48,000 pounds. At that muzzle velocity it had an extreme range of 5,700 yards as compared with an extreme range of about 3,400 yards for the 150 grain flat base pointed bullet at the same velocity. Moreover, its sheaf or pattern was dense and could be controlled reliably and definitely up to about 3,500 yards as compared with about 2,500 yards for the old bullet. However, a little difficulty was experienced with obtaining good accuracy with this boat tailed bullet.

The problem of developing and manufacturing a satisfactory boat tailed bullet of this form was then assigned to Frankford Arsenal, the arsenal of the Ordnance Department of the Army where small arms ammunition is made. First experiments showed extremely poor accuracy. The bullets would not group in a three-foot circle at 600 yards. Many slight variations were tried with no material improvement. Finally as a result of conferences between the writer (who was then in command of the arsenal) and Mr. Matthews, the foreman of the bullet shop, the thought was advanced that the reason this boat tailed bullet did not shoot accurately was because it was not uniform enough, and also because it was not hard enough to pass through the bore without being deformed. No matter how uniform a bullet is made it will not shoot accurately if that uniformity is destroyed by any deformities it may receive in the bore before it passes out into the air.

Therefore it was decided to slightly increase the thickness of the gilding metal jacket, to harden the core, and to pass each completed bullet through what was termed a "rectifying die" at very heavy pressure. This die was very uniformly made so as to give each bullet as perfect a form as possible, and the die was changed as soon as it showed the least sign of wear. Compressing the bullet in this die would also result in hardening it materially. This did the trick. Thereafter these boat tailed bullets shot even more accurately than the previous 150 grain flat base bullets. Finally this bullet was tried in the National Matches of 1925, and found so splendid in every way that it was adopted as the service cartridge for both rifles and machine guns, and the cartridge containing it was called the Ball Cartridge, Caliber .30, M1. It continued to be the service cartridge from then until 1940.

Now for some of the facts about this bullet. Its angle of elevation for 1,000 yards at M.V. 2640 f.s. was 39 minutes as compared with 48 minutes for the 150 grain flat base bullet at M.V. 2,700 f.s. A 172 grain flat base bullet with the same point as the boat tailed bullet, and fired at the same velocity required an angle of elevation of 44 minutes at 1,000 yards, but up to and including 400 yards the two angles of elevation were identical. Therefore the boat tail did not show any advantage at all at short ranges where the velocities were very high, and it was not until 500 yards where the remaining velocity had dropped to about 1,800 f.s. that it began to show a slight advantage, and there only to about the extent of one minute. At 1,000 yards the boat tail showed about five minutes less angle of elevation as compared with a flat base bullet of the same weight. But beyond 1,200 yards, where the velocity had dropped below that of sound, the advantage of the boat tail was very marked.

The accuracy of the boat tailed bullet when carefully made was fully equal to that of flat base bullets. When a machine happened to be turning out exceptionally accurate boat tailed bullets they proved just as accurate at 1,000 yards and shorter ranges as the specially selected 180 grain Palma Match flat base bullets. For distances up to and including 300 meters, the most accurate .30-06 cartridge ever produced is the International Match Cartridge, which consisted of this 172 grain boat tailed bullet with a powder charge of 36.4 grains of Hercules HiVel powder, the muzzle velocity being about 2,200 f.s.

The diameter of the bearing portion of this bullet was about .3084 to .3087-inch. It gave its best accuracy in bores having a groove diameter of .308 to .3084-inch, but shot very accurately in bores as large as .309-inch. The writer has no data on its accuracy in larger bores. There was no trouble from metal fouling and the bores were as easy to clean as when using flat base bullets. The first shot fired from a clean, cold bore would almost always be found well within the group of succeeding shots, with apparently no tendency for this first shot to strike high or wild.

This cartridge did give slightly more erosion than the 1906 cartridge, as might be expected, for it is a much heavier cartridge. After about 7,000 rounds had been fired with it barrels gave the same appearance and showed about the same falling off in accuracy as from firing 9,000 rounds with 1906 ammunition. As a result of further experience it is thought that the shape of the base of a boat tailed bullet tends to "funnel" the hot gas in between the sides of the bullet and the neck of the case and barrel walls, and there is more evidence of gas cutting, which is a form of erosion.

In this connection, for a number of years around 1930 the Massachusetts Rifle Association at their Walnut Hill range held almost weekly a 500 yard rest match. Rifles were fired from a bench rest. Any rifle, any sights, and any ammunition were permitted, and the target was divided by fine scoring lines. This match was won regularly and almost exclusively by Mr. Philip Nutting of Cambridge. He used a .30-06 Springfield Type T heavy barrelled match rifle, and his load was the International Match load above referred to. After firing 9,000 rounds of this ammunition, all slow fire, of course, and barrel never excessively heated, Mr. Nutting noticed a slight amount of erosion and a slight falling off in accuracy, so he loaded his bullets protruding a little further out of the case so they would extend further into the slightly eroded leade, and touch the lands. This restored the fine accuracy, and it so remained for 5,000 additional rounds, when the experiment came to an end due to the death of Mr. Nutting. The writer was privileged to see a number of his 10-shot 500 yard groups which were often within four to five inches extreme spread.

Finally, about 1940, this 172 grain boat tailed bullet was discarded for service use in the United States Army, and was replaced by the former 150 grain flat base bullet for the following reasons.

1. Long range barrage fire had lost its tactical importance in modern warfare.

2. As compared with the 150 grain bullet, the 172 grain bullet gave greater recoil which increased the difficulty and time consumed in training troops to a high degree of marksmanship.

3. The 150 grain bullet functioned better in machine guns and semi-automatic rifles than did the 172 grain.

4. The cost of the 150 grain bullet was less, it used a smaller amount of critical raw materials, and it gave less erosion than the 172 grain bullet.

5. In extreme quantity production in war it was very much easier to maintain the prescribed standards of excellence for the ammunition with the 150 grain bullet than with a boat tailed bullet.

From an analysis of the above it will be seen that practically speaking the only advantage of the boat tailed bullet is in machine guns. It presents no advantage, or only a microscopic advantage in a rifle. Particularly in a rifle to be used for sporting purposes, always under 400 yards, it is no advantage at all.

Theoretically a boat tail would be a slight advantage in a bullet to be fired at very low velocities, such as a revolver bullet, and bullets for rim fire cartridges. But the increased cost of manufacture, and the difficulty of obtaining fine accuracy would be out of all proportion to the advantage gained.

Streamlined Bullets

Theoretically the most efficient bullet ballistically would be one with a long streamlined form, long and sharp pointed at both ends as shown in Figure 82. Such a bullet having no broad and distinct surface on which to bear in the bore, has to be fired with a sabot which is a form of wad made of copper, fiber, or plastic, and intended both to confine the powder gases behind the bullet, and to cause the bullet to rotate with the rifling. The sabot is supposed to leave the bullet at the muzzle. The form of sabot shown in Figure

82, so far as the writer knows, was designed by Mr. A. O. Niedner about 1915, and he conducted some interesting experiments with it about that time. His bullets were accurately turned of steel, as he found it impossible to make a bullet of this form of heavier material (lead) that would not be deformed on firing. His sabot was made of copper, and had a cavity below the rear point seat as shown. When the assembled bullet and sabot were fired, and while still in the bore, the inertia of the bullet plus the forward movement of the sabot, made the bullet set back and wedge itself tightly in the sabot. This the bullet could do because its point was unsupported and could extend down into the open cavity below it. The bullet, tight in the sabot, thus received the full rotation from the rifling. But the instant the assembled bullet and sabot left the muzzle the side pressure between bullet and sabot was released, and the tightly compressed sabot sprang away from the bullet completely without disturbing the bullet's alignment. Air resistance also helped to part the bullet and sabot, and the bullet did continue its flight alone, while the sabot soon fell to the ground. In Mr. Niedner's experiments these streamlined bullets shot with remarkable accuracy, but he had no facilities for testing their ranging ability.

Experimenting with stream line projectiles is an interesting ballistic pastime, and it is possible that at some future date such a projectile may be of value in heavy, long ranged ordnance. But it is doubtful if it will ever be developed into a practical bullet for small arms.

Revolver and Pistol Bullets

So far as the flight of the bullet is concerned we are not interested in the trajectory of hand gun bullets because the effective range is so short that over it any trajectory is flat. Velocity is important only in so far as it effects stopping or killing power. Nor are we interested in expanding bullets because at the velocities that are obtainable in revolvers and pistols lead will not expand unless we so lighten and weaken the bullet as to rob it of its penetrating and stopping power which was what we hoped to obtain from expansion. We are, however, deeply interested in accuracy and light recoil.

Everything points to a light, short bullet for pistols and revolvers. If we also give it a large diameter that will help to increase its stopping power, as will a flat point. To be of use for practical shooting a handgun must not weigh over 2½ pounds, and the recoil must not be excessive at that weight. The maximum weights of bullets that we can use at velocities high enough to give good stopping power, without causing excessive recoil, are about 250 grains in .45 caliber and 160 grains in the so called .38 calibers which are really .358 caliber.

To obtain good accuracy all experience has proved that the bullet should be large enough to fit to the bottom of the grooves, but if we make it larger than groove diameter we are liable to increase pressure and recoil to an undesirable degree. In revolvers, lubricated lead bullets are quite essential as metal jacketed bullets quickly wear out a revolver, allowing gas cutting and making the mechanism shaky. However, a slightly copper plated lead bullet is not objectionable, provided it is lubricated.

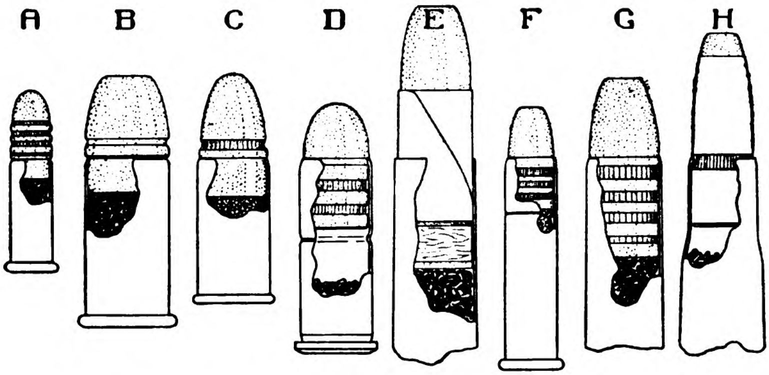

FIGURE 94. CARTRIDGE LUBRICATION AND LOADING METHODS

A—Showing a present day .22 Long Rifle cartridge, with outside lubricated heel bullet securely crimped into the case. For many years after its introduction, this .22 LR was an uncrimped cartridge with the bullet merely seated down into the case with no crimp; it was recommended as the most accurate type of loading for target ammunition. The lubrication used on present day ammunition of this type is a great improvement over the earlier types of hard grease.

B—The .44 Henry Flat cartridge, as loaded some 60 years back. This shoots a heel bullet, outside lubricated. Bullet is heavily crimped down onto a case full of black powder and the entire front end of case and bullet dipped into a mixture consisting mainly of beeswax. Cartridges such as this were a sight to behold once they had been dropped in dirt or sand, and by the time this dirt was cleaned off most of the lubricant had gone along with it. Such early lubricant melted easily in the summertime and cracked off in thick flakes in winter; after such cartridges had been carried around or kept for any length of time they had generally shed most of their lubricant.

C—An early .38 S. & W. revolver cartridge, center fire, with outside lubrication, black powder. Its single cannelure was not intended to hold all of the lubricant as a heavy coating was also spread over the entire bullet and front end of the case.

In automatic pistols we cannot give the bullet a very flat point to increase its stopping power as considerable curve to the point is essential for reliable loading from magazine into the chamber, so most automatic pistol bullets must have more or less rounded points. Also metal cased bullets function through automatic pistols more reliably than lead bullets, although it is possible to use a lead bullet with a metal cased tip.

D—One of the first examples of center fire, inside lubricated ammunition, the .38 Colt Long revolver cartridge. On its bullet all lubricant was forced into the two bullet cannelures and the bullet then seated down into the case so these cannelures and their lubrication were covered and protected by the neck of the case. Such ammunition was a great improvement over the earlier types, as it could be carried loose in the pocket without picking up dirt and foreign matter, or of losing the lubricant. This cartridge is shown loaded with Bullseye smokeless powder and it will be noted that the charge fills but half of the powder chamber, a bad fault as often a double charge would become loaded into a case and the gun burst from the resulting excessive pressure. For a great many years this .38 Colt Long was the service cartridge of the U.S. Army and the Navy, but in 1911 it was supplanted by the .45 Automatic.

E—The .40/70 Sharps Straight cartridge, loaded with a paper patched bullet seated down into an uncrimped case. Lubrication was supplied by a thick wad of beeswax, seated below bullet and between two tough pressboard or jute wads, with a caseful of black powder underneath. This was the most accurate type of target ammunition of its day and it was the practice to clean out the bore after each shot. The paper patch blew off the bullet as it left the muzzle and the unmarred bullet gave superior accuracy.

F—The .25 Stevens cartridge, one of the few rim fire cartridges with inside lubrication. This was a very popular hunting cartridge in its day, but has only been loaded to black powder velocities.

G—Another example of center fire cartridge with inside lubrication, the .38/55, here shown loaded with a case full of black powder and the 255 grain lead bullet, the latter crimped in place. This was a very accurate target and hunting cartridge and was one of the most popular of its day.

H—An example of present day ammunition, the .250 Savage loaded with the 87 grain soft point bullet and smokeless powder. Such modern ammunition is never lubricated, but fires a dry metal cased bullet which needs no lubrication.

CHAPTER XII

AMMUNITION

The Loaded Cartridge

SO FAR we have dealt only with the components that go to make up the completed round or cartridge. We here take up the cartridge as a whole.

Each of the components has been more or less inspected and tested during its manufacture, and we may assume that they come to the point of assembly into the completed cartridge in a more or less perfect form. They are then assembled into the cartridge in such manner that the latter can be introduced and loaded into the gun in a satisfactory manner, and with a single motion of the hand or gun mechanism. The assembled cartridge must fit the gun properly, and must be suitable, satisfactory, and safe in every way for it. As we shall see, there is much more to this than simply seating a primer in the case, putting in the right amount of powder, and then seating the bullet to the required depth. The matter is best explained by describing certain details of the loading of cartridges in a modern factory.

The Factory Loaded Cartridge

The gages that are used in the manufacture and inspection of both gun and cartridge are standardized with the master gages retained in the laboratory of the factory. This insures positively that a cartridge passed by its gages will surely fit in the gun for which it is intended.

The first operation is the insertion of the primer in the case. This is done in a machine that insures straight line insertion of the primer cup just to the bottom of the primer pocket, and no further, and without any distortion of the primer. After insertion a stylus places a drop of shellac on each primer, which seeps down between primer and pocket walls, and makes the cartridge waterproof at the rear end. Military cartridges further have the primers crimped into their pockets as an insurance against dropping or blowing out, particularly in automatic arms. An automatic device on the priming machine insures against a case having no primer, one too shallowly or too deeply seated, or one seated upside-down. The primed cases then have one hundred percent visual inspection.

In some factories a cone-headed plunger, attached to the priming machine, is inserted in the mouth of each case and very slightly bell-mouths the case so the bullets will center the case mouth and enter without scraping, and also to prevent the base of a bullet coming down on the wall of a case and crushing the wall. In other factories this operation is performed on the loading machine just prior to insertion of the powder.

The primed cases then go to the loading machine where they are fed on circular dials, mouth up, under the mechanical powder measure which drops just the right amount of powder into each case. The case then passes a plunger which drops down inside the neck of the case until it rests on the powder charge. If this plunger goes down too far, or not far enough, indicating too small or too large a powder charge, it stops the machine at once. Further along on the dial plate the case comes under the bullet seater which inserts the bullet to the correct depth, and under another plunger which crimps the case on the bullet. However, some cartridges are crimped on special crimping machines.

The loaded cartridges then go to an automatic gaging machine which rejects any cartridge that is over or under size in any respect. Some factories also have an automatic weighing machine which rejects any cartridge over or under the tolerances in total weight.

