STUDY UNIT 14, PART 1

METALLIC SIGHTS: DESIGN AND APPLICATION

POINT TO POINT – TO POINT SIGHTING

For thousands of years, man's ability to hit an object with a muscle-powered projectile, rock, spear, or boomerang depended entirely on coordination, practice, and instinct (Figure 1). It wasn't until the development of the bow and arrow, which utilized an *external force* (the rapid expansion of the compressed wood) to augment his muscles and propel a missile, that "sighting" entered the picture. The head of the arrow provided a reference point against the target and, providing the arrow was always anchored at the same spot on the face and drawn to the same length, surprisingly good accuracy was (and is) attained.

The medieval crossbow incorporated the forerunners of today's iron sights. Old drawings show crossbows with a notched or grooved post extending out of the stock a few inches in front of the shooter's eyes. Thus, the three-reference-point method of sighting, where the marksman had to line up the post (rear sight) with the tip of the bolt (front sight) relative to the target, was established. This is the same principle employed with modern metallic sights. Sometimes the steel point of the bolt had a small raised blade which, when the bolt was laid in its groove, served as a front sight; at other times an inverted "V" bridge was placed over the front of the crossbow groove, which was the front sight. Antique and modern crossbows, in skilled hands, are often as accurate as a modern handgun, with one inch MOA groups at 25 yards and even farther quite commonplace.

THE FIRST GUNS WERE SIGHTLESS

The first "gonnes" of the 14th century, with their "slow-match" ignition (Figure 2), were nothing more than plugged tubes mounted on a block of wood or on a pikestaff simply pointed in the general direction of the target. As shooting was usually done at sword or spear range, and accuracy was par with a thrown bean bag, the rudimentary but efficient crossbow sights *stayed* on crossbows.

During the matchlock period and the development of the first shoulder arms, crude sights gradually evolved. Most often a blade front sight was combined with a hump at the breech end of the barrel, which was sometimes grooved or notched (Figure 3). A few surviving matchlocks have primitive aperture (peep) sights resembling a small, empty scope tube mounted flush with the barrel and just ahead of the breech.

Through the evolution of firearms from the matchlock to the flintlock, sights were not universally used. Some guns had sights, others did not — and considering the inherent lack of accuracy (a four-foot group at 50 yards was "acceptable") and short range of such arms — the matter wasn't critical. Sights on handguns were hardly ever used with short-range smooth-bore pistols, even on those of the dueling variety. Accuracy, as with the bow and arrow, depended on coordination and instinct.

WHY THE RIFLED BORE SPURRED SIGHT DEVELOPMENT AND USE

The invention and widespread use of the rifled bore, and of guns that could shoot straighter than the aimer could hold, made sights mandatory. The first rifled flintlocks combined a blade front with a notched rear sight mounted extremely low on the barrel (Figure 4). The height of the blade and depth of the notch determined accuracy with a given charge, and adjustments could only be made with a file. As shooters began to understand the importance of accuracy relative to sighting equipment, and the principles involved, means of adjusting sights more conveniently evolved. The first improvement was to mount the front sight in a dovetail which, when driven to one side or the other, provided a lateral adjustment (Figure 5). The dovetail also provided a more secure attachment for the blade than the soldering and solder/bore-notching methods used earlier.