A certain percentage of the cartridge manufacture each day is sent immediately to the testing range where it is tested by expert shooters or "targeters" usually by shooting from a bench rest at a target at from 25 to 100 yards range. If the group, usually of five or ten shots, comes within the established standard for accuracy, and if each cartridge functions perfectly in the arm, they pass this inspection. There are also other tests for pressure and velocity, and military cartridges have a still further test for bullet pull, that is the force required to pull a seated bullet straight out from the case. Finally the cartridges are given a last visual inspection and pass to the packing department, and then to the shipping room or storage.

About forty percent of the cost of manufacture of a cartridge lies in its gaging and inspection. Notice certain details in this factory cartridge. The primer seating is waterproofed. The bullet is crimped in the case to insure against its dropping out, getting loose, or being forced down into the case beyond standard depth. Crimping is very necessary in a factory cartridge to be handled by every Tom, Dick, and Harry, although in some instances it may be slightly prejudicial to the very finest accuracy.

The bullet is seated to a standard overall length of completed cartridge, which length is usually such that it insures that when the maximum cartridge is inserted in the minimum chamber the ogive of the bullet will just touch the origin of the lands in the leade. Thus, in the majority of cases when the normal factory cartridge is seated in a normal chamber, the ogive of the bullet does not quite touch the lands, and when a minimum cartridge is inserted in a maximum chamber it may come quite a little way from this land contact. Elsewhere we have said that such land contact is desirable for the finest accuracy, but it cannot be obtained with quality production of cartridge and rifle. If it were attempted some cartridges would be sure to fit too tightly in some weapons, the breech of the weapon could not be closed without prohibitive effort, and when a loaded cartridge was extracted the bullet might pull out and remain in the bore.

Of course when a minimum cartridge is inserted in a maximum chamber it will be a relatively loose fit therein. It will not line up perfectly with the bore, but will drop to the bottom of the chamber from gravity, or assume that position into which it is forced by the spring of the extractor. But imagine what a complaint there would be if an occasional user obtained cartridges that he could not get into his gun, or get them in only with extreme effort!

It is on these matters of crimping, short overall length, and loose fit that the handloader bases his contention that he can load cartridges of his own that are more accurate than the factory product. So he can in many instances, for use in his own individual weapon, but his hand loads might be very unsatisfactory, impossible to load, or positively unsafe in an occasional arm that had no fault other than being very slightly larger or smaller in some details than his own piece for which he made his cartridges. Also in practically every case a handloader can be relied upon to handle his own ammunition and gun with much greater care than the average hunter and soldier will bestow on his.

The following defects may be found in rifle and pistol cartridges during or after firing.

(a) **Misfire.** Primer shows a normal impression of firing pin. Indicates that the primer is defective. May be caused by too thick metal in cup; too thick primer pellet which cushions blow; no priming mixture; no anvil; no vent, and various combinations of these.

Primer shows light impression of firing pin. May be caused by a mechanical defect in weapon; short or broken firing pin; weak firing-pin spring; bolt not completely closed; grease in firing pin hole or around firing pin; primer seated too deep in primer pocket; too little headspace in cartridge (shoulder too far to rear); defective primer.

Primer shows normal indentation but off center. Due to a defect in weapon.

(b) **Hangfire.** Delayed ignition may be caused by a small or decomposed primer pellet; damp powder; or light blow of firing pin.

(c) **Pierced primer.** This may be caused by an improper firing pin that is too sharp, or too sharp at edge, or that protrudes too far beyond breech face; or very thin metal in the primer cup.

(d) **Primer leak.** Gas escapes between primer cup and pocket. Caused by too large a primer pocket, too small a primer cup; too large a flash hole in bottom of the primer pocket, or too heavy pressure in the cartridge.

(e) **Blown primer.** Primer is blown completely out of primer pocket. Same causes as primer leak, but exaggerated.

(f) **Primer setback.** Primer protrudes beyond head of case or is flattened out over case head. Caused by excessive headspace either in weapon or cartridge, too thin a head to case; or excessive pressure.

(g) **Leak at back of case.** Gas escapes through a hole or crack in case, discoloring case, and may escape into breech action. Caused by defective case, usually scale or other defect in case metal.

(h) **Failure of case to extract.** Due to faulty extractor; defect in cartridge case; heavy pressure which expands case and causes it to hug the chamber walls tightly, or too soft anneal of case.

(i) **Blow back.** Any escape of gas to rear caused by pierced primer, blown primer, primer setback, or ruptured case is referred to as a blow-back.

(j) **Split neck.** Neck of case splits on firing, and sometimes allows an escape of gas. Usually caused by season cracking. If case did not show a season crack when examined before firing, it may still be due to the weakening of the case just before season cracking actually occurred.

(k) **Split body.** A more or less regular longitudinal split in the body of the case, allowing gas to escape. Due to defective brass, probably scale, or to a deep draw scratch.

(l) **Separation.** The case splits in two completely around its body, usually a short distance forward of the head, and the head only extracts, leaving the forward portion of the case in the chamber. Or it may be only a *partial* circumferential separation. Almost always due to excessive headspace either in the weapon or the cartridge.

(m) **Complete rupture or blowout.** The entire head of the case blows out allowing a large volume of gas to escape to rear, which may wreck the breech mechanism and splinter the stock. Brass may flow over the bolt head. Caused by very excessive breech pressure, or by slightly excessive pressure combined with excessive headspace, or by very soft anneal in the head of the case.

The following defects may be found in rifle and pistol cartridges during inspection.

Name of Defect	*How to Recognize*	*Cause and Precautions*
Body or shoulder split	Visual or pressing on case.	Improper annealing, weak structure, strain. Do not fire.
Corrosion	Green, blue, yellow or white colors. Not to be confused with darkening of brass with slight age.	May cause rupture when fired. Interferes with chambering. If corrosion is advanced should not be fired.
Crease	Similar to a fold in case neck or shoulder.	Thin metal at crease spot. Do not fire.
Draw scratch	Longitudinal scratch on case.	Caused by grit in draw dies. If deep do not fire.
Folded neck	Overlapping of metal in case and neck indicated by longitudinal protuberance.	Metal thinner on one side; insufficient annealing.
Indent and bur	Dent and burring.	Rough handling. Dangerous only if large or deep.
Inset primer	Primer too deep in pocket.	Likely to misfire.
Loose round	Bullet loose in case.	Should not be fired.
Mouth pull-down	Mouth of case shoved to one side or down by bullet when seating.	Case not chamfered. Mouth anneal very soft. Do not fire or load.
Oil dent	Smooth surface indent in or near shoulder or neck of case.	Excess oil used in tapering or resizing. Negligible unless very large.
Round head	Head of case beveled on outer edge.	Too little metal to form head properly. Troublesome extraction.
Scale	Impurities in case metal, sometimes invisible.	May cause case to break or split, and gas to escape.

Name of Defect	*How to Recognize*	*Cause and Precautions*
Season crack	Longitudinal split in neck.	Due to strain and severe weathering conditions usually over long period. If fired shot may not strike mark.
Short round	Bullet seated too deep.	Not serious unless base of bullet extends well below neck. In pistol cartridges do not fire.
Shoulder bulge	Pucker at junction of shoulder and body.	Metal too soft or thin. Also by forceful seating of bullet.
Split mouth	Split in edge of mouth of case.	Caused by plugging or chamfering operation.
Thick head	Head thicker than maximum allowed.	Gives trouble in loading. Bolt won't close.
Thin head	Head thinner than minimum allowed.	Extractor may pull through thin metal of head.

The following precautions should be taken in handling rifle and pistol cartridges. They should be protected from mud, sand, dirt, and water, and if they get wet or dirty they should be wiped off at once. Verdigris or light corrosion should be wiped off. However, cartridges should not be polished to make them look better or brighter. Cartridges should not be exposed to the direct rays of hot sun for any length of time as the heating would temporarily increase the pressure and cause the bullet to strike high by increased velocity.

Cartridges should never be greased or oiled, and the bullets should not be greased. Grease on the cartridge or in the chamber creates excessive and hazardous pressure. It operates to reduce the size of the chamber and thus increases the density of loading and the pressure. Also there is no adhesion of the case in the chamber, and when fired the case slips back easily and the bolt head receives a greater rearward thrust. This does not apply to rim fire cartridges.

Whenever cartridges are taken from the pasteboard cartons or bandoleers the carton or the paper slip which comes in the bandoleer should be preserved as it contains the lot number of the ammunition which may become necessary should any defect in the cartridges have to be reported. On commercial cartons the lot number is usually indicated by numbers and figures stamped on with a rubber stamp.

Defective cartridges should be destroyed. The safest way for the ordinary person to do this is to throw them into a deep river or lake. Or if there be no such body of water available, place them in a hot fire and at once retire to at least 200 yards. The cartridges will explode one at a time, the bullet flying in one direction and the case in another, but seldom flying more than two hundred yards. It is safest to build the fire up but not ignite it until the cartridges have been placed on top of the pile. Do not throw cartridges in a stove.

Clips and Chargers

Cartridges for use in certain military rifles, notably the Mannlicher, Mannlicher Carcano, Mauser 1898, and Springfield 1903 are usually issued assembled in clips containing five or more cartridges. By means of the clip, all the cartridges contained in it can be inserted into the magazine of the rifle in one motion instead of having to insert the five or more cartridges one at a time. This enables the shooter to fill the magazine very quickly, and greatly increases the rapidity of fire for more than one magazine full.

The older types of Mannlicher rifles such as the Mannlicher Carcano (Italy) and the Dutch Mannlicher (Holland), with single column magazines that projected down below the stock in front of the trigger guard, used a steel clip which inclosed the heads of the cartridges and the bodies about half way up their sides, but was open at top and bottom. The bolt being opened, this clip with the five cartridges in it was pressed down into the magazine in one motion. Without withdrawing the clip or stripping the cartridges from it, the bolt was then closed, forcing the top cartridge out of the clip and magazine into the chamber. The clip remained in the magazine until the five cartridges had been fired, when it fell out of the bottom of the magazine, clearing the latter for the insertion of a new clip. Cartridges could not be inserted singly into the magazine, the clip being essential for holding the cartridges in the magazine.

The clip for the Garand rifle is of similar type. It is a steel box, open at top and bottom, its sides fully inclosing the cartridges. It holds eight .30-06 cartridges arranged in a double column. The bolt being open the clip, either top or bottom up, is inserted through the magazine opening and is pressed down into the magazine, where it is retained against springing up again by a catch. The bolt is then pulled back slightly and allowed to go forward, carrying the topmost cartridge from the clip and magazine into the chamber, and closing and locking the rifle ready to fire. All cartridges feed in a similar manner from the clip into the chamber. Single cartridges cannot be fed into the magazine, nor can the magazine be filled with cartridges unless they are contained in a clip. When the last (eighth) shot has been fired the empty clip jumps upward out of the rifle, leaving the bolt open ready to insert another clip. The operation of loading the clip is almost fool-proof, and bungling seldom occurs.

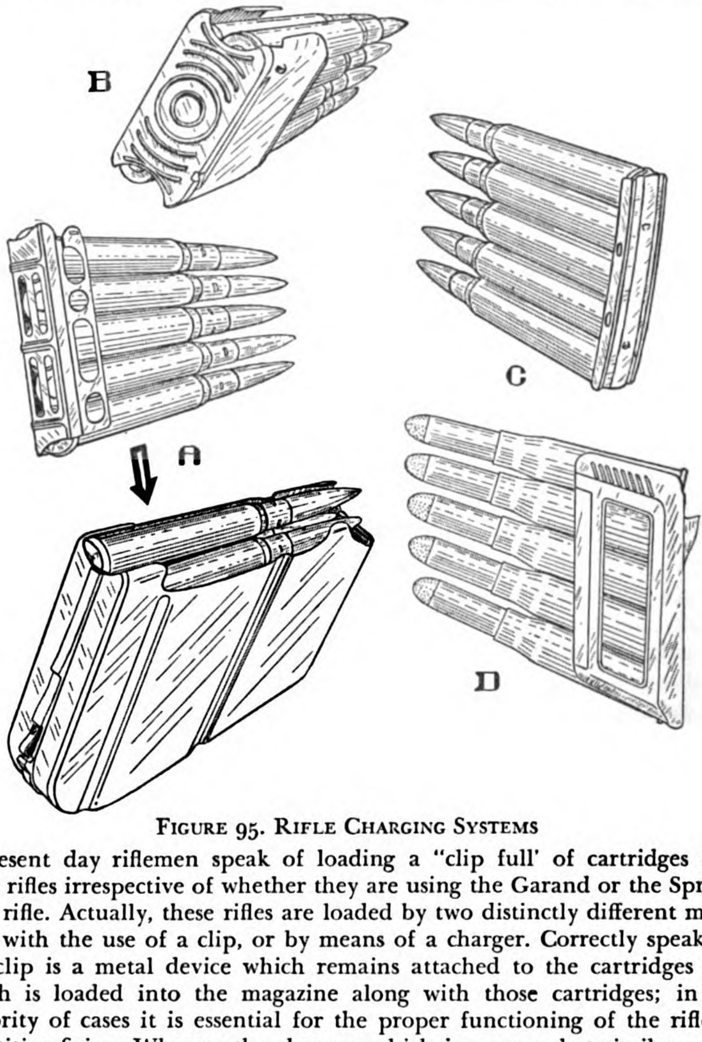

FIGURE 95. RIFLE CHARGING SYSTEMS

Present day riflemen speak of loading a "clip full' of cartridges into their rifles irrespective of whether they are using the Garand or the Springfield rifle. Actually, these rifles are loaded by two distinctly different methods: with the use of a clip, or by means of a charger. Correctly speaking, the clip is a metal device which remains attached to the cartridges and which is loaded into the magazine along with those cartridges; in the majority of cases it is essential for the proper functioning of the rifle in repetitive firing. Whereas the charger, which is a somewhat similar metal device, is used only as a means of filling the magazine of a bolt functioning action but does not enter into its magazine and is discarded when emptied.

A—Illustrates the method of loading the .303 British Lee Enfield rifle

The clip for Mauser 1898 types of rifles, including the Springfield 1903, operates on a different principle. The light brass clip holds five cartridges together by their heads only, the extraction grooves of the cartridges fitting into a slot in the clip. The bolt being open, either end of the clip is inserted into the clip slot located at the forward end of the bridge of the receiver. The five cartridges then stand, bullets to the front, just above the magazine, the cartridges being held in a single column stack by the clip. The thumb is then placed on the topmost cartridge, and with one motion all five cartridges are then pressed straight down into the magazine, the cartridges being stripped out of the clip in the process. Closing the

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which, according to the Englishman, is "charger loading." At bottom is shown the magazine of the early models of the British Enfield, which is detachable and can be removed, just as we can take the magazine out of any "box magazine" repeating rifle. Originally, this is how the rifle was loaded, by means of a number of separate magazines carried on the soldier's belt; and it might be noted also that when originally designed these Lee magazines held but seven cartridges, arranged in single column. Later on, this Lee Enfield magazine was redesigned to accommodate two rows of cartridges and its capacity thereby increased to ten. The British Enfield of today holds ten cartridges, loaded into the magazine from above by two chargers of five cartridges each, shown as **A.** This is an odd and not any too satisfactory charging device, due to its having to accommodate rimmed cartridges, which must be carefully "staggered" into the charger as shown above. It was an afterthought, the British Lee rifle having been designed about 1888, and loading by means of a charger adopted around the year 1907 when the use of the spitzer bullet became universal. The arrangement is, therefore, a not-any-too-good compromise as these chargers frequently jam or spill their cartridges when loading the magazine.

B—The 8-round packet of cartridges for use in the Garand rifle. This is a true "clip loading" rifle and this clip is shoved into the magazine along with the cartridges; the Garand rifle will not repeat unless this clip is in position in its magazine.

C—The Springfield "clip." Actually this is a charger, which fits into slots in the rifle receiver as its five cartridges are swept out and down into the magazine, the empty metal strip then being thrown aside. However, in the American service it has always been called a "clip." Unlike the British service rifle, the Springfield, its .30'03 cartridge, and its clip-of-five loading system were all designed at the same time, the one for the other—and the designers did a mighty good job of things while they were at it.