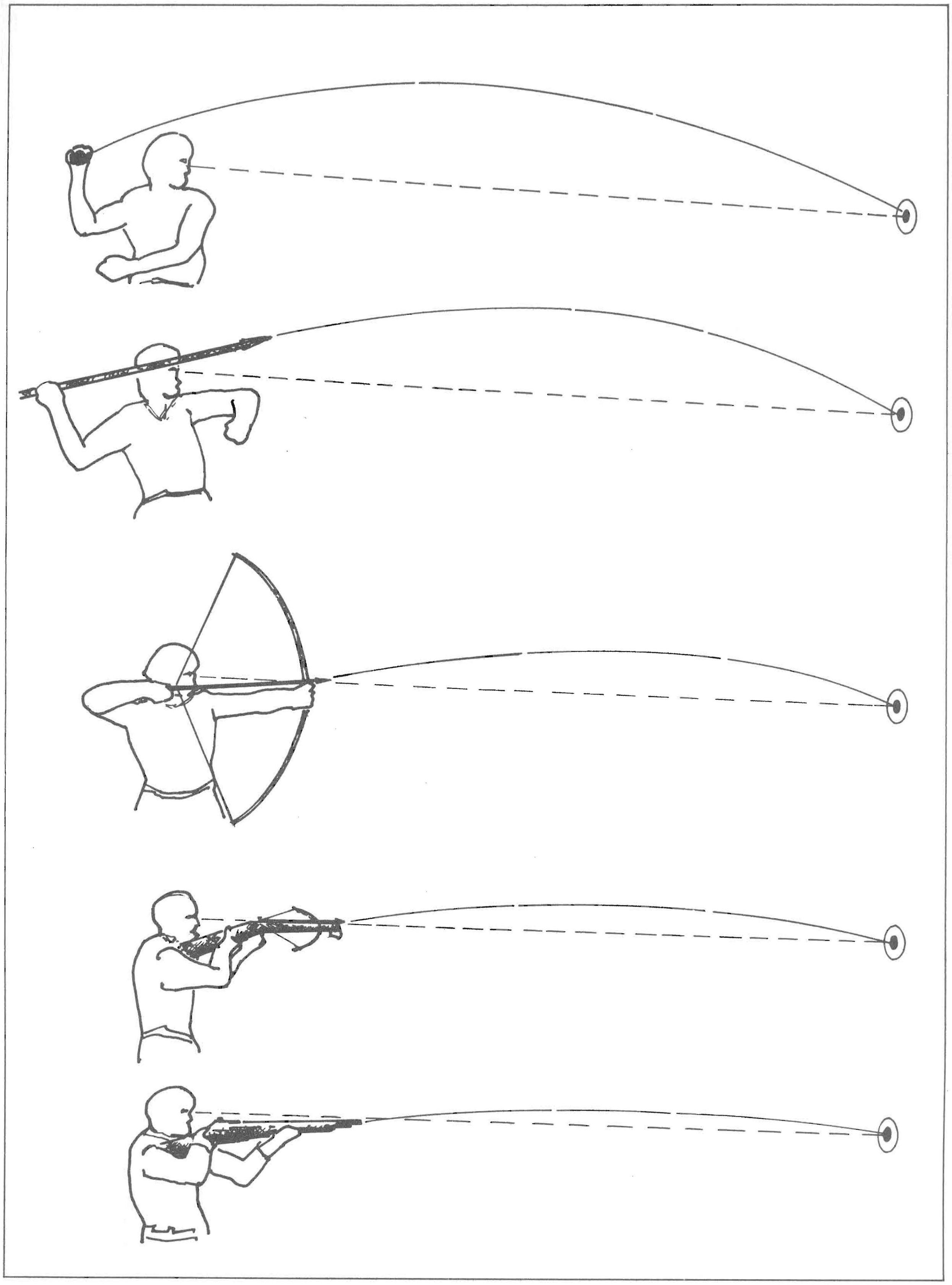


FIGURE 1 — Evolution of sighting. Aiming a rock or a spear utilized one reference point, the target; the bow and arrow employs two visual reference points, the tip of the arrow and the target; the crossbow and open-sighted rifle use three reference points, the rear sight, front sight and target.

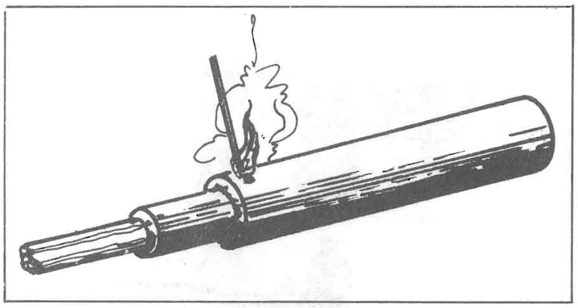


FIGURE 2 — The cannon lock was fired by a slow match. Whether small and hand-held or large and wheel-mounted, it had no sights.

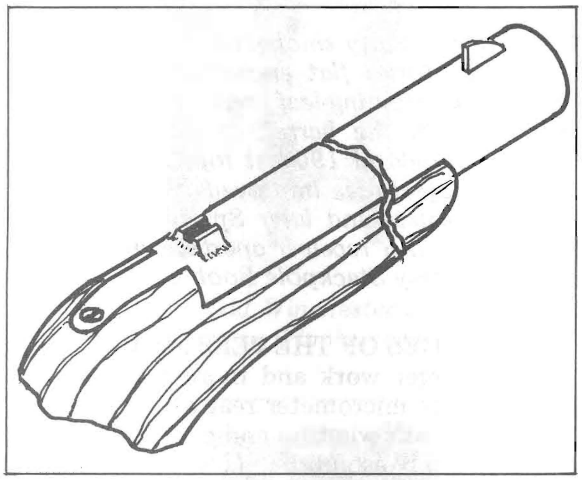


FIGURE 3 — The first shoulder arms employed a crude front blade and a rounded hump at the breech, sometimes notched, which served as a rear sight.

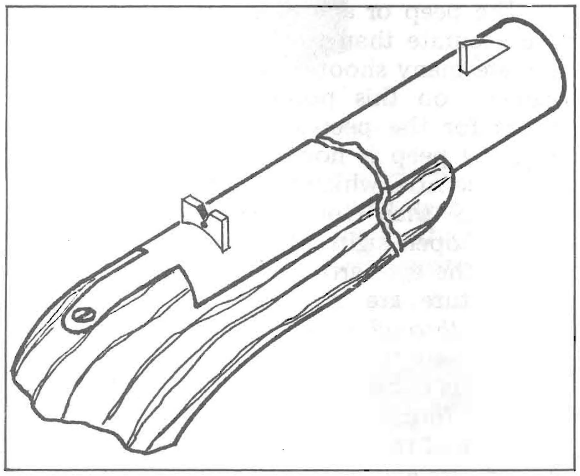


FIGURE 4 — Flintlock rifles had sights similar to those used today. They were not, however, adjustable — except with a file.

Not much was understood about using the rear sight for vertical adjustment. Usually it was left as is, with the high front blade gradually filed down to raise the center of impact to the desired level. In effect, the owner was stuck with his rear sight height. When he ran low on powder, he simply held higher to compensate for the reduced charge and velocity. Eventually a system involving multiple, progressively higher leaves became popular. The leaves were attached to the same base, and the "proper" leaf for a given range was raised when needed. Such a sight, while hardly adjustable, was interchangeable.

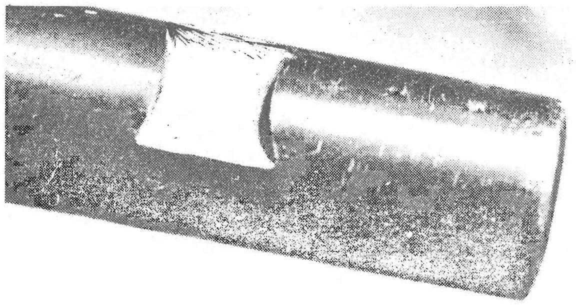


FIGURE 5 — The invention of the dovetail slot made possible the first adjustable sight.

THE FIRST ADJUSTABLE SIGHT

In the last half of the 19th century, the first truly adjustable sight was developed. It consisted of a stem with an aperture at the top which was threaded into the tang of the gun (Figure 6). By turning the stem in or out, range adjustments could readily be made in the field. A refinement of this type of sight was the later "vernier," which was mounted on the heel of the butt to provide a maximum sighting radius. The shooter fired while lying on his back, and often achieved astonishing accuracy at ranges up to and exceeding 1,000 yards (Figure 7).

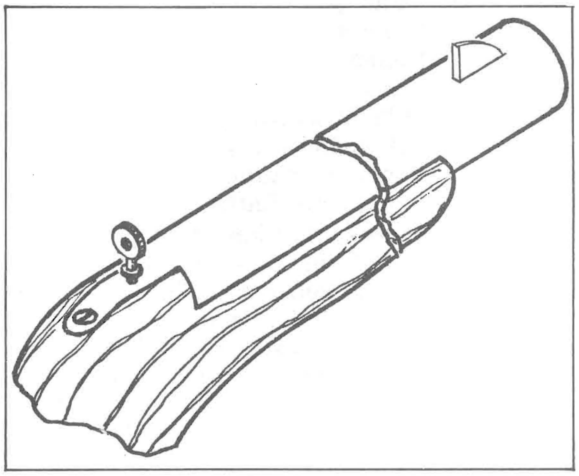


FIGURE 6 — The first vertically adjustable rear sight was of the peep variety which threaded in and out of the tang.

The common and still widely used "elevator" rear sight, with a tapered wedge which was moved backward and forward in an L-shaped slot to lower and raise the notched rear leaf, arrived on the scene at about the same time as the metallic cartridge (Figure 8).

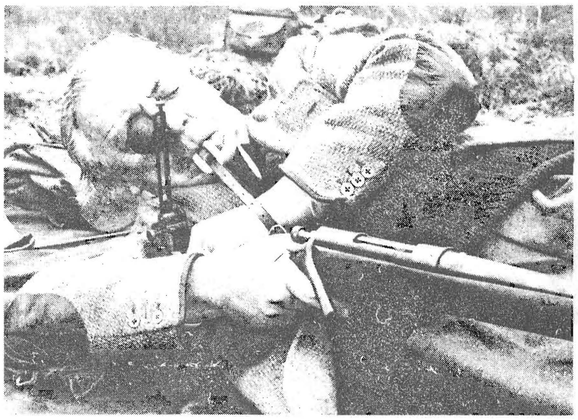


FIGURE 7 — For long-range blackpowder match shooting, vernier sights mounted on the buttstock were popular. Their use required the unusual "prone" position shown above. (Courtesy Guns magazine)

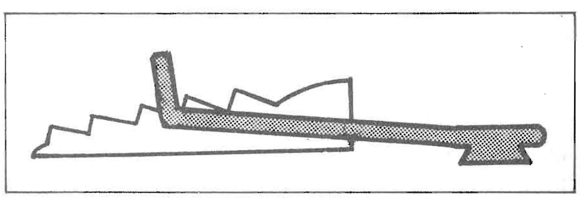


FIGURE 8 — Cutaway view, typical elevator-type rear sight. (Courtesy Stoeger Arms Corp.)

THE EFFECT OF SMOKELESS POWDER ON METALLIC SIGHT DEVELOPMENT

By the time smokeless powder was invented, the basic principles used in modern metallic sights were already established. However, the flattened trajectories resulting from the new powders meant smaller adjustments within the sights. Where the aperture bar on a vernier type of sight had previously moved perhaps three inches or more to conform to a looping trajectory, the flatter trajectories of the new smokeless cartridges required a vertical adjustment of less than an inch at the same range. Rear sights thus became more compact and provided ample room for the integration of lateral adjustments (Figure 9). Over the years, metallic sights became pretty much standardized. Today, the familiar elevator rear sight, adjustable vertically by moving the tapered wedge, and adjustable laterally by driving the sight mount to either side in its dovetail, has become the factory standard for general-purpose shooting (Figure 10).