D—The clip for the 8 mm Steyr-Mannlicher straight-pull rifle. This is a true clip, loaded into the magazine with its cartridges and necessary for proper functioning of the rifle. This is an odd clip in that it can only be loaded into the magazine from one end, with bullets slanted upward, as shown above, it fires a rimmed cartridge and these must be arranged into the clip with the rims positioned so they will not jam when leaving the clip. Sporting ammunition is shown, with soft pointed bullets.

bolt then knocks the clip aside out of the clip slot, and forces the topmost cartridge from the magazine into the chamber, leaving the rifle ready to fire. With this type of rifle it is also possible to load one or all five cartridges singly into the magazine without the clip, or at any time to open the bolt and load one or more cartridges into the magazine so as to continually keep up its contents of five cartridges. The soldier must be well trained in the operation of this type of clip for if the thumb be not pressed squarely above the center of the top cartridge, and the cartridges be not pressed

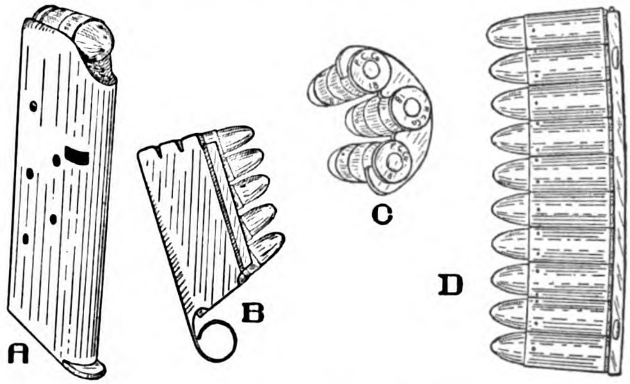

FIGURE 96. PISTOL CHARGING SYSTEMS

A—Shows magazine for the .45 Colt Automatic pistol, where cartridges are previously inserted into magazine one at a time and the loaded magazine shoved into the butt of the pistol when needed. This type of magazine is used over and over. However, some few automatic pistols have been fitted with a less elaborate magazine, cheaply made and intended to be thrown away when once emptied; in the present war most of the submachine guns are loaded with these "expendable" magazines. This is also a common type of magazine with .22 caliber bolt action rifles. It should not be called a "clip."

B—A clip of ammunition for the Bergmann automatic pistol, the 6.5 mm Bergmann cartridge. Clip and cartridges are both loaded into the pistol magazine, the clip generally being essential for proper functioning of cartridges into the pistol chamber.

C—The distinctive clip used in the .45 S. & W. and Colt revolvers designed in 1917 to shoot the .45 Automatic pistol cartridge. This clip must be left attached to the cartridges when loading these revolvers; two clips comprising a loading. In the case of the first Colt revolvers furnished for this combination, the clip was essential as it positioned the cartridges in place for firing; in the S. & W. revolvers the chambers were more accurately bored and each chamber had a shoulder upon which the mouth of the cartridge case positioned. Later, both makes were so chambered. With either revolver, the clip is necessary for proper ejection of the fired cases.

straight down into the magazine, the stack of cartridges is liable to stagger and buckle, and the clip "spill" causing a jam that may take ten seconds or more to rectify. With proper training there is no trouble. This type of clip is, in reality, a charger and is termed such by the British and Europeans.

Small steel clips holding three cartridges are also necessary to load the .45 Colt Automatic (rimless) cartridge into the Colt and Smith & Wesson Model 1917 revolvers, but more particularly to extract fired cases or loaded cartridges from the cylinder. Single cartridges can be loaded into the cylinders of these revolvers, one at a time, without the clip, but the extractor will not operate on the rimless heads of these cartridges, and without the clip it would be necessary to insert a stick or pin in the mouths of the chambers and punch the fired cases out of each chamber from the front. This steel clip holds the extraction groove of three cartridges in a semi-circle ready to be inserted in one motion into three adjacent chambers of the cylinder. A second clip completes the loading of the cylinder which is then closed, the clips remaining on the cartridges. When the cartridges have been fired the extractor operates on the rims of the clips and easily extracts them and the contained fired cases from the cylinder.

To obviate the use of these revolver clips the commercial cartridge companies manufacture a cartridge known as the .45 Colt Auto Rimmed, which has a rim, and is intended only for use in these Model 1917 revolvers and not in the automatic pistol, but in the Army the regular rimless cartridge is always issued assembled in clips for those troops armed with these revolvers.

In warfare it is presumed that the above three types of clips will be discarded and thrown away when once used, but in time of peace they are salvaged and again loaded with cartridges.

The little box magazines used with .22 caliber bolt action rifles, and also the box magazines used with such larger rifles as the Browning Automatic rifle (BAR) the Winchester Carbine M1, the Colt automatic pistol, and the Thompson "Tommy Gun" are sometimes called clips, but this is a misnomer. They are complete magazines, including the magazine spring, and are inserted in the magazine well of the receiver from below, where they are retained by a magazine catch. These detachable box magazines are filled, when detached, by pressing cartridges singly into them, sliding each car-

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D—Illustrates a "clip" of cartridges for the Mauser pistol, these being the seldom-seen 9 mm Export cartridges. Actually, this is a charger which fits into slots on top of the receiver to allow the ten cartridges to be swept out of the holding receptacle and into the pistol magazine, after which the charger is discarded.

tridge in turn backward so that its head comes below the lips at the top of the magazine. By having two or more of these box magazines rapidity of fire for more than one magazine full is obtained. Care must be taken with detachable box magazines that the lips that hold the head of the topmost cartridge in exactly the right position to be forced by the bolt from the magazine into the chamber, are not deformed by rough handling. When only slightly deformed they can usually be bent into correct shape again with the fingers.

In late years the box magazines for certain military automatic rifles have been made cheaply of sheet metal with the idea that in combat they will be expended when their contained cartridges have been fired, and will not be salvaged.

Care of Shotgun Shells. Normal atmospheric variations in a temperate climate will not affect the ballistic properties of loaded shotgun shells. Paper shells that are allowed to become alternately damp and dry may develop a loose crimp, which, in turn, loosens the shot charge and has the effect of lowering both velocity and pressure. Also a paper shell which has become too dry shrinks in diameter and length, the crimp offers more resistance, and there is a tendency to develop higher pressures and velocities. The converse is also true; a damp case expands and weakens the crimp, tending towards lower pressure and velocity, and the shell may expand to such an extent that it cannot be got in the gun.

Hand Loaded Cartridges

The well informed and careful handloader of rifle and pistol ammunition makes continual visual inspections of his components, of each of the loading operations, and finally of the completely loaded cartridge.

The hand loading starts with either new primed cases which are purchased from the factory, or with cases that have been fired one or more times. In either event he inspects each and every case to see that it is in suitable condition for loading. Dirt, corrosion, cracks, dents, or splits are causes for rejection.

If the cases have never before been loaded—that is if they are new primed cases—or if they are cases that have been fired only once with the factory load, they should be slightly chamfered at the mouth with a reamer. It is assumed that this has already been done to cases that have previously been *re*loaded. It is necessary to do it only once when bullets have not been crimped in the case.

If the cases have been fired in the handloader's own weapon, and are intended to be used again only in that weapon, they should be resized at the neck only to make the bullet secure. The neck should also be expanded to bullet diameter inside. This is not necessary, of course, with new primed cases unless the cases are to be reloaded with oversized lead bullets.

If fired cases are to be used in weapons other than the one in which they were originally fired they must be tried in the weapon in which they were to be used to see that they chamber correctly, or else they must be full body resized in addition to the neck resizing above. When resizing the body care must be taken with rimless cases to see that the headspace measurement of the case is not disturbed; that is that the shoulder is not set back. A headspace gage will probably be necessary for this inspection or setting of the resizing die.

While priming the empty cases the handloader can tell, by the pressure required on the handle of the tool, whether the primer is entering the pocket normally, or whether the fit is too loose or too tight. After they are primed the cases can and should be inspected to see that each has its primer; that no primer projects above the head of the case, that no primer is too deeply seated, and that none is upside down.

The selection of the proper powder charge to use from the tables, the setting of the powder measure, and finally the actual weight of the charge thrown, should all be checked at least twice. After the cases have been filled with powder each should be checked in a good light to see that the powder charge stands at the normal height in the case. This will prevent cartridges with too light or excessive powder charges.

After seating the first bullet the overall length of the cartridge should be checked to see that the bullet has been seated to the correct depth. Otherwise adjust the bullet seater.

In seating bullets note the normal pressure on the tool handle required to seat the bullet. For accurate shooting reject all loads where this pressure is noticeably lighter or heavier than normal.

Finally inspect the loaded cartridges visually. Stand all upright on a level surface and note that all bullet points are at a uniform height indicating that all bullets have been seated to a uniform depth. Lay all on their sides and see that all primers have been seated correctly, and particularly that no primer is upside down or has fallen out in the loading operations. Rotate each cartridge in the hand to see that there are no defects, and particularly no splits in the sides of body or neck. With cartridges to be used in warfare, on dangerous game, in important shooting matches, or on important shooting trips, pass each cartridge through the magazine and chamber of the weapon to see that it fits normally.

Pack cartridges in a box containing a card giving the complete loading data, approximate number of times the cases have been reloaded, and the date of loading.

Figure 97 shows a factory loaded .257 Roberts cartridge in comparison with a similar cartridge carefully assembled by a well informed handloader for use in his own rifle. The factory cartridge shows no marks on its bright case, the case has been crimped on the bullet, the cartridge is of standard overall length, and it will operate easily through any normal rifle and its magazine. The bullet is of the usual round nose type as at present loaded in all .257 factory cartridges. This cartridge can be relied upon to function and fire normally in any standard .257 Roberts rifle in good condition.

The handloaded cartridge shows slight scrapes on the neck indicating that the neck has been resized, and slight chamber scrapes on the body just in front of the head showing that it has been fired

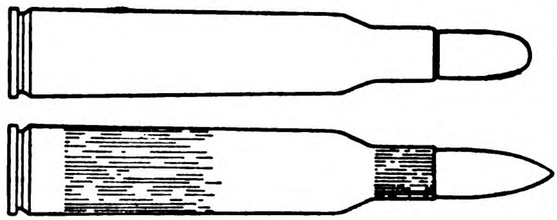

FIGURE 97. FACTORY VS. HANDLOADED CARTRIDGES

A—Factory loaded .257 Roberts cartridge. The case is bright and shiny without marks or scratches. The mouth of the case is crimped on the groove of the bullet, and the bullet is seated to such a depth that the cartridge has the standard overall length. Factory loadings of this cartridge to date employ only round nose bullets.

B—The same cartridge case reloaded by a skilled handloader. The case has slight longitudinal scratches on the neck from the neck resizing die. The longitudinal scratches on the body were caused by the chamber of the rifle when the case was first fired and extracted. Similar scratches but extending closer to the head of the case might have been caused by resizing the case in a full length resizing die. The case mouth is not crimped on the bullet, the bullet being held friction tight by resizing the case neck so it is about .002-inch smaller in inside diameter than the bullet, and then seating the bullet in this tight neck. A sharp pointed bullet has been loaded to give greater sustained velocity than the factory round nose bullet. The bullet has been seated projecting further out of the case than is the factory practice in order that the ogive of the bullet shall just touch the origin of the lands in the bullet seat. This has considerably increased the overall length of the cartridge, and such a long cartridge will not operate through a normal magazine. The Winchester Model 70 rifle has a magazine box which is the correct length for the .30-06 cartridge, and to shorten this box to the standard overall length of the factory .257 Roberts cartridge the manufacturer inserts a vertical steel plate in shallow slots in the rear of the box. By removing this plate the magazine box is made long enough to contain hand loaded cartridges of increased overall length as shown.

at least once. If the case had been full length resized the resizing die would have made longer and deeper scratches on the body. The case has not been crimped on the bullet, and the bullet has been seated a little further out of the case than with the factory cartridge, resulting in increased overall length, in order to have the ogive of the bullet touch the lands. A pointed bullet with better ballistic coefficient has been used.

This handloaded cartridge has too great an overall length to operate through the magazine of a normal rifle. The reloader may have intended it for single loading only for slow fire target shooting or varmint hunting where magazine fire is of no importance. Or he may be using it in a Winchester Model 70 rifle and has removed the magazine shortening plate in the rear of the magazine which limits the magazine to standard length cartridges. By removing this plate the magazine can be used with cartridges up to the length of the .30-06 cartridge.

This cartridge may show slightly better accuracy than factory cartridges because the bullet touches the lands, and is straightened up in line with the axis of the bore in front, having no jump to make from the case to the rifling. Also the expanded body of the case fits the chamber walls snugly and straightens the rear of the cartridge in line with the chamber.

It may be that due to its tighter fit this cartridge will require more of an effort to turn down the bolt handle and fully seat it in the chamber than would a factory cartridge. If the handloader feels that the effort to turn down the bolt handle is too great for effective rapid fire he will probably have to full length resize his cases, and may have to seat the bullet just a trifle deeper in the case. He tries a number of these cartridges in his rifle to see that they operate smoothly, and particularly that there is no tendency for the lightly seated bullet to stick in and remain in the bore when he extracts a loaded cartridge.

The user of this handloaded cartridge will have to handle it more carefully than he would the factory load. He should not, as a rule, carry it in an ordinary cartridge belt, but preferably when not loaded in his rifle such cartridges should be carried in one of the twenty-round pasteboard cartons so there will be no danger of the bullet being forced down deeper in the case.

Note that had this been a cartridge for use in a rifle having a tubular magazine, the handloader would have used a bullet with a round or flat nose, would have seated his bullet to standard depth, and would have crimped the case on the bullet. He would not then expect better accuracy than that given by the factory cartridge unless he was using a bullet noted for better accuracy than the bullet loaded in the factory cartridge.

Safety in Experimental Work

If there is any doubt as to the safeness of the pressure of a certain cartridge, or as to the ability of the weapon to safely handle the cartridge, the weapon should be placed in a rest, or weighted down with sand-bags, and at least two rounds should be fired from a distance and from shelter by means of a long string tied to the trigger.

The first evidence of excessive pressure is usually the swelling of the case so that it is difficult to extract from the chamber. A cleaning rod may even have to be used from the muzzle to drive the fired case out of the chamber. Any material extraction difficulty is a clear indication that the pressure is too high for safety, and the powder charge should be reduced, or the suitability of all the components should be examined. Still further increase in pressure will probably result in the following indications in the order given.

Noticeable flattening or extrusion of the primer.

Leaking of gas around the primer.

Blowing out of the primer.

Blowing out of the head of the case, usually resulting in more or less injury to the breech action and stock of the weapon.

However, the firing of only two sample cartridges is not a sure indication that the particular load or weapon is entirely safe, for a weapon might fire 500 rather excessive (for it) rounds with apparently good results, and an accident might occur on the 501st shot. Every weapon should have been proved by firing high pressure test cartridges in it which give a pressure much higher than any load that a well informed handloader would be likely to assemble.

Although he may be criticized for repeating himself, the writer would like to again call attention to this important matter of breech pressure. The .30-06 cartridge and bolt action rifles for it may be taken as an example of all high intensity cartridges in modern bolt action rifles. Such rifles are proof tested by firing two high pressure test cartridges in them. This cartridge gives a pressure of 68,000 pounds per square inch, but the case used is a specially heavy one as the ordinary .30-06 case would not stand such a pressure. New rifles before test have a headspace of 1.940-inch. If, as a result of this proof test, the headspace has not increased to over 1.943-inch, and the rifle is otherwise unchanged, it passes the test, and the barrel and receiver are stamped with the proof mark.

In such a rifle, whether it be .30-06, .270, .257, or .220 caliber, the standard cases in good condition should never be loaded to a breech pressure of over 50,000 pounds. There has been quite a lot of loading of such cases to a pressure of 55,000 pounds. Some lots of cases which are new and extra strong will perhaps stand such loadings in rifles that have very tight headspace, but there will be many cases that give hard extraction, and a few that show leaking primers indicating that the pressure is higher than it should be. And with cases not quite so strong, or with slightly excess headspace, there is always danger of serious accident. Thus everything points to a safety limit of 50,000 pounds, and indeed to 48,000 pounds for cartridges that are to be used in tropical countries, or exposed to hot sun anywhere.

The standard cases for such high intensity cartridges are all made very strong, but the cases for other cartridges will not stand anything like such pressures. Cases for such cartridges as the .30-30 series were never designed for pressures in excess of 40,000 pounds, and black powder cartridge cases should not be subjected to pres-

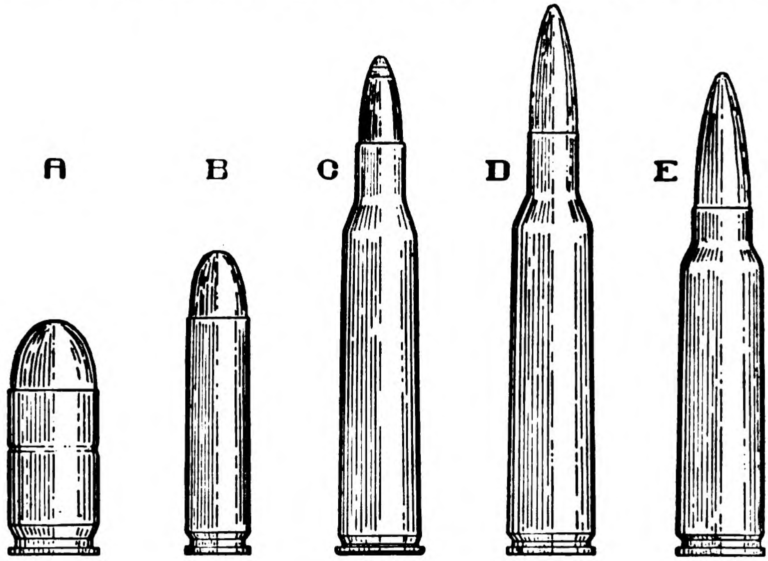

FIGURE 98. MODERN CARTRIDGES WITH RIMLESS CASES

Modern smokeless cartridges are made with a rimless case mainly to meet the requirements of the military for ammunition which will be as compact as possible; which can be assembled into tight and handy charging devices, or "clips," for rapid recharging of the magazine; which will fit compactly into the various changeable magazines of automatic pistols, submachine guns, etc.; which will fit closely into magazines similar to the Mauser type where the cartridges lie in double column; and above all so the cartridges will slide smoothly over one another and thus feed evenly and reliably through the actions of modern repeating and automatic firearms.

There is no special virtue or superiority of the rimless case over the older rimmed type, other than those mentioned above. As a matter of fact, all points considered, the rimmed case is the safest to use at extreme sures in excess of 25,000 pounds. In the course of improved design it may be that we will come to steel cartridge cases in order to use higher pressures and thus obtain flatter trajectory and greater penetration. In that case it will probably be the primer and the barrel steel which limits the pressures, and not the brass case as at present.

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pressures as it can be entirely inclosed within the chamber of the rifle in which it is fired, whereas existing actions for the rimless cartridge permit its base to extend out into the lug well to an extent which, in the very rare instances where a defective case is encountered, the case head may blow out and wreck the rifle action. Headspacing is also more difficult and costly with weapons for rimless cartridges, and the cartridges themselves require more rigid and frequent inspections during manufacture.

A—Ball Cartridge, caliber .45, Model 1911 (.45 Colt Auto).

B—Cartridge, carbine, caliber .30, M1 (for Winchester Semi-automatic Army Carbine).

C—.220 Winchester Swift.

D—.257 Roberts.

E—.300 Savage.

Note: Cartridges A and B headspace on the mouth of the case, which comes against and is "stopped" by a shoulder at the front end of the chamber. This is also referred to as the "position" or "chambering" of the cartridge. C is a semi-rimmed case, and headspaces on the rim as with all rimmed cases. Its rim measures .468" in diameter while the body of the case just ahead of the extracting groove measures .443". D and E are true rimless cases, but they headspace on the shoulder (just back of the neck) which is stopped against a similar shoulder in the rifle chamber.

Advantages of Superior Arms

THE time has passed when a designer can work in a closet and hope to produce a superior weapon, no matter what his mechanical ingenuity. He must have experience—experience under service conditions, experience with successful arms and also with those that have not proved successful, and a great deal of experience in marksmanship. He must mingle with the users of weapons and gain their viewpoint.

Our military arms have not been designed in a closet nor wholly in an arsenal. Rather they are the combined product of the soldiers who use them, the designers, and the technicians who finally make them. The using service, that is the combatant arm, expresses a need for a certain type of weapon. The Ordnance Department produces one or more samples until one has met the approval of the equipment board of the service. A few of the approved model are then manufactured for a first test by the service board. Many alterations may be suggested and made. If the weapon appears entirely suitable to the equipment board enough are finally manufactured under the conditions that would pertain in quantity production for an extended service test, probably by two or more large bodies of troops in different climatic conditions. Further alterations may then appear desirable until finally a design is approved as a standard for manufacture and issue. This is our system, and we have never been beaten in war.

Too much emphasis cannot be placed on exterior finish, gracefulness of lines, and even on ornamentation. But more important is that the weapon shall be strong, durable, reliable, accurate, and shall adapt itself to our methods of marksmanship. It should be strong, to stand hard warfare or wilderness use. Durable, to remain in perfect condition for at least the accuracy life of its barrel. Reliable, so it will always function even in adverse climates and other severe conditions. Accurate, so as to respond to all the skill in marksmanship that its user can possibly acquire. Its dimensions, feel, balance, trigger pull, and sights must meet the approval of our skilled riflemen.

Men love such weapons. They will learn them in every detail. They spend much time on their care and they keep them in perfect condition and adjustment. The soldier feels that he can depend on such an arm. He takes pride in his skill with it, he bestows much affection on it, and he has even been known to take it to bed with him. And thereby he becomes an unexcelled fighting man, one who makes hits instead of misses or near misses, high in morale and courage. The wilderness hunter also swears by such a friend, always ready, always efficient, pulling him through many a tight place, providing his food and clothing for years and years.

Such are the weapons that the Ordnance Department of our Army has always furnished our Fighting Forces. The .45 caliber Springfield rifle, Model 1873 was the most reliable and accurate rifle we knew firing fixed black powder cartridges. The Krag Jorgensen rifle was noted for its fine reliability and its speed and ease of operation, and it was accurate enough to teach large numbers of men to shoot well at 1,000 yards for the first time. With the Springfield 1903 rifle we made a most enviable reputation as the finest rifle shots in the world, winning most international matches, and it proved second to none in World War I. The Garand semi-automatic rifle is making an equally enviable reputation in the present war. All the product of Army Ordnance.

Our sportsmen, particularly our hunters and explorers, who travel far from human habitations and remain for long months, and who encounter arctic cold, desert heat, and tropical dampness have always felt they could place absolute reliance on the better grade weapons made by our Remington, Savage, and Winchester organizations. These plants, now most excellently supplementing our Army arsenals, are supplying equally superior weapons to our fighting forces.

On the other hand, if weapons are not superior, not entirely reliable, not attractive, not finely accurate, even if they are just mediocre, soldiers acquire no interest in them, do not become expert in their use, have little faith in them. Armed with such weapons they cannot be made into good fighting men. They cannot hit the enemy. They do not have that morale and courage that comes from knowing that they are decidedly better armed than the enemy, and better shots. There is no use in enlisting, clothing, feeding, training, and transporting a soldier to the battlefield if in combat he cannot make hits. We see innumerable cases of this kind among our enemies in the present war.

In this matter of superiority we must not forget the ammunition. The weapon and its cartridge are a team—no matter how fine the one is, superior results are not obtained unless the other shows equal excellence. Accuracy is the first earmark of a superior weapon, but it will be accurate only with near perfection ammunition.

To produce such ammunition with our present precision machinery means establishing a high standard of specifications with small tolerances, and then close inspection to assure them. This does not necessarily delay quantity production, even war production, although it does increase its cost because it means replacement of dies and punches before they are entirely worn, and many more inspectors and machine operators. But our country can well afford this price when it means so much to National Safety, Liberty, and the Pursuit of Happiness.

What a dud is to the artilleryman a misfire is to the user of a small arm. Nothing wrecks morale and courage as do duds and misfires. Sooner or later G. I. Joe gets a misfire; he cusses arm, ammunition, workmen, the Ordnance Department in no uncertain terms. But if others hardly ever have a misfire the solitary occurrence merely operates to create the impression that with their good ammunition misfires do not occur oftener than once in a million rounds, and all doubt as to the reliability of the ammunition is removed. The duds coming from the enemy's lines and the bullets that crack high overhead furnish a comparison vastly to our advantage.

To this team of superior arm and ammunition, accurate, dependable, durable, we then add the soldier who knows his tools like unto his alphabet. The trio is unbeatable.

It used to be thought that soldiers could not be relied on to aim accurately in battle, to estimate distance, to set their sights, to squeeze the trigger, or to care for their weapons properly; and that therefore the time spent in the niceties of marksmanship training, and the money expended on superior weapons was wasted. The present war has proved the absolute falsity of this so far as American Manhood fighting for its Institutions and its Homes is concerned. Marksmanship and superior weapons are absolutely essential for a victorious army. We are most fortunate in that we have both.

1955 SUPPLEMENT

to

SMALL ARMS DESIGN AND BALLISTICS

VOLUME I—DESIGN

The purpose of this Supplement is to bring the original text (actually completed by me in September 1944) up to date as of January 1955, so far as my knowledge of and familiarity with new material will permit.

No important errors in the original text have been brought to my attention. But there are now probably some statements in the original text which will need slight modification in view of the new material here presented.

TOWNSEND WHELEN.

A NEW AND STRONGER BREECH-CLOSURE FOR RIFLES

The increase in velocity of many modern rifle cartridges is accompanied by an increase in breech pressure, and the ability of the cartridge case and the breech mechanism of the rifle to safely contain such pressures has become of increasing importance.

With regard to the brass cartridge case, ability to withstand these higher pressures, (roughly in excess of mean pressures of 48,000 pounds per square inch) has been met by increasing the wall thickness of brass in the head and rear portion of the case in many cartridges of modern design. But while this does give increased strength to withstand higher pressures, it alone has not proved sufficient, under abnormal conditions which might possibly occur, with the types of breech actions in common use prior to about 1949, employing rimless cartridge cases.

With these breech actions, notably of Mauser 98, and Mannlicher design, the head and a portion of the side walls of the case is not supported by steel, as shown in Figue 99. Strength to sustain gas pressure here depends entirely on the web thickness of the case at this point.

The brass case is the weakest link in such an assembly. In the event of excessive pressure, approximately in excess of 55,000 to 60,000 pounds per square inch with modern cases of increased wall thickness and at slightly lower pressures with older brass cases, the unsupported brass at the head and rear sides of the case is frequently ruptured cracked and melted, releasing white-hot gas at pressures in excess of 50,000 pounds per square inch into the interior of the receiver. With most commercial and military rifles of older design as above, the effect of a burst case head is disastrous, completely wrecking the action and seriously injuring or maiming the shooter. When pressures are not quite so high, and with a few of the stronger actions, the bolt may not be blown out of the

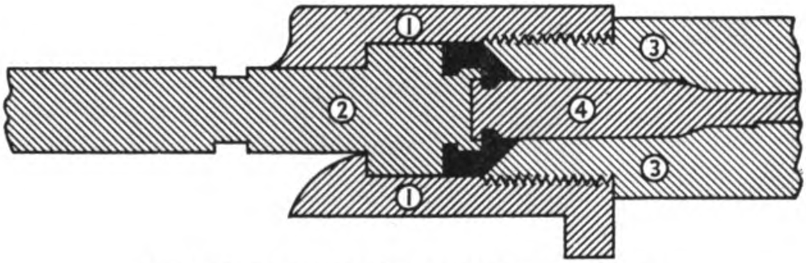

FIGURE 99. MAUSER 98 AND SIMILAR BREECH-CLOSURE

1. Receiver 2. Bolt 3. Barrel 4. Cartridge

Solid black section indicates where head of cartridge case is unsupported, and where gas may break through in event of very excessive pressure.

receiver but the gas may come back around the bolt, endangering the shooters' eyes; much of the gas may escape into the magazine well, wrecking the magazine and splitting the stock of the rifle, with probably less injury to the shooter.

With thoroughly standardized and carefully manufactured rifles and ammunition of United States and English production, and even with ammunition carefully hand-loaded by experienced riflemen, the chance for such an accident is very remote. However, with rifles and cartridges not made to such high standards, with war salvaged weapons often modified in many ways, with a wrong selection of cartridge, and with cartridges carelessly hand-loaded, there is always this chance of a serious accident with rifles handling rimless cartridges of high intensity.

To increase the strength of their breech actions, and to largely or completely eliminate the possibility of such accidents, the Remington Arms Company has recently produced a series of new rifles with improved breech design. These are their Models 721 and 722 bolt action rifles, and their Model 760 pump action rifle. They incorporate U. S. Patent No. 2,585,195 issued to M. H. Walker of the Remington Arms Company, incorporating the breech design, and U. S. Patent No. 2,473,373 issued to J. D.

Howell, also of the Remington Arms Company, incorporating the bolt head and extractor design.

As will be seen in Figure 100 the rear of the case, its head and its walls, are completely encased, surrounded and supported by strong steel; the brass case, therefore, cannot give way under any circumstance liable to occur, even at extremely high pressures.

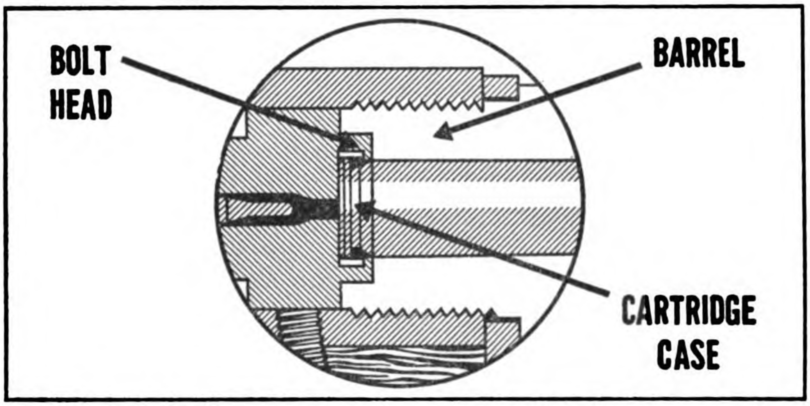

FIGURE 100. NEW REMINGTON BREECH-CLOSURE.
The brass cartridge case is supported everywhere by solid steel.

This invention and improvement provides a recess in the head of the bolt adequate to receive and entirely surround the head of the cartridge case and by providing a reinforced flange on the barrel, barrel extension, or receiver ring into which the flange on the bolt-head may fit when the bolt is fully locked. In the preferred embodiment this improvement is obtained by recessing the end of the barrel in such a fashion as to receive and support the flange defining the recess in the bolt head. Thus, in the remote event of a failure of the supported cartridge head, the bolt flange will, before expansion to a dangerous degree, be supported by and will obturate with the barrel to prevent the escape of gas from the joint.

The conventional extractor on breech actions of prior design consisted of a claw on the end of a long spring. The spring pressed the claw into the extractor groove in the case head. This claw covered considerable of the circumference of the case head, and being supported by its spring only, provided little or no resistance to pressure. In fact, in event of a failure this extractor was usually blown off the bolt. A necessary adjunct to this new Remington breech-closure is the new design of ring extractor. The circular spring of this extractor is completely housed in the flange of the bolt head, continuing all around the circumference of the head, and is solidly supported by the flange, against which it is in solid contact when a cartridge is loaded. Thus the steel support of the case-rim is as solid as though no extractor were present.

In the course of design and initial production of the Remington rifles of this improved design, they were subjected to many rigid tests to verify and determine their strength. In one of these tests with a standard production Model 721 rifle of .30-06 caliber, three 220-grain metal cased bullets were forcibly seated in the bore just in front of the chamber; then a normal factory cartridge was inserted in the chamber behind these three bore-obstructing bullets, and the rifle was fired. Nothing happened, although the action had "frozen," and was difficult to open. This test would have demolished all, or almost all, of the older breech mechanisms of Mauser design.

Then the experiment was repeated, except that this time an over-loaded proof cartridge giving greater breech pressure than the regular proof load (which gives about 70,000 pounds) was substituted for the normal factory cartridge. On firing there was no evidence of gas damage to the breech, although enough pressure was exerted to push the four 220-grain bullets out of the barrel. This pressure apparently had no effect on the bolt, barrel, or receiver. However, it was impossible to unlock the bolt, and the firing pin was forced rearward almost ¾-inch past the cocking position, but stayed in the bolt. Remington has no idea what breech pressure was developed in this test.