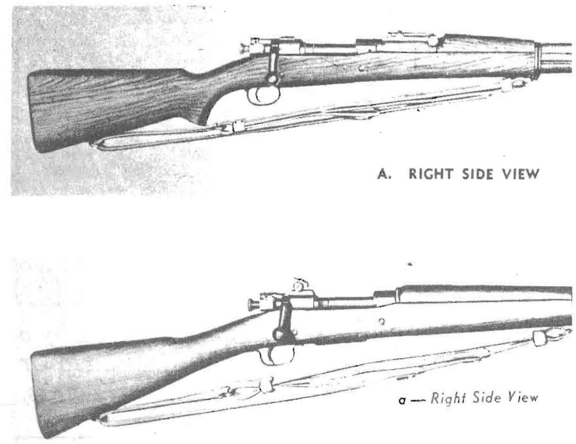


FIGURE 9 — Early smokeless cartridges produced trajectories flat enough to move the vernier-type, folding-leaf rear sight to the breech end of the barrel, as shown on the early Springfield M 1903 at top. As ammunition and trajectories improved, the leaf sight became obsolete and later Springfield's were equipped with a receiver aperture sight (bottom). (Courtesy Stackpole Book Co.)

ADVANTAGES OF THE PEEP SIGHT

For target work and more precise field accuracy, the micrometer rear aperture sight, combining both windage and elevation adjustments, is firmly established (Figure 11). Front sights are invariably of the fixed-blade variety and dovetail-mounted for lateral adjustment, although highly specialized, hooded-globe type front sights are used for precision target work (Figure 12).

The peep or aperture sight is inherently more accurate than the open sight, although there are many shooters who will give you an argument on this point. There are several reasons for the peep's superiority. For one thing, the peep is normally mounted on the tang of the rifle, which provides a longer sighting radius than does the front-of-chamber mounted open sight. Because the aperture is close to the eye, errors in holding and in the sight picture are minimized. Also, because you look *through* and not over the rear sight, you have only to align the front sight with the target, thus contending with *two* (rather than the usual *three*) reference points. Regardless of the size of the aperture, your eye automatically adjusts and centers the front sight in the opening. In other words, you're not really aware of the peep hole. You see a clear, sharp front sight and a slightly less well defined target image. The human eye, like a camera, is capable of *focusing* on only one object at a time. You can *see* both the blade and the target, but you're focusing only on the front sight. Conventional iron sights require that

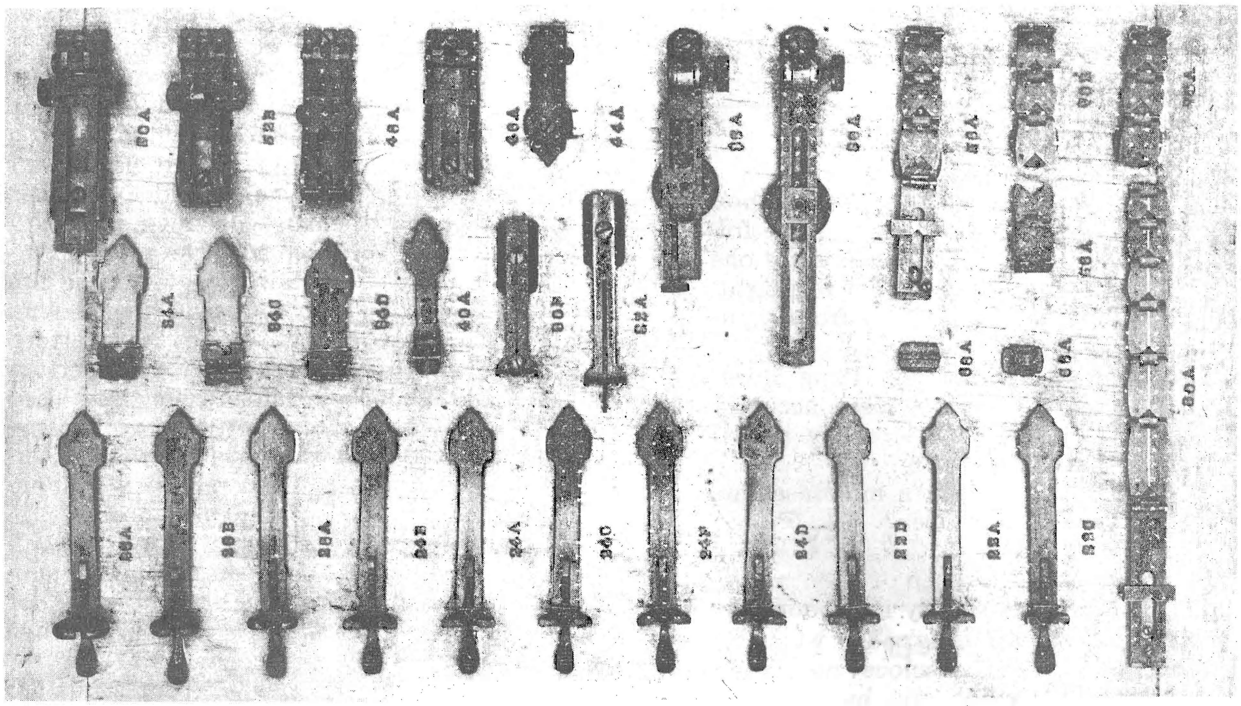


FIGURE 10 — Old Winchester open sights. Note the multiple-leaf version at the extreme right of the photo. (Courtesy Winchester-Western)