NEW TRIGGER MECHANISMS

The one most important attribute to fine rifle marksmanship is trigger control. In the language of our marksmanship manuals; "The good shot is not the man with the keen eye and iron nerve; rather he is the one who has learned to squeeze or press the trigger correctly." That is, the trigger must be so pressed that the act of doing so will not disturb the accurate aim and steady hold at the instant the rifle is discharged. The timing is important also. The weapon should discharge, as a result of a proper press, very close to the instant that the shooter wills it to discharge; that is, when aim seems perfect. For a near-to-perfect trigger press the trigger action should also be near-to-perfect. A poor trigger pull will not be tolerated by a good rifle or pistol shot.

There are two forms of triggers, the "single stage" and the "set trigger." Set triggers are of two types. The double set where there are two triggers in which pulling back the rear trigger until it "clicks" sets the front trigger, and it then takes only a light pressure of one to three ounces to discharge the weapon by pressing the latter. The single set has but one trigger; pushing forward on it sets it to release with a similar light press. Set triggers are seen almost exclusively on target weapons, and are usually of German design.

The single stage trigger is the simple trigger usually seen. Pulling or pressing straight back on it, with a pressure differing on individual weapons at from one to ten pounds, discharges the weapon. Such a trigger has, or may have the following increments or characteristics of pull, some of which are more or less serious defects.

Creep. On applying pressure the trigger moves or "creeps" backward, often in a rough or jerky manner, a more or less short distance, before discharge takes place. The shooter cannot tell, even approximately, at what point of the increased pressure, movement, or drag that the trigger will release the sear and discharge take place. Creep is a very serious fault in any trigger.

Backlash. As the trigger is pressed, and discharge takes place, the trigger continues to move back a slight distance. This is undesirable, but not necessarily a serious fault.

Slack. A slight pressure, usually about 1 to 2 pounds, must first be placed on the trigger, causing it to move backward about 1/10th to 1/5th of an inch, before the trigger contacts the sear, and the main or important part of the pressure to discharge begins. Slack is undesirable in that it takes more training for the shooter to learn to take up all of it before he starts his careful trigger press.

The National Rifle Association Regulations require a minimum trigger pull of 3 pounds for rifles to be used in competitions. The United States Revolver Association requires a minimum of 2 pounds for single shot pistols, 2½ pounds for "any revolver," and 3½ pounds for military and police revolvers. For International rifle and pistol shooting there is no weight limit, set triggers being often used.

The ideal trigger is one which has practically no movement at all—no slack, no creep, no backlash. When the necessary pressure is applied the weapon is discharged, and the shooter is not conscious that the trigger has moved at all. Where it is not prohibited by competition regulations almost all of our highly skilled target shooters and hunters prefer such a trigger that discharges on an applied pressure of one to two pounds. However, such a light pull would probably be dangerous in the hands of a beginner and the ordinary "one week a year" hunter, and so the ideal weight for factory produced sporting arms is between 3 and 4 pounds.

With lever action hammer rifles and with revolvers there is usually no slack to the standard triggers. As these triggers come from the factory the pull varies from 4 to 7 pounds, and there is sometimes a little creep, and more or less backlash. A skilled gunsmith can usually adjust such triggers to a very excellent and light pull, eliminating all creep. On most revolvers practically all of the backlash can also be removed.

Adjustment to a pull of this kind is much more difficult on an automatic pistol. There are few gunsmiths competent to do it, and they often spoil several parts before they get it right. It is a job that no gunsmith relishes. The writer lately had three gunsmiths (selected for their reputation at this job) operate on the trigger of an automatic pistol of his, only the last one getting it to a "fairly satisfactory" pull.

The trigger mechanism of bolt action rifles is different from that of the above weapons. Prior to 1937 almost all factory produced bolt action military and sporting rifles for center-fire cartridges had a trigger mechanism of the Mauser 98 design, and as these rifles came from the factory the trigger pull was usually exceedingly poor, having a long slack pull, a great deal of creep, and always backlash. To fire a bolt action rifle rapidly the bolt must be operated fast—jerked back and slammed forward and shut. Therefore the surface of the sear must stand up rather high against the nose of the cocking piece, so that the cocking piece will not over-ride the sear and result either in the firing pin lowering without firing, or in a discharge just as the bolt is closed. Therefore, for safety, this design of trigger must have considerable slack. As the slack is taken up the sear moves down until there is just a bare contact between its upper edge and the lower edge of the nose of the cocking piece.

It is possible to eliminate this slack by stoning the sear so that it stands up only to fine contact with the nose, but such an alteration is both undesirable and dangerous because the nose is liable to over-ride the sear with the above results.

It is comparatively easy for the gunsmith, without eliminating the slack, to stone and polish the surfaces of sear and nose so as to give a very satisfactory and creepless pull of three to four pounds. With a trigger of this kind a shooter could be trained, or could train himself to excellent skill in marksmanship. It was necessary to invariably place about 2 pounds pressure on the trigger (to take up the slack) as the hand grasped the stock, and before starting to co-ordinate aim and trigger press—in fact the shooter had to train himself to doing this subconsciously so that it was invariably done even when firing rapidly or under excitement. However, the slack was a detriment to the shooting of beginners because they so often forgot to take it up, and pulling the trigger with a long, quick motion and jerk, invariably missed the target by yards.

This was the situation until 1937 when the Winchester Repeating Arms Company introduced their Model 70 bolt action rifle with a new trigger mechanism invented by Mr. Al. Laudensack of their staff. With this mechanism as shown in Figure 101, the upper portions of the sear and nose of the cocking piece that contact each other are rounded instead of being flat, and there is nothing to prevent these two surfaces pushing past each other, and the firing pin falling to discharge the rifle, except the upper pressure of the sear by the sear-spring. An arm of the sear extends downward, and the point of it rests in a notch in an arm of the trigger, this contact preventing a lowering of the sear and the discharge of the rifle. When the trigger is pulled this engagement between sear and trigger is broken, and the cocking piece and firing pin rod press past the top sear nose, and the rifle is discharged. Thus the bolt can be slammed forward hard without causing the nose to over-ride the sear. The pressure of the engagement between sear arm and trigger arm is controlled by springs and adjusting nuts, and by adjusting these, and with possibly a little judicious stoning, a very excellent pull without creep, and as light as about 2½ pounds can be obtained, and there is also no slack or backlash. The result is that ideal trigger pull that all riflemen have wished.

Triggers operating on much this same principle are now found on the Remington Models 721 and 722 rifles, and similar custom triggers, adaptable to the Mauser 98, Springfield 1903, Enfield 1914 and 1917, and Winchester Model 54 rifles are now being furnished by the firms of Canjar, Dayton-Traister, Jaeger and Mashburn.

Similar triggers, operating without slack, creep and backlash have also been adapted to the Winchester Model 52 and Remington Model 37 small bore match rifles, the latest one, the "Micro-Motion" trigger, which is practically vibrationless, adapted to the latest type of Winchester Model 52 rifle is shown in Figure 102.

Such triggers are contributing considerably to fine marksmanship.

However, these triggers, other than that on the Winchester Model 70 rifle, hardly seem to be satisfactory for military service because their mechanisms are inclosed in housings that do not permit of field dismounting and assembly for cleaning. This might lead to rusting of the parts, or if an oil of low viscosity is used, to their failing to operate in extremely cold weather.

PRESENT THOUGHTS ON RIFLE BARRELS

A good sporting rifle barrel for one of the more accurate cartridges, with bore and chamber close to standard dimensions, and fired with carefully hand-loaded cartridges employing bullets of

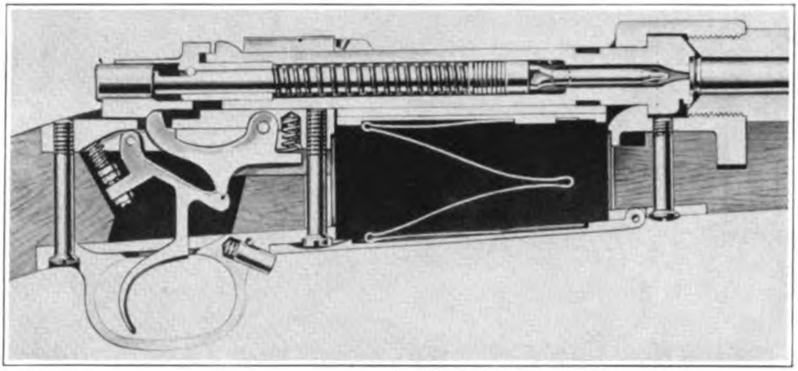

FIGURE 101. THE NEW TRIGGER MECHANISM DESIGNED FOR THE MODEL 70 WINCHESTER RIFLE

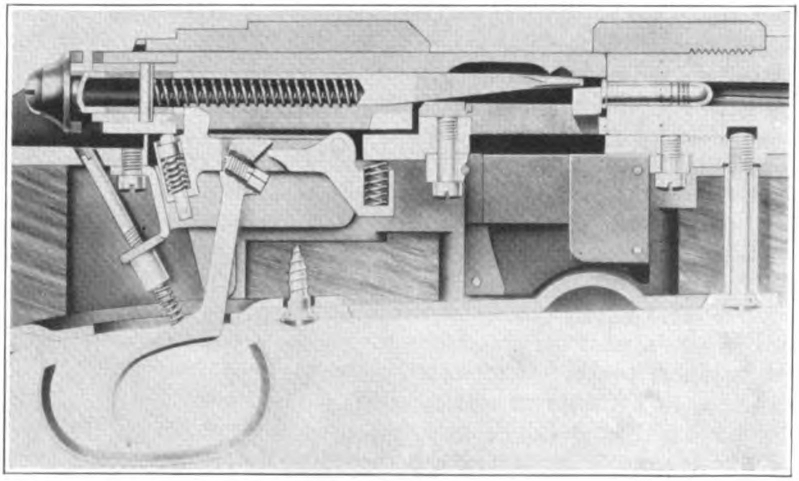

FIGURE 102. THE WINCHESTER MODEL 52 RIFLE AS FITTED WITH THE TRIGGER MECHANISM INVENTED BY AL. LAUDENSACK

proved accuracy, will give an average dispersion of about 1 to 1½ minutes for 5-shot groups, and about 1½ to 2 minutes for 10-shot groups at the ordinary short and mid ranges at which the cartridge is designed to be fired. With standard factory ammunition manufactured by anyone of our four largest cartridge companies, the average dispersion will be about ½-minute to 1 minute larger than this. This pertains to bolt action rifles, well bedded in their stocks, and fired from bench rest with a telescope sight, all in the hands of a very skilled shooter.

Such accuracy is entirely satisfactory for the hunting of large game, even at the longest sporting ranges. It is also ample for the smaller mammals and birds (varmints) up to approximately 200 yards, but for longer ranges the skilled rifleman specializing in varmint shooting prefers a custom built rifle for one of the more accurate special .22 or .25 caliber cartridges of slightly better accuracy and very flat trajectory.

However, what follows pertains more particularly to those who seek the ultimate in accuracy, to our target shooters, and particularly to those who indulge in bench rest shooting. To date these riflemen, as a result of much careful shooting, selection of equipment and experiment, have been preferring custom built rifles for such cartridges as the .219 Donaldson, .219 Improved Zipper, .222 Remington, .22-250 (Varminter), .22 Wilson Arrow, .250 Donaldson Ace, and .250-3000 Savage. For bench rest shooting these rifles are built to incorporate all the details that make for exceptionally fine accuracy—heavy barrels, heavy stocks, elimination of the magazine, tight and perfect action bedding, and the barrel is usually free-floating in the forearm. The very best bullets are used, at present chiefly those of Sierra, Hornady, or Speer make, or bullets made by the shooter himself in hand operated dies. Such rifles weigh upwards of 13 pounds, some as much as 18 pounds, and are fired from bench rest with telescope sights of 20 or 25 power magnification. Such competition is to determine who can build and assemble the most accurate rifle, rather than a test of individual marksmanship, and experiment for the improvement of accuracy and dependability in rifles is also involved. The average dispersion of these rifles in the hands of the more skilled shooters has been, for the past five years, approximately .6 minute for 5-shot groups, and about .75 minute for 10-shot groups up to 200 yards, and sometimes to 300 meters. This is about the best accuracy that the most skilled shooter can expect, and also the best that any private or custom rifle maker can produce to date.

But, since about 1950, at the more important bench rest matches which attract the most skilled shooters, the winners have had aggregates of ten consecutive matches, running about .45 to .50

minutes for 5-shot groups, and about .52 to .58 minutes for 10-shot groups. In the language of the bench rest shooters these competitors are said to have had "hot" barrels. Thus a competitor who has a hot barrel will consistently win, or place high in all the matches in which he enters, even when competiting with other shooters of equal skill, but having average barrels. Such a competitor will win pretty consistently for several years, winning four or five hundred dollars in prize money, so long as his barrel retains its gilt edge. Then, after from 2000 to 3000 rounds have been fired through it, the fine accuracy begins to fall off, usually through throat erosion, and the competitor replaces it with another barrel, in all probability to find that his accuracy has fallen to the average for such rifles as given above. A significant fact is that a number of such competitors having hot barrels, and finding them falling off in accuracy due to long use, have cut the barrel off at the breech and rechambered it (thus eliminating the throat erosion) and have then found the barrel to continue to be "hot." This seems to indicate that the excellence of the barrel depends on the barrel itself, that is on the bore, the rifling and the steel, and not on other factors.

What exactly constitutes a hot barrel? Frankly we do not know. We do know that with two barrels manufactured exactly alike, and each as perfect and identical so far as we can possibly determine with the most modern instruments, one may be hot and the other average. Our most skilled barrel makers naturally try to produce hot barrels for their preferred shooters, those who can appreciate them. To date these barrel makers, employing all the skill they are capable of, will produce perhaps 25 to 50 barrels of average accuracy to one hot barrel. They can hardly themselves determine if one barrel is hot or average, and therefore they cannot guarantee a hot barrel. The barrel must be assembled into a complete rifle, the best load determined for it, and then fired to determine its quality.

All that we can say today is that, given equal smoothness and uniformity of bore, we think that this superior accuracy depends on the homogeneity of the steel in the barrel, but we do not know how to select a bar of steel that will be homogeneous from breech to muzzle.

We also think that the bore should be very smooth and of uniform diameter throughout, with no tight or loose places. One barrel maker who has been very successful in turning out barrels of excellent accuracy, and an occasional hot barrel, reams his barrels very slightly small in diameter, and then polishes the bore in the rifling machine (with the same twist that the finished barrel is to have) to eliminate all the tool marks of the reamers. Then he rifles this smooth barrel.

Another barrel maker, who has a number of hot barrels to his credit, always laps his barrels (with a lead lap and fine emery) after they are rifled to insure a very smooth bore with no tight or loose spots.

One of these barrel makers submitted six barrels which were bored straight, and six barrels which required a minimum of straightening, but which were otherwise identical so far as he could tell, to one of our most skilled bench rest riflemen for test. The shooter tested these twelve barrels very thoroughly, but did not know which was originally straight, and which had been straightened. All gave good average accuracy, but each of the unstraightened barrels slightly excelled any of the straightened barrels in average accuracy. This was in 1950. This shooter told the writer that he had not had what he considered a "hot" barrel since 1949. The inference is that he did not consider any of these unstraightened barrels exceptionally hot. There have been other such tests, and undoubtedly a barrel that happens to have been bored straight helps in super-fine accuracy.

This is a fascinating subject. Everyone would like to have a "Killdeer" and like Natty Bumpoo, become the "King of the Woods." But so far it is like looking for a needle in a haystack, and the rifleman who gets one is extremely lucky.

Chrome molybdenum still remains the preferred steel for the barrels of high power rifles. A few custom barrel makers have done considerable experimenting with stainless steels, not particularly to avoid corrosion, but rather erosion which proceeds very fast with some of the new ultra high intensity cartridges. To date it is the opinion of most of these makers that while they can machine a barrel of these very hard steels to give quite satisfactory accuracy for hunting rifles, they cannot as yet produce one which is quite accurate enough for the skilled target shooter. Winchester, however, does use stainless steel for the barrels of their Model 70 rifle in .220 Swift caliber to delay erosion and lengthen barrel life.

1955. Since the above was written some of our large rifle makers, as well as a few of our custom barrel makers, have been changing their method of rifling their barrels. Instead of cutting the grooves in the smoothly reamed barrels, they broach or emboss them. The broach presses the grooves into the smooth steel surface instead of cutting or scraping them. This is often accomplished with one passage of the broach through the bore thus greatly simplifying and speeding the operation. It usually required about twenty minutes to cut the grooves by the old method. Apparently the process is very successful, and results in just as perfect a barrel as the older method at a fraction of the cost.

One maker, using this broaching method, has increased the number of grooves from six to about sixteen, and has made the grooves much shallower. Whether this is an advantage remains to be seen, but to date has not been proved to be detrimental to accuracy or barrel life.

One custom barrel maker, G. R. Douglas, has developed his own method of broaching barrels which he terms "Ultrarifling" resulting in an exceedingly smooth bore of very uniform diameter from breech to muzzle. On May 30, 1954 one of his barrels in the hands of Samuel Clark, Jr., made the 200 yard world record for accuracy for ten consecutive shots, the extreme spread of the group being .5276-inch.

NEW EXPERIMENTAL MILITARY RIFLES

The armies and navies of all the major powers are continually experimenting with and developing new weapons and ammunition in order that they may be prepared to furnish their forces, if necessary, with equipment that will be at least equal to, and preferably superior to that of any possible enemy nation. It is not always possible to adopt an evidently superior weapon for service use as soon as it is developed because of various matters involved, principally that of finance.

An army also continually strives to decrease the weight of equipment on its Infantry soldier because lighter weight makes for maneuverability, decreases fatigue, increases the morale and fighting spirit, and makes the Infantryman a better fighting soldier. Decrease in weight also diminishes the demand on transportation, and if this decrease includes the amount of metal involved in manufacture, it decreases the cost. This applies to both arms and ammunition, and equally to other items of the soldier's pack. Also there is the additional matter of the recoil of the rifle, lighter recoil increasing the excellence of marksmanship and making for fire superiority.

The Infantry rifle used by the United States in World War II was the U. S. Rifle, caliber .30, M1, popularly known as the Garand. It fires the cartridge known as the Ball Cartridge, Caliber .30, M2, a military type of that cartridge popularly known as the ".30-06." The rifle weighs approximately 9½ pounds, and the cartridge approximately 5.57 pounds for one hundred rounds. The M1 rifle has proved to be a most excellent military arm, we think superior to that of any other nation, and there has been no criticism of it except as to its weight and its recoil. The recoil is by no means excessive, but better marksmanship would result from lighter recoil.

Many millions of the M1 rifle have been manufactured, not only for the supply of our own troops, but also for many nations in the North American Treaty Organization. A very large supply of spare parts for repair and maintenance are also on hand. The war reserve of ammunition runs into the billions of rounds. The present replacement of these with others would be a very costly matter, not to be lightly considered. It is of course highly desirable that all Nations in the N.A.T.O. use the same rifle and the same ammunition for reasons of simplified supply. The majority now use the M1 rifle and its cartridge.

In 1951 press releases revealed the fact that England had developed a new infantry rifle, at present known as the EM-2, with a view to its adoption by their own forces, and they hoped and suggested, by the other nations in the N.A.T.O. This rifle is very radical in design as shown in Figure 103. The walnut butt-stock has been eliminated, the butt-plate being located directly in line with the barrel and line of recoil, thus lightening and shortening the rifle, and reducing the vertical jump in recoil. This necessitated raising the sight line, and the new sight is an optical one, somewhat like a telescope sight, with a reticule for aiming, but no magnification. The tube of this sight provides a convenient handle for carrying the rifle. The rifle is semi-automatic, but pressing a button makes it full automatic at the will of the soldier. The length of this rifle is 35 inches as compared with 43.6 inches for our M1 rifle, and its weight is 8 pounds. The box magazine holds 20 rounds. An entirely new cartridge of .280 caliber (7 mm) has been designed for it. This cartridge fires a 139-grain bullet at M.V. 2530 f.s. and has an overall length of 2.53 inches. The weight of the complete round is not known to the writer, but must be approximately 330 grains. This in comparison with a bullet of 150 grains, a weight of 387 grains, and a length of 3.34 inches for our M2 cartridge.

The British War Office demonstrated this new EM-2 rifle to our Department of Defense in August 1951, thereby rather forcing our hands, and causing the premature release of information on two new infantry rifles and a new cartridge for them which our Army Ordnance Department had developed, but information on which to that date had been restricted.

It is thought by us that none of these rifles, including the EM-2, can be adopted for N.A.T.O. service, within the near future at least, because of the enormous cost of replacement, but they are models to be considered for the future, and it is entirely possible that one or more of them may be considerably improved before such adoption. At the same time our Ordnance Department naturally considers that their two developments are superior to the

British, although no comparison or competitive test of our two rifles and the British model has been made publicly. In absence of such a test it would be foolish to attempt a comparison here, except as to the exterior ballistics of the cartridges employed.

The two new experimental United States rifles are known as the T44 and the T47, and together with our present M1 rifle (Garand), are shown in Figure 104. Both are gas operated semi-automatic rifles, with provisions for full automatic fire if desired at the will of the soldier, and both have a 10-round box magazine.

The T44 operates on the same principle as our present M1 rifle (Garand), but is a little shorter, about a pound lighter, and the gas port in the barrel is farther back from the muzzle, with a shortened operating rod.

The T47 has a mechanism quite different from the M1 and T44, with a sliding block type of breech. Upon firing the operating rod forces the hammer block to the rear, which, as it starts to move, pulls the locking bolt down out of a recess. The block moves backward and downward, opening the slide on top of the action. With the slide open the fired case, which has been pulled out of the chamber, is ejected. When the slide moves forward to close the action, a new cartridge is stripped from the magazine and loaded into the chamber ready for firing. This T47 rifle weighs 8 pounds.

The newly designed cartridge adapted to both the T44 and T47 rifles is known under the generic designation of T65, the various types having separate designations such as T104E1 for the ball cartridge. The caliber is .30, the bullet diameter, and also the groove diameter of the barrels for it, both measuring .308-inch as with our present M2 (.30-06) cartridge. The rimless head also is the same diameter as the M2. The jacketed bullet with lead core weighs 150 grains, with slightly different weights for armor piercing, tracer, incendiary and spot-light bullets. The muzzle velocity with the 165-grain armor piercing bullet is 2,785 f.s.; 100 rounds weigh approximately 5.14 pounds as compared with about 5.57 pounds for the M2 cartridge. And finally its overall length is 2.84 inches which is just half an inch shorter than the M2. This new cartridge gives considerably less recoil than the M2, but its exterior ballistics are very similar, and it can also be adapted to light machine guns.

We have particularly thought it necessary to retain the .30 caliber and the same weight of bullets in this T65 cartridge as in the M2, because of the difficulty of manufacture of tracer and spot-light bullets in a caliber as small as the new British .280 caliber cartridge. Incidentally, the Winchester Repeating Arms Company has recently introduced a new sporting cartridge which they term the .308 Winchester, which is practically identical except for bullets, with the T65, and have adapted it to their featherweight (6½ pound) Model 70 rifle. This T65 cartridge has now been officially adopted by the countries in the N.A.T.O. for any rifles or machine rifles that may be hereafter manufactured and adopted, and its name has been changed to the "7.62 mm N.A.T.O. cartridge."

LIGHT WEIGHT SHOTGUNS, RIFLES AND PISTOLS

The sportsman as well as the soldier has always desired lighter weapons, provided that the safety factor is not lowered, nor the recoil increased to an undue extent. The reason is obvious. For example, consider the weight of our pump and autoloading shotguns, two typical American arms. The older guns of these types weighed in 12 gauge about 7¾ pounds for the pump, and about 8¼ pounds for the autoloading. Whereas the better models of double barrel guns weighed about 6¾ to 7 pounds, which latter weight was considered to be much preferable and an ideal weight, except for a heavy duck gun shooting maximum loads.

The breech action and magazine of pump and autoloading shotguns comprise a large proportion of their weight. Just prior to World War II some attempt was made to decrease the weight of these guns by making the receivers and some other parts of a high tensile aluminum alloy, but sportsmen did not altogether approve of this metal although it probably had ample strength. Guns lightened in this manner did not become popular, and their sale was not satisfactory to their manufacturers.

Following the war, development in high speed motion photography with X-ray, and stress coating has enabled our designers to determine definitely the weight and thickness of steel alloys in all parts of guns that is necessary to give the strength needed for safety, and thus decrease the weight of many weapons where such reduction seems to be called for. In most cases it was found that we had been using a much greater weight and thickness of steel in our present guns than was called for from the standpoint of safety and durability. With these aids to the designer the Remington Arms Company have recently developed and produced two new shotguns and a new rifle of much lighter weight than the models that preceded them.

Remington New Autoloading and Pump Shotguns

The new Remington Model 11-48 Autoloading Shotgun has replaced their older Model 11 which in 12 gauge weighed about 8¼ pounds. This new gun in 12 gauge weighs about 7¼ pounds. Many of the features of the Browning mechanism have been retained, as this is the only autoloading mechanism that has proved entirely satisfactory in shotguns. Many parts, particularly the receiver, have been considerably lightened, using modern alloy steels, without decreasing the safety factor or durability, and the model has been made much more attractive by streamlining the receiver.

The new Remington Model 870 Pump Action Repeating Shotgun, weighing about 6¾ pounds has replaced the older Model 31 which weighed about 7¾ pounds, both in 12 gauge. The receiver walls have been made thinner, and a unique feature is the "Vary-Weight" steel magazine plug to interchange with the wood plug, so that the shooter can increase the weight of the 12 gauge gun to 7½ pounds for more comfortable handling of maximum loads when desired. The outward appearance of the new model is very similar to that of the older Model 31, but it includes many new features such as the double action-bars that divide the operating power, giving a smooth, straight-line control with no twisting, binding, or tilting action. The barrel is lighter than the old one and is made with a hardened extension into which, for the first time on a pump gun, the breech block locks up securely to the head of the shell, making for less wear and constant headspace. There is an easy take-down design, the barrel quickly detaching from the receiver and magazine tube, and thus allowing a quick and easy interchangeability of barrels without disturbing the fore-end or magazine tube. If a new or extra barrel is desired, for example a 26″ improved cylinder for upland game, and a 30″ full choke barrel for wildfowl, it is not necessary to purchase a new fore-end and extra magazine. The magazine can be unloaded without working the shells through the action.

Remington Model 760 Slide-Action Rifle

The newest Remington development is their Model 760 slide-action big game rifle, replacing their older Model 141 which did not handle cartridges quite powerful enough for our larger species of big game. There has always been an insistent demand for a lever or pump action rifle adapted to our highly efficient .30-06 cartridge. This new rifle is adapted to that cartridge as well as to the .270 Winchester, the .35 Remington and .300 Savage cartridge, and modern design aids have enabled Remington to produce it at the very low weight of 7¼ pounds.

In outward appearance, balance, and fit of stock and fore-end it is quite similar to their Model 870 pump action shotgun. One of its outstanding advantages is that the great number of our sportsmen who are familiar with and skilled in the use of the pump shotgun can handle this new 760 rifle so effectively that, without knowing anything about rifle marksmanship, they can make quick body-hits on deer up to about 75 yards, within which distance probably ninety percent of our Eastern deer are shot. It also is the fastest to operate in rapid fire of any high power rifle other than an automatic.

The Model 760 has several unique and excellent features of design. The breech bolt locks into an extension of the barrel with the extremely strong design of breech-closure seen on the Remington Models 721 and 722 rifles, where the entire head of the rimless case is completely supported by thick steel, making it impossible for gas to escape to the rear, even in event of extremely excessive pressure. As a rule lever and pump action rifles have not been nearly as accurate as the bolt actions, partly because of the tubular magazines and forearms that were attached to their light barrels. Indeed the most accurate bolt action rifles have been those in which the barrel was made free-floating, that is, not touching the forearm at all. The barrel on this new Model 760 rifle is likewise free floating, not touching the fore-end at all, and the fore-end hanger is attached to the receiver only, and not to the barrel. Preliminary tests of this new rifle by leading riflemen to whom it was submitted just prior to placing it on the market, indicates that it is at least slightly more accurate than any of the lever action rifles using high power cartridges of similar power.

It has a detachable box magazine holding three rounds, in addition to a fourth in the chamber, and the receiver is drilled and tapped for receiver sights and telescope mounts. As the barrel is a close, sliding fit in the receiver, and is not screwed into the receiver ring, it is logical to suppose that in time a small amount of wear will occur in this sliding joint, with a slight increase in the drop-down of the muzzle. As a telescope sight will be attached to the receiver only, it would be expected that slight wear in the receiver ring-barrel fit will result in the rifle gradually shooting lower and lower with respect to its telescope sight adjustment. However, it is extremely unlikely that any noticeable wear will occur in many hundreds of rounds, or several years of use, and will be so gradual as to be easily compensated for by a readjustment of the telescope by sighting shots, say every 300 rounds or so. No sudden change resulting in a hunter's missing his game will be likely to occur. With a receiver sight no change would be noticed, as the front sight will go down with the muzzle of the rifle as slight wear occurs. This is not a criticism of the rifle, but is mentioned here as a detail of this design which should be understood.

Remington Model 740 Auto-Loading Rifle

The outline, and in many respects the design of this new rifle introduced in February 1955 is quite similar to that of the Remington Model 760 Slide-Action Rifle, the slide being operated by gas instead of by hand. Like the Model 760 its bolt has locking lugs with segments like interrupted threads that lock the head of the bolt into the rear of the barrel instead of into the receiver. The bolt head has a short spiral ram on each side, and when the slide moves to the rear a pin in each of these spiral cuts rotates the bolt to the unlocked position. The gas port in the bore is 8½ inches from the breech of the barrel, and leads the gas into a hollow drilled in the action bar sleeve, which is inside the fore-arm. The gas forces the sleeve with its attached "U" shape action bar to the rear. The action bar carries the bolt body to the rear, the cams first rotating the bolt head to the unlocked position. The further rear movement of the bolt body extracts and ejects the fired case and cocks the hammer. This also compresses the action spring which is coiled around the action tube inside the forearm. This compressed spring now causes the bolt to close and lock, and feeds a fresh cartridge from the magazine into the chamber, leaving the rifle ready to fire again when the trigger is pressed. The detachable box magazine holds four cartridges. The Model 740 thus far has been produced in .30-06 caliber, but later will probably be made available for the same cartridges as is the Model 760. The rifle weighs about 8 pounds, and functions perfectly without adjustment with all types of .30-06 ammunition.

Similarity of Recent Remington Design

The new series of Remington shotguns and rifles are very similar in their design in many respects. The Model 870 slide-action shotgun, the Model 11-48 auto-loading shotgun, the Model 740 auto-loading rifle, the Model 760 slide-action rifle, and the smaller Model 572 slide-action .22 caliber rifle all have receivers that are nearly identical in outside shape and dimensions so that it is probably possible to machine all from the same forgings, and to fit the butt-stocks to the receivers with the same attaching cuts. The aluminum trigger guards and plates are also identical for all these weapons. This similarity considerably reduces cost of manufacture of these arms.

The .308 Winchester Model 70 Featherweight Rifle

The demand for lighter big game rifles has been met by the Winchester Repeating Arms Company with the introduction of their Model 70 bolt action rifle in featherweight type, weighing only 6½ pounds as compared with about 8¼ pounds for their standard Model 70 rifle. The reduction in weight has been accomplished, with a lighter barrel, smaller in its outside diameters, and 22 inches long instead of the heavier 24″ barrel on the standard rifle. Also an aluminum alloy is used for the guard, floor-plate and butt-plate.

This Featherweight Model 70 is at present adapted only to the new .308 Winchester cartridge which has the same case and overall length (2.84") of the new experimental T65 Army cartridge. It is best described as a cartridge almost exactly the same as the .30-06, but exactly half an inch shorter, and giving the same muzzle velocities as the .30-06 with similar weight bullets, and similar barrel length.