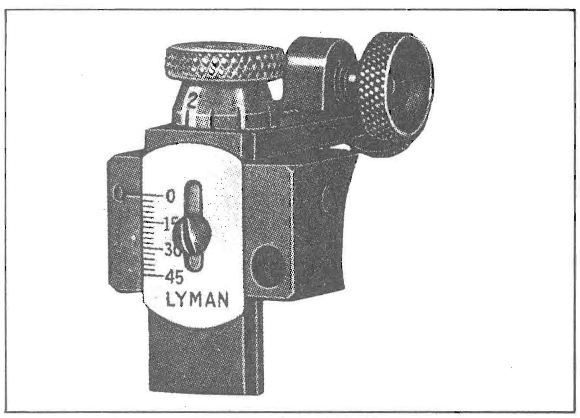


FIGURE 11 — Modern Lyman aperture sight of the type used mostly for hunting. It's adjustable for both windage and elevation.

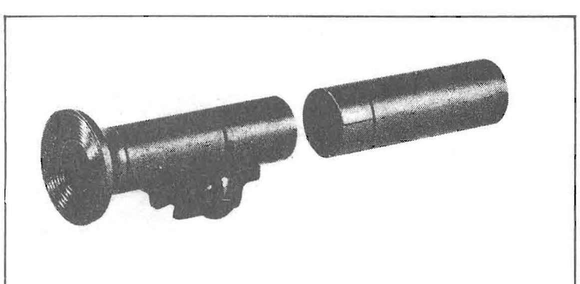


FIGURE 12 — Redfield Olympic front sight, which holds a variety of crosshair, post, and dot inserts. It's compatible with many types of rear sights.

you line up three reference points — the front and rear sights and the target. When one's eyes are young, one can "connect" these points rather well, seeing *one* of the three (the front sight) sharply and the other points to a lesser degree. Older shooters whose eyes have lost the elasticity of youth simply can't see the secondary reference points (the rear sight and target) well enough to line things up properly and get good accuracy.

Aperture sights also make possible better accuracy for shooters with sharp, *youthful* vision. For older fellows, they are the logical transition from three-plane open sighting to two-plane aperture sighting. The telescopic sight, with its one-plane sighting, is, of course, the ultimate solution for "stiff eyeballs" — providing hits that with *any* type of iron sight would be difficult or impossible.

A final, though less important, advantage of the peep over the open rear sight is that of better visibility in poor light. In dawn or dusk, trying to line up a shadowy rear notch with an equally shadowy blade, and "placing" that blade against an all but invisible buck, isn't usually very productive. By eliminating one reference point, the aperture increases your chance of seeing and hitting by the same amount — about one-third!

Before going on, please do Programmed Exercise 1. Be sure to write your answers on a separate sheet of paper before looking at the answers on the page specified.

PROGRAMMED EXERCISE

1

1. The "three-reference-point" method of sighting refers to all of the following *except* one. Which is *not* one of the three points? (a) rear sight. (b) eye. (c) target. (d) front sight.

2. The old-time shooter using a vernier sight could achieve accuracy up to around how many yards? 1,000

3. Which is basically a more accurate sight — peep or open? PEEP

4. Which sight — peep or open — gives you better visibility in a poor lighting situation? PEEP

Answers on Page 8

Aperture Sights Preferred at Matches

The final squelch to the (usually young) hardnose who "wouldn't trade a buckhorn open sight for a bucketful of peeps!" is in calling his attention to the sight preference at any organized rifle meet where any type of metallic sight is permissible (Figure 13). Offer to give your argumentative friend a $100 bill for every open sight used, if he'll give you a buck for every aperture sight. If he doesn't back off, you'll be money ahead. Naturally, an experienced rifleman with open sights will do better than a novice with the most elaborate aperture device. However, everything else being equal, the peep sight will always win, and in a breeze (or a flat calm for that matter).

To sum up, modern open and aperture sights aren't much different from those used nearly a century ago. As rifles have become more accurate and their trajectories flatter, the adjustment mechanisms have become more precise (Table 1). The principles, however, go back to the crossbow. Open sights are still widely used because they are cheap to manufacture, and most novice shooters settle for factory sights — until they know better. Then they usually switch to a scope.

Micrometer "click-type" peep sights are precision instruments and are relatively expensive to manufacture. Not nearly as many varieties are on the market today as their popularity has declined in direct proportion to the increasing popularity of the rifle scope. Indeed, except for specialized target work, the aperture sight usually serves as an auxiliary or back-up sight on a scope-mounted rifle.