Heretofore the skilled rifleman has rather looked with disfavor on very light rifles shooting heavily charged cartridges. The accuracy is liable to be mediocre, the rifle often varies its center of impact considerably in the various firing positions and with different tensions of holding, and the recoil is usually unpleasant. This new rifle seems to be an exception to this rule, largely we believe because its barrel is free-floating, not touching the forearm at all. The writer has made an extended test of this rifle, shooting it from bench rest, and in the prone, sitting, and standing positions, rifle fitted with a telescope sight, and with Winchester and Western factory cartridges loaded with 110, 150 and 180-grain bullets. The accuracy was practically identical with that obtained with Winchester and Western factory loaded .30-06 ammunition with similar weight bullets when fired in standard Winchester Model 70 and other good sporting rifles of .30-06 caliber weighing from 8¼ to 9 pounds. The variations in center of impact in the various firing positions, and with cartridges having the different weight bullets was the same as would be expected from .30-06 rifles of 8¼ to 9 pounds. No appreciable difference in recoil could be noticed between this featherweight rifle and a standard Model 70 in .30-06 caliber and weighing 8¼ pounds. Apparently the reduction of 1¾ pounds has resulted in no decrease in shooting efficiency.

Winchester Model 50 Auto-Loading Shotgun

Winchester introduced this new shotgun in May 1954. Its design is a radical departure from that of most previous auto-loading shotguns in that the barrel is non-recoiling. A short, strong steel chamber operates and slides within the barrel. When the gun is fired the chamber, bolt, and inertia rod move backward together less than 1/10th inch. The chamber then unlocks from the bolt, but the bolt and inertia rod continue back on their way through the cycle of operation, extracting and ejecting the fired shell, compressing the closing spring, and raising the next shell from the magazine into position to be forced into the chamber. The compressed closing spring then completes the cycle, carrying the bolt forward, pushing the shell into the chamber, and locking the breech ready to fire again when the trigger is pressed.

The tubular magazine within the forearm holds two shells, which with one in the chamber, makes it a three-shot weapon. Loaded shells are inserted into the magazine through a port in the bottom of the receiver, and the fired shells are ejected through a port on the right side of the receiver. To date this gun has been made in 12 gauge only, but Winchester contemplates later producing it in 20 gauge. It operates perfectly with field, trap and high velocity loads without any adjustment.

New Winchester Lever-Action Rifle

In the Spring of 1955 Winchester produced an entirely different high power lever action rifle known as their Model 88. The design is unique in that it has a revolving bolt head with two locking lugs that locks the breech close to the head of the cartridge similar to bolt action rifles, and also a one-piece walnut stock. The detachable box magazine holds four .308 Winchester cartridges. The finger lever is a two-piece one somewhat similar to that on their Model 1895 rifle, locking in its closed position, but unlocking at the first down pressure on the bottom member of the loop. The flat rear end of the receiver abuts against a steel reinforcement secured at the rear of the receiver opening in the stock, the abutment of the receiver against this reinforcement forming the recoil shoulder. The barrel and receiver are held in the stock only by the forearm screw and by abutment into a tenon in the reinforcement. When the forearm screw is removed the barrel and receiver can be lifted out of the stock. Apparently there is no easy method of removing the bolt for field cleaning. The rifle weighs about 7 pounds, and the receiver is drilled and tapped for hunting scopes, but not for a receiver sight. The initial accuracy test by the National Rifle Association showed quite steady grouping with factory cartridges in about a 2½ inch group at 100 yards. At the present writing this rifle has not yet been in the hands of the using public, but its whole design is such, that it will probably be recorded a very enthusiastic reception among sportsmen desiring a light lever action rifle.

Browning Double Automatic Shotgun

This is an entirely new departure in shotguns, designed by Val A. Browning, son of the late great gun designer John M. Browning. It is manufactured for the Browning Arms Company in the Fabrique Nationale factory in Liege, Belgium. The gun has a single barrel, and the mechanism holds only two shells. It has been designed to cater to the many sportsmen who prefer a two-shot gun like the old double barrel gun, but at the same time realize the advantage that comes from the single sighting plane of one barrel. This new Browning provides this, together with many of the attractive lines and balance of the old double gun. As compared with the double gun, manufacture is much simplified so that without sacrificing quality the new gun can be produced to retail at about half the price of a really good double gun.

To load the gun, the breech being open, a shell is pressed into the loading port on the left side of the receiver, and this shell is immediately and automatically fed into the chamber ready to fire. A second shell is then similarly pressed into the loading port, but remains in the shell carrier, plainly visible. When the gun is fired the first shell (empty) is automatically extracted and ejected through the port on the right side of the receiver, and at the same time the second shell in the carrier is automatically fed into the chamber, ready to fire. Thus two shells can be fired as rapidly as with a double gun.

This Browning gun is made in 12 gauge only, and is a take-down with very easily interchanged barrels. Two models are made, one with aluminum alloy receiver weighing about 6 pounds 14 ounces, and the other with a steel receiver weighing about 7 pounds 11 ounces. The gun handles all 2¾ inch shells from field to high velocity loads without any adjustment, and the recoil is no more noticeable than with any fixed breech gun of the same weight.

LIGHTER HANDGUNS

The Colt's Manufacturing Company have produced a new and lighter model of their .45 Government Automatic Pistol. This pistol in our present service type has a 5 inch barrel and weighs 39 ounces. This lighter model is known as the "Zephyr Commander," has a 4½ inch barrel, weighs 26½ ounces and is furnished in .45 Colt Auto, .38 Super Auto, and 9mm Luger calibers. Reduction in weight has been accomplished by the shorter barrel and frame, and by constructing the receiver and mainspring housing only of "Coltalloy," an aluminum alloy of high tensile strength. A number of our expert pistol shooters have used this light weight pistol extensively, and have been unable to find any difference in accuracy, apparent recoil, or durability between it and the heavier 39 ounce standard Government pistol. It became extremely popular with Army and Marine Corps officers who served on the battle front in Korea.

Smith & Wesson are likewise making light weight models of their .38 Special revolver for the U. S. Air Force, with 2-inch barrels, and weighing 19 ounces in the all-steel model, and only 10½ ounces with a cylinder and frame of a lighter alloy. These light weight revolvers have not yet been produced for sale to the public, but the firm is now producing a "Combat Masterpiece," of the same design as their standard .38 Special Masterpiece Target Revolver. The Combat model having a 4 inch barrel, adjustable target sights and weighing 34 ounces as compared with 38½ ounces for the target type with 6 inch barrel. This revolver likewise proved very popular with officers serving in Korea, many of whom preferred a revolver to an automatic pistol.

In addition to the weight saved with these light handguns there is an additional saving in the weight of the holster in which to carry them. In service it is the combined weight of the gun and the holster on the man's belt that counts. The writer can well appreciate this, having carried a .45 cal. Colt New Service Revolver weighing 40 ounces on his belt for two years in the Philippines, and likewise a .45 cal. Colt Government automatic pistol weighing 39 ounces for two years in Panama.

NEW TELESCOPE SIGHTS

Our experienced big game hunters came to the conclusion long ago that a telescope sight to be satisfactory for use in wooded country, particularly where quick snap-shots, and shots at running game were frequent, should have a field of view of at least 30 feet at 100 yards. With a smaller field than this it is difficult to throw the rifle to the shoulder, into the firing position, so that the game will surely be in the field of view when one first looks into the scope, or to hold running game in the field as one swings with it, and leads it, waiting for an opening in the woods and brush through which to fire.

Up until about 1945 the only telescope sights that had this desirable field of view were those of 2¼ to 2½ power magnification. The field of these low power scopes varied from 30 to 36 feet. Generally speaking, due to their lack of resolving power, they were suitable for sure aim and hits in the vital portions of animals the size of woodchucks to only about 125 to 150 yards, and on big game only to about 200 to 250 yards, when the game did not stand out clearly defined against a contrasting background, or when it was partly hidden by brush or shadow.

About 1945 our manufacturers began to produce scopes of 4 power which had fields varying from 30 to 34 feet at 100 yards. They are equal to the 2½ power scopes for quick shots and for running game, and likewise give much better resolving power, so that they extend the sure hitting range by about fifty percent. Among these are the 4X Lyman Challenger, the 4X Bear Cub, the K4 Weaver, 4X Leupold, 4X Texan, 4X Bushnell Scopemaster (Japanese) and 4X Supra (German).

Some very excellent 6 power scopes, having fields of about 20 feet at 100 yards have also been produced, which have proved excellent for varmint shooting, and also possible for big game shooting over open terrain, due to their excellent resolving power. Some of these scopes are indeed so excellent that they excel six power coated binoculars in their resolving power, or indeed 8 x 30 uncoated binoculars. Among these are the 6X Bear Cub, the 6X Bushnell Scopemaster (Japanese), 6X Supra (German), and the K6 Weaver.

All of the above 2½ to 6 power scopes have very large exit pupils, so that the illumination is as great as the human eye can avail itself of. All of best make have all surfaces of their lenses hard coated with magnesium fluoride. Theoretically this increases the illumination, because a coated lens passes about 10 percent more light than an uncoated lens. Practically the increase in illumination will hardly be noticed with the coated lenses because in these scopes, even of 6 power, the uncoated lenses pass more light than can pass through the pupil of the human eye. But they have one very important advantage in that they very greatly decrease the flare or halation that occurs when the shooter aims toward the sun, and sunlight strikes the object lens, or when one aims with the sun at a slight angle back of him so that sunlight comes over the shoulder and strikes the ocular lens.

There has also been considerable improvement in the internal reticule adjustment of these game scopes. Prior to the introduction of the 2½ power Lyman Alaskan scope little reliability could be placed on these internal reticule adjustments, and most of these scopes had adjustment for elevation only, it being necessary to use a mount that had windage or azimuth adjustment.

However, there is much room for improvement in the internal reticule adjustment of most hunting types of telescope sights. Not only does there seem to be some lost motion in the reticule movement so that it does not correspond at once or reliably to a movement of the reticule dial, but the graduations on the dials themselves bear little relation to reticule movement, are poorly graduated so that they are difficult to read and almost impossible to record, and indeed many do not have any index or zero line from which one can start to read the graduations. Most dials are furnished with clicks which are supposed to change the center of impact 1 minute, ½-minute, or ¼-minute per click, but it is not clearly indicated on the scope which distance the click will change the center of impact, and the clicks are merely serrations around the circumference of the dials, and are not co-ordinated with the graduations on the dials.

There is, however, one make of hunting telescope sight which seems to be very satisfactory in these respects. The reticule movement mechanism on the Bear Cub scopes having internal reticule adjustments, and manufactured by the Kollmorgen Optical Corporation, are constructed like precision mechanics micrometers, and are entirely free from lost motion. The dials on these scopes are also clearly and distinctly graduated in minutes, with an index line so that the graduations can be read and recorded in any fairly good light. There are no clicks, and the graduations are easily subtended and read to quarter minutes. Moving the dial one minute or three minutes reliably moves the reticule a corresponding amount, and when so adjusted and then returned to the original adjustment, the center of impact reliably comes back to the original position. They seemingly have all the reliability of adjustment and of recording that riflemen have found so satisfactory with the double micrometer mountings found on the four leading makes of target telescope sights.

Lately, some new game scopes have been introduced that do not have reticule adjustment for elevation and windage, but have the tubes sealed practically airtight, and filled with nitrogen. If a hunter takes a scope from a very cold temperature, such as when hunting in late fall or winter, into a heated house, the scope at once condenses a film of moisture all over it, inside as well as outside. The outside film can easily be wiped off, but there is nothing to do about the inside film except to wait until the scope has become warm, and the film has gradually evaporated, often a matter of many hours before one can see clearly through that scope. Moisture does not condense inside nitrogen filled scopes, which, however, require mountings adjustable for elevation and windage. The remedy with scopes that are not nitrogen filled is obvious. Simply leave the rifle and scope outside in the cold, and when finally obliged to bring it into a warm temperature, first wrap it up tightly in cloths and place it in its case so it will warm up very slowly. Sometimes similar precautions must be taken when bringing a very cold rifle and scope into a heated automobile.

For small bore target shooting prior to World War II the most popular scopes were those of about 8 to 12 power. Today those mostly in use by our successful competitors have magnifications of from 18 to 25 power. The reason for this is not entirely because these very high power scopes permit of more accurate aim. They do permit of more accurate aim on certain targets, but not on targets having aiming rings because the shooter can center the cross-hairs of the low power scope in a ring about as accurately

Figure 103. New .280 caliber British Experimental Rifle EM-2.

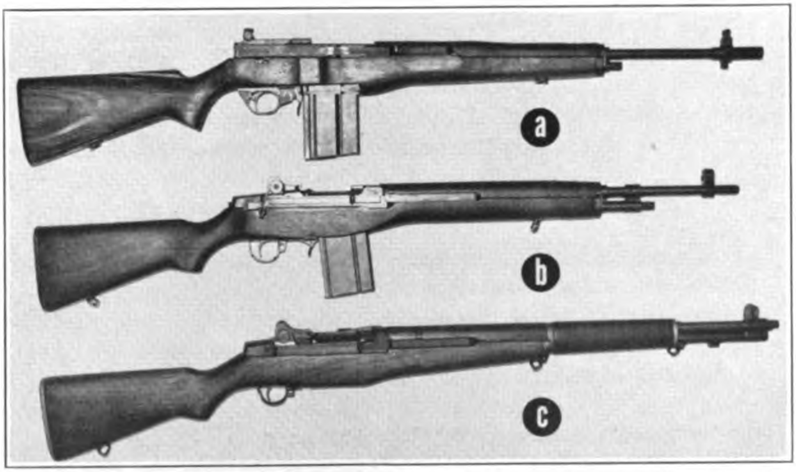

Figure 104. New Experimental United States Military Rifles,
A—the T47. B—the T44. C—our present M1 (Garand) for comparison.

Figure 105. The Two New Cartridges.
Lower the .30 caliber United States T65. Upper the .280 caliber British. Reproduced on same scale.

as with one of higher magnification. Rather these higher power scopes are preferred because they permit the shooter to spot his bullet holes on the target (up to 100 yards at least) without the aid of a high power spotting scope. If one has to use a spotting scope to tell him where his last shot has struck the target, he has to more or less get out of his uniform firing position to see through the spotting scope. Any change in the firing position is very liable to alter the position of the next shot in the target. In fact if the shooter is shooting steadily into the 10-ring, and he alters the tension on his gunsling, or changes the position of his left elbow on the ground, the next shot is almost certain to go out for a nine at least. This is because of the influence of a changed position on the jump or vibration of the rifle. The high power scope also makes it easier for the competitor to fire his score within the prescribed time limit, because time is not taken up in looking through the spotting scope, and he sees where his last bullet struck almost instantly. A good 20 power target telescope sight with coated lenses will usually spot .22 caliber bullet holes in the black portion of the target quite clearly to 100 yards at least, and .30 caliber bullet holes to 200 yards at least in almost any good light.

NEW BREECH ACTIONS FOR CUSTOM RIFLES

The Firearms International Corporation of Washington, D. C. is now supplying Mauser 98 breech actions complete to custom rifle-makers and individuals in the United States. These actions are made by Fabrique Nationale in Belgium, and are identical with the standard German Mauser 98 actions except in the following respects.

There are no clip slots in the receiver, nor is the receiver cut away on the left side to accept the thumb in clip loading. The top of the receiver bridge is smooth and rounded to facilitate the mounting of telescopes and receiver sights. The bolt handle is turned down and reformed so that it can be operated under a low mounted telescope sight. A new safety lock on the left side of the bolt sleeve permits operation under a low scope. The trigger mechanism has been altered so as to eliminate all the slack and most of the creep. The floor-plate has a button release which can be operated with the fingers. The length of the magazine and bolt throw have been altered so as to accommodate cartridges as long as the .30-06 (3.36″), and the action can also be had with a short magazine-follower, and a filler-piece in the magazine for better fit with short cartridges like the .250 and .300 Savage.

The writer understands that in the past eight years over 100,000 of these Mauser breech actions have been furnished to custom rifle-makers and others, and invariably they have given excellent satisfaction. They are very fine actions. The Firearms International Corporation is also prepared to furnish these actions with barrels fitted and chambered by Fabrique Nationale, and for practically all cartridges which have a case head of the same dimensions as the .30-06. They can also furnish complete rifles with sights and sporting stocks.

The same corporation is likewise supplying the Sako breech action made in Norway. This is also an excellent action of Mauser 98 type, but small, short, and miniature, adapted to the .22 Hornet, .218 Bee, and .222 Remington cartridges. It has a detachable box magazine which is of a different length for each of the above cartridges. The excellent trigger mechanism is of the same type as that seen on the Winchester Model 70 rifle. The bolt handle is turned down for low scope mounting, and two taper-dovetail blocks are located on top of the receiver ring and bridge to facilitate scope mounting. The safety also functions under a low scope. Barrelled actions and complete rifles can also be furnished for the above cartridges. The complete rifle weighs only 6½ pounds, and is in great demand, particularly in .222 Remington caliber. It is at least as accurate as any of our American rifles made for the same cartridges.

THE BEDDING OF STOCKS

Since the first edition of this work was written, as a result of much bench rest shooting, both experimental and competitive, we have found out much more about the bedding of rifles in their stocks. Bench rest shooting eliminates the human errors of marksmanship and aiming, and permits the excellence or defects in materiel to stand out alone. Thus we have found that bedding is far more important than was previously supposed, particularly in accuracy and maintenance of zero. Good bedding will not make a poor barrel, action and ammunition shoot well, but on the other hand the best of these will give poor accuracy and the location of the center of impact may vary continually, due entirely to poor bedding. Moreover, a stock originally well bedded, may at any time become poorly bedded because of the warping, swelling, or shrinking of the wood.

We shall discuss this matter first with reference to well made bolt action rifles; that is a rifle and ammunition which will average a dispersion of one minute or less, and the center of impact of which will not vary more than one minute when shot from a constant firing position and in a well bedded stock.

Walnut is the preferred wood for stocks. Nothing else is quite so good, although a few excellent stocks have been made of other woods. The walnut should be dense and close grained, and the grain of the blank should run parallel with the action and barrel in this portion of the stock, or else the grain may slope very slightly upward towards the tip of the forearm. The wood should be thoroughly air-seasoned by at least several years of dry storage, and then, just before it is made into a stock, it should be further kiln-dried to a moisture content approaching seven percent. Many firms who furnish stock blanks have kilns and can assure this small moisture content. This thoroughly dried blank should be gotten from the dealer to the stock-maker as promptly as possible, before it has had a chance to absorb moisture in air of high humidity. It should preferably be received by the stock-maker in winter while his shop is heated and the humidity is low, so it will not absorb moisture while he is working on it. In the southwest portion of the United States the air is continually so dry that stocks can probably be fabricated there without danger of absorbing moisture. Just as soon as the stock-maker has completed the stock its surface, inside and out, should be thoroughly impregnated with a filler to seal the pores of the wood before the stock is polished. These are the ideal conditions. They cannot always be achieved, but an attempt should be made to do so.

The receiver and guard of this rifle should be bedded very accurately and tightly. The wood should press tightly against the metal over all points of contact. It should not be possible for the action to rock back and forth, side to side, or twist in the stock. The recoil shoulder of the receiver must have bearing and full contact with the corresponding shoulder in the stock. There should be at least two guard screws, front and rear, and these should be set up very tight, and must remain turned up tight at all times. If the action is bedded in this manner in a well seasoned and dry stock it is unlikely that any defect in action bedding will ever occur due to warping, swelling, or shrinking of the wood.

Due to the fact that the forearm is long and thin, it is more prone to warp than other portions of the stock, and if this warping places any undue pressure against any part of the barrel (except upward at the tip of the forearm as noted below) it is sure to have an injurious effect on the shooting of the rifle. For these reasons the bedding of the barrel in the firearm is of the utmost importance.

It has been proven quite conclusively that the best accuracy and maintenance of zero occurs when the barrel is "free-floating" in the forearm. That is when the forearm does not touch the barrel at all, and it is possible to run a piece of ordinary blotting paper everywhere between barrel and forearm channel from the tip right up to the receiver. There is no screw or band attaching the barrel to the forearm. This permits the barrel to always jump and vibrate uniformly and normally when fired. Such free floating results in a visible gap between barrel and forearm groove. If the gap is uniform the whole way its appearance is not objectionable. Thus with a gap of approximately .05-inch between barrel and forearm, it is unlikely that the forearm will ever warp enough to put pressure anywhere on the barrel, but this should be continually watched for by occasionally running a blotting paper strip between the two.

There is another method of barrel bedding which has been used fairly successfully by some stockers and target riflemen. This is to have the barrel free-floating as above, except that the forearm for about an inch at its front end presses straight upward against the bottom of the barrel, with such pressure that it requires about a five pound pull-down on the tip of the forearm to so separate the forearm groove from the barrel that a strip of writing paper can be run between the two at this tip contact point. Such bedding has often resulted in an excellent shooting rifle, but the writer has noticed that many shooters who use this method are continually running small shims of paper between the forearm tip and barrel, or varying these shims to maintain the good grouping of the rifle. A number of devices have also appeared, notably the electric bedder, for attachment to the forearm tip to alter or preserve the proper pressure between forearm tip and barrel. The simplest of these is the adjustable barrel band seen on the newest type of the Winchester Model 52 .22 caliber match rifle.

The older stock-makers who have not been in close personal contact with skilled riflemen, particularly the bench rest shooters, or who are not excellent marksmen themselves, generally prefer to bed the barrel its entire length to full, perfect and tight contact with the forearm. There is no visible gap between edge of barrel channel and barrel, giving an attractive appearance and indicating skilled workmanship. A rifle bedded in this way may shoot excellently at first, but there is much danger that slight warping of the forearm may place pressure at some point on the barrel more than at others, and the rifle begins to shoot with mediocre accuracy until the stock-maker has rebedded it.

The critical period when a stock is liable to warp, shrink, or swell is in the spring and fall when it passes from storage in a heated house to out-of-door use. Such swelling and shrinking at these times can often be noted by the fit of the steel butt-plate to the stock. It seldom affects the action bedding of a well seasoned stock, or the full-floating forearm bedding.

Another critical time is when the rifle may become soaking wet in a rain, or completely wet due to a canoe upset or a fall when fording a river. To protect a rifle in such instances a rifle raincoat can now be had. This is a completely waterproof cover of thin plastic which is so light and thin that the hunter can fold it and carry it in his pocket, where it occupies no more room than a handkerchief, but the rifle can be slipped into it when necessary.

If a shooting gunsling is fitted to the bolt action rifle the front sling swivel should be attached to the forearm only, about 2 to 2½ inches in rear of the forearm tip. The swivel should not be secured to the barrel in any way, either directly or by a band. If the swivel is attached to the forearm only, then pull or tension on the sling is not transmitted to the barrel to interfere with or vary its jump or vibration. Long experience has shown that if the swivel is attached to a full floating forearm only, and the rifle is fired in the prone position with a tight gunsling, that the resulting center of impact as compared with that when fired offhand, is either not altered at all, or else is never more than a minute lower in the prone position. With the sling swivel attached to the barrel, or to a barrel band, the center of impact firing prone with the gunsling may be anywhere from about three to ten minutes lower than when fired offhand, and the elevation will vary according to the amount of tension on the sling.

Next we turn to the single shot rifles, and repeating rifles like the Savage Model 99 which have two-piece stocks, and either no magazine, or a box magazine in the action. Here the butt-stock should be very tightly bedded to the receiver and the tangs, and the tang screws should turn up to tight compression. A thru-bolt passing through the stock from butt-plate to rear of receiver, as seen on the Savage Model 99, and on the old Sharps-Borchardt and Ballard rifles, helps to secure tight and stiff contact between butt-stock and receiver. Some gunsmiths fit such a thru-bolt to custom remodeled Winchester single shot rifles, and the Hauck single shot action, the most accurate of all single shots, has this thru-bolt.

The forearm of such a rifle may be tightly bedded to full contact with the barrel, and secured to it with screws. But the rear vertical surface of the forearm must not touch the receiver at all. It must be possible to pass a piece of paper between forearm and receiver. Almost always this makes for much better accuracy, and often the accuracy is miserable until all contact here is removed. The Hauck single shot action has a long, square bar of steel screwed to the front of the receiver, and extending under the barrel and parallel to it, but not touching the barrel. The forearm is bedded tightly to this bar, but does not touch the barrel at all, which is free to jump or vibrate uniformly without restraint.

Finally we come to rifles having two-piece stocks and a tubular magazine under the barrel, with the magazine and forearm tip fastened to the barrel. Here the only thing the stocker can do is to assure tight bedding of butt-stock to the receiver and tangs, with tight tang screws. Partly because the attachment of the tubular magazine and forearm to the barrel interferes with the jump and vibration of the letter, the best accuracy that can be expected with this design of rifle is a dispersion of about 2½ to 3½ minutes, which is not too much for successful use in big game shooting up to 200 yards, which is the use for which these rifles were designed. Also, as the rifle heats up from repeated firing this dispersion increases, and the center of impact changes, and both become unpredictable.

Such rifles should be sighted in, and tested for accuracy by firing only three rounds at a time, and then allowing the rifle to become cold before resuming the firing. That is sight adjustment and accuracy should be based on three-shot groups, starting with the barrel clean and cold. Of course this is entirely logical because these are game rifles and not target rifles, and it is very unlikely that one would fire more than three shots in succession at game.

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Gunsmithing

By Roy F. Dunlap

A 1950 work on gunsmithing—the most complete ever written, containing information on every phase of gunwork from selection of the stock blank on through to the metal engraving and blueing. It is *thorough!*—with not only the "what" and "how" but also the "why." This work was instigated by the publisher and written at his request by Roy Dunlap with a view of replacing Baker's *Modern Gunsmithing*, which was written back in 1927. Everyone who has read Dunlap's manuscript says it is "better'n Baker."

The average user of firearms will find this book to be of value in its technical information on barrels, action bedding, accuracy adjustments and trouble corrections. The shotgun information is exceptionally complete and practical. One can read exactly how the job he wants should be done and how to have the guns fitted properly to himself so that he can get the most out of them.

The targetshooter will be interested in the chapters on modern target rifles, their barreling and chamber work, their special furniture and fittings. Dunlap is a hard-boiled, competent rifleman and his information on rifles of precision is backed by trial, experience, quite a few medals and trophies, and many a head of big game.

The general gunsmith will gain information he has never been able to find except through trial and error. Individual shotguns, rifles, revolvers and pistols are covered in detail, their weak points mentioned, and instructions given as how to fix them without the use of a fully equipped shop and special, expensive machinery.

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Professional Gunsmithing

By Walter Howe

Gunsmithing methods and textbooks, like everything else, are matters of evolution and change for the better. This is particularly true of the many technical books on gunsmithing now in existence—each in part records or augments the gradual but positive progress of the craft as time goes by.

Here is a recent work written entirely from the professional outlook and devoted mainly to the repair and modification of existing stock weapons. "*Professional Gunsmithing*" approaches the subject from an entirely new angle, supplementing and enhancing all other previous Samworth Books on Firearms treating of this vital matter of gun repair and upkeep. It combines both business and technical phases of gunsmithing, in that matters such as time, ethics, price estimation, how to deal with shooters as customers, and the idea of doing the job exactly as someone else demands and not as the gunsmith himself might want to do it, are given paramount consideration throughout the text.

How to best set up a gunshop and what is more important, how to keep it going on a profitable basis is included in this volume. Subjects such as business set-up and customer relationship are presented in a clear, understandable manner. Several speciality lines which will provide a satisfactory source of revenue are included and the listing of sources of supplies for all gunsmithing materials is the most extensive yet published.

Anyone entering the gunsmithing field, either as a means of livelihood or merely to work on their personal firearms, will find a mass of applicable material herein. The subject of commercial gunsmithing is taken up by Howe in a broad and comprehensive manner, approached from the angle of basic principles and logical reasoning. He tells how to diagnose gun troubles when the weapon is brought in for repair and explains the general reasons and causes for necessity of such repairs. By applying Howe's "approach" to the problem in hand any gunsmith will be enabled to correctly and profitably remedy the fault or repair the defective part.

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"*Professional Gunsmithing*" is today's outstanding textbook for the gunsmithing profession, and is now being used as such in colleges and training schools which include gunsmithing in their curriculum. 520 pages, 120 special drawings, 21 plates. Price $6.00.

Gunsmith's Manual

By Stelle and Harrison

Back in 1882, when every town and village of any size whatever had its own hardworked gunsmith, J. P. Stelle and William B. Harrison wrote THE GUNSMITH'S MANUAL—one of the very few early American works on firearms, and a book immediately recognized and accepted as the standard textbook of the gunsmithing profession. This publication held that position of eminence for several decades; in fact, it was the authority until the coming of smokeless powder.

Stelle and Harrison produced a most authentic work thoroughly up to date for those times and exceptionally complete in that it treated upon all of the early breech loading firearms just then beginning to come into popularity and general usage. The book also was most thorough in its coverage and treatment of the muzzle loading firearms, which were then in their heyday.

The long established standing of this early textbook, as well as its literary excellence, was such that we have reproduced it, page for page and word for word, as it was originally published.

Despite the unique style and phrasing of its text, this is an enjoyable and at the same time a most instructive work. There is much amongst its material that is yet good workable shop practice; sound procedures and methods fully applicable by the gunsmith of today. Many of the formulae and bench tricks described herein can still be employed with profit. It fully covers all standard methods and processes followed in the days of muzzle loaders, both flint and cap-lock. In addition to clear and lengthy descriptions of proper fabrication methods, the book is profusely illustrated with most of the hand and bench gunsmithing tools necessary at that time.

The average town gunsmith of the '80s and '90s made practically everything he needed except shotgun tubes, rifle barrels and gun locks—and this book gives explicit directions, with illustrations, for the making of gun screws, nipples, keys, thimbles, hammers, ramrods and springs. Much data is given regarding the treatment, forging and processing of gun and barrel steel. The tools and processes necessary for the boring and rifling of those early gun barrels are described and illustrated. Quite a bit of text is devoted to cap-lock and early cartridge revolvers. Many are illustrated.

This book is of considerable practical value to the present day gunsmith, as it is the only work in existence which treats authoritatively of the construction and repair of the muzzle-loading gun. Its extensive instruction relating to the fabrication of gun parts by means of hand tools and simple methods can also be of particular benefit to the worker with limited means at his disposal. 296 text pages with many illustrations. **Price $4.00.**

Gunstock Finishing and Care

By A. Donald Newell

This is an extensive and thoroughly complete contribution to the art of modern gunsmithing, a work equally valuable to either professional or amateur craftsmen. It includes materials, suitability, methods of application, and the history of ancient and modern protective and decorative films. The author of this timely book is a technician in the laboratory of one of the largest American paint and varnish manufacturers; then, to further qualify in the preparation of so definitive a work he is a rifleman and amateur gunsmith of several years' standing.

In this most thorough work, Newell sticks entirely to his vocation in that he treats solely of gunstock finishing. In some 16 elaborate chapters, replete with heretofore unpublished trade data and technique, he tells everything known today by the people who make these finishing materials, so that they can be properly applied by the individual gunsmith seeking the most beautiful and thoroughly practical stock finishes for both modern and antique firearms. The greater portion of these procedures and formulae will provide virgin knowledge for the majority of our guncraftsmen.

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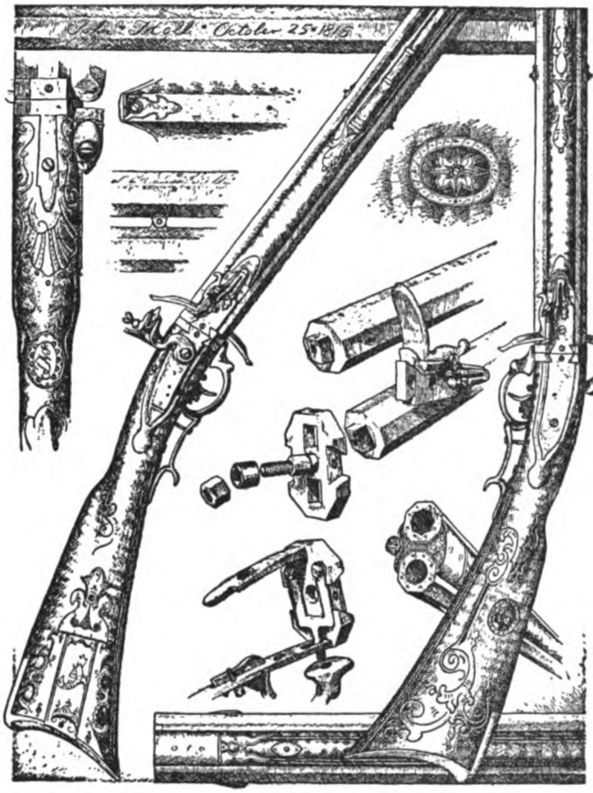

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By
Ray M. Smith

Drawings by
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