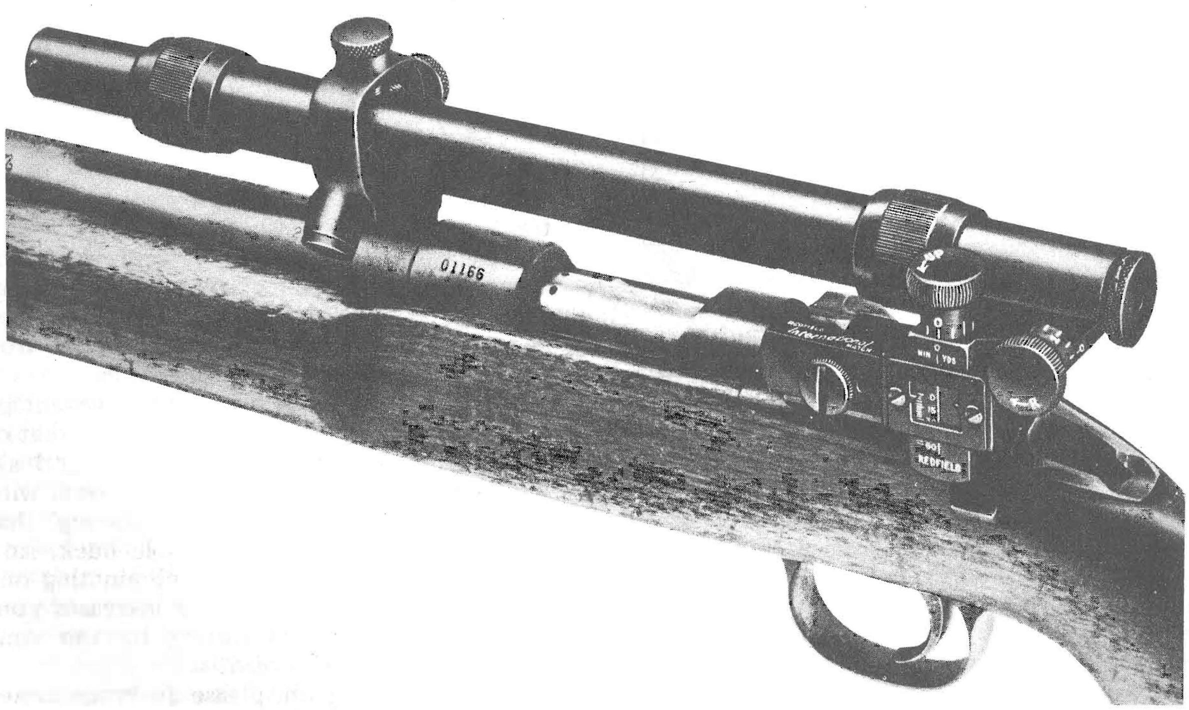


FIGURE 13 — No, this isn't a scope. This Redfield tube sight is used for shooting competition and is adjusted by the micrometer mechanism visible to the right.

Sight Radius	Click or Graduation Value (Minutes Of Angle)		
(Inches)	1/4	1/2	1
15	0.500	1.000	2.000
16	0.467	0.934	1.868
17	0.442	0.884	1.768
18	0.417	0.834	1.668
19	0.396	0.792	1.559
20	0.375	0.750	1.500
21	0.358	0.716	1.432
22	0.341	0.683	1.366
23	0.326	0.652	1.315
24	0.312	0.624	1.248
25	0.298	0.596	1.192
26	0.284	0.568	1.136
27	0.275	0.550	1.100
28	0.267	0.534	1.068
29	0.258	0.516	1.032
30	0.250	0.500	1.000
31	0.241	0.482	0.964
32	0.233	0.466	0.932
33	0.224	0.448	0.896
34	0.216	0.432	0.864
35	0.217	0.414	0.828
36	0.199	0.398	0.796

TABLE 1 — Bullet impact shift with rifle-mounted micrometer rear sight. Measure sight radius and locate value in left column. Follow across to proper click or graduation value column. Value given there is the amount one click or graduation of sight charge will move bullet impact at 100 yards. (Courtesy Stoeger Arms Corp.)

HANDGUN SIGHTS

Until the invention of the revolver, handgun sights as such were nearly non-existent. Any "target" practice usually involved banging away at a man-sized silhouette placed at a 10 to 20-pace dueling distance. If a gambler or cowhand could hit an opponent at card table range, or down the length of a bar, his sightless gun was sufficiently "accurate" for his purpose.

With the advent of the rifled bore and the revolver, a slightly rounded rear notch milled into the frame was often paired with a rather thick blade (Figure 14). The combination was better than nothing, and produced some rather fair accuracy. By the 1880's and 1890's, such sights were refined to the point where the front blade was thinned and a bead was mounted on the top. "Fine" and "coarse" beads were used for long and short-range shooting. As the rear sight was an integral part of the frame, and the front blade was also integral or fixed, no adjustments were possible. This situation continues today on many military and service revolvers, except for those which are specially made or modified for target work.

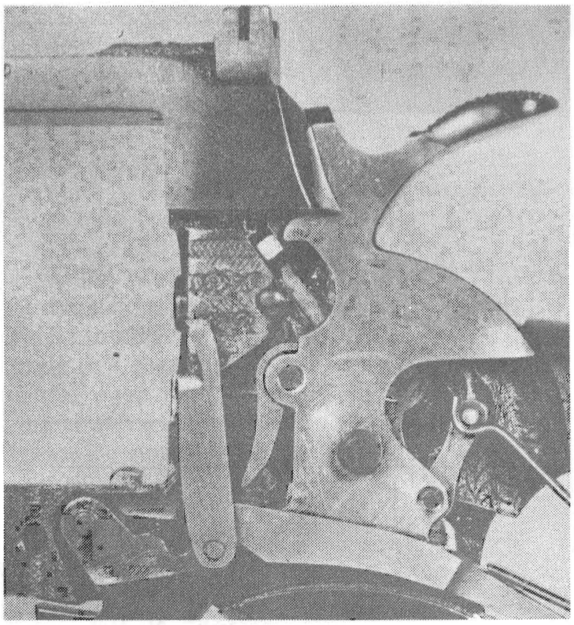


FIGURE 14 — Early Colts, unlike the modern double-action revolver shown, had a standard V notch milled into the frame for the rear sight.

Most big-bore autoloading handguns have either or both the front and/or rear sights mounted in dovetails for lateral alignment. As the front sight is readily removable, blades of different heights can be interchanged for various loads and ranges (Figure 15). Generally, it's better to get a high front sight and file it down for the load you'll be using than to try to get a blade of the exact and proper height.

Cheaper and/or small-bore center-fire autoloaders often have no sights at all, only a shallow groove down the length of the barrel. Considering the general low level of accuracy, this isn't much of a disadvantage. On the other hand, many .22-caliber autoloaders are superbly accurate arms and are equipped with adjustable sights for target work.

Domestic handguns are almost always sighted with the square-notch rear and plain-blade front sight, known as the "Patridge" type, named after E. E. Patridge, a famous exhibition revolver shooter of the 1890's, who preferred this arrangement (Figure 16). Foreign handguns employ a variety of sights. The famous Luger has a V-notch rear sight and a triangular (or barleycorn, as it's called) front sight. The Walthers usually have a U-notch rear and a barleycorn or plain front sight. The Japanese Nambu pistol of World War II has an unusual inverted V rear sight and a triangular front sight. All, however, are not adjustable — except in the sense that the dovetails permit lateral drifting.

ANSWERS

1

1. B.
2. 1,000.
3. Peep.
4. Peep

ADJUSTABLE HANDGUN SIGHTS

Following World War II, handguns underwent considerable refinement, with adjustable sights available on a standard or option basis. Such modern sights are mounted in a dovetailed notch and consist of a notched leaf which rides in a movable base. The base moves laterally by means of a screw or a screw and spring arrangement, and pivots up and down at the rear by an elevation screw acting against a spring (Figure 17). Both elevation and windage screws operate against detents which provide audible and/or easily felt "clicks" while exerting sufficient pressure to prevent movement from recoil.

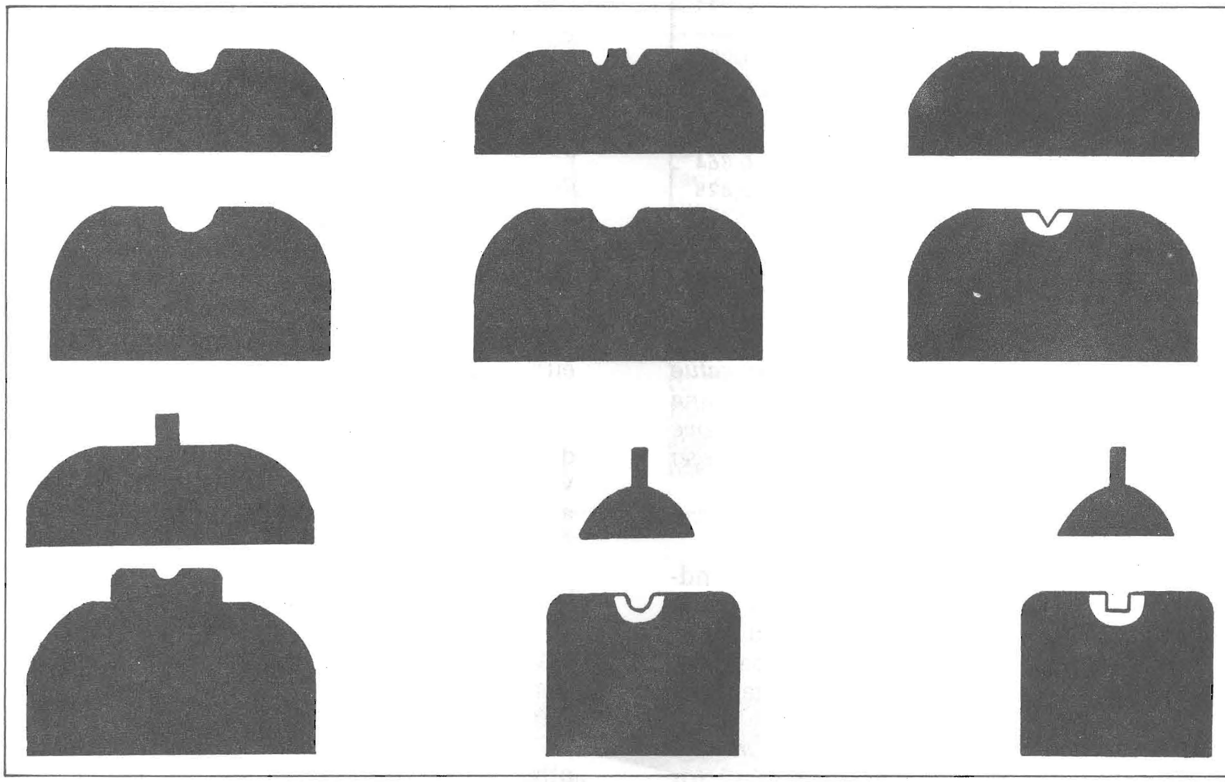


FIGURE 15 — Typical rear and front sight forms of semi-automatic pistols, as they appear to the shooter's eye. (Courtesy Stoeger Arms Corp., Hackensack, New Jersey)

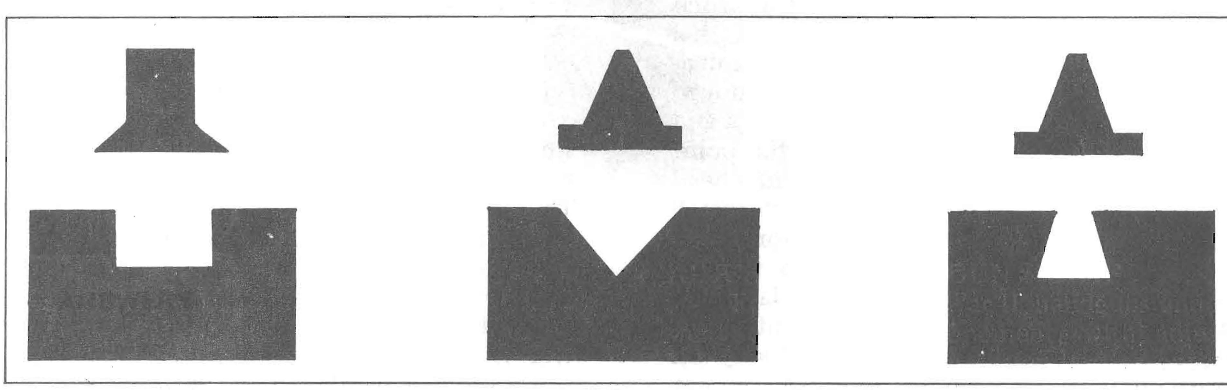


FIGURE 16 — Conventional handgun sights. From left, Patridge type; V notch with barleycorn; inverted V notch with barleycorn. (Courtesy Stoeger Arms Corp.)

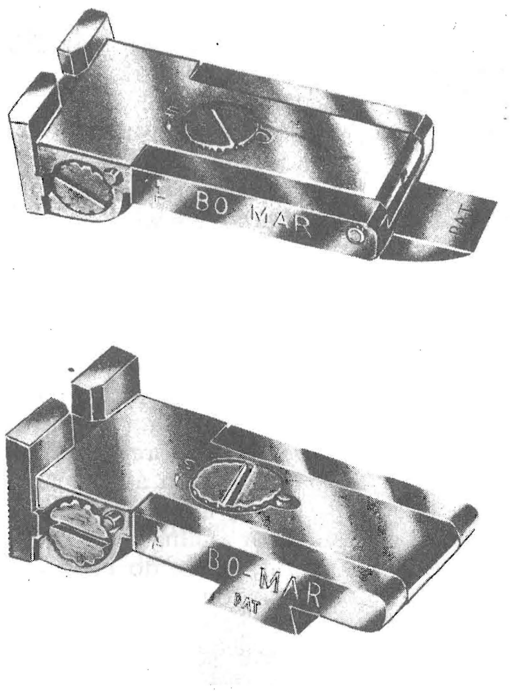


FIGURE 17 — Two types of Bo-Mar adjustable handgun sights, for use without rib. (Courtesy Stoeger Arms Corp.)

Some sights of this type are part and parcel of a solid or ventilated rib (Figure 18). While such ribs probably do some good in dissipating heat waves and mirage in rapid firing, their biggest advantage is in providing a means of regulating barrel weight without changing the barrel itself. Also, ribs provide a neat base for adjustable sights.

Peep sights on a handgun are as rare as an udder on a bull, for the reason that an aperture sight must be positioned close to the eye to justify its existence. Close to the eye a handgun's rear sight "ain't." Various experimental peep sights have been tried on handguns, but never with much success or popularity. To our knowledge, none are commercially available.

Recoil and Sight Radius

Handguns are a lot more difficult to shoot accurately than rifles — not because the barrel is shorter (a short barrel is as accurate as a long barrel), but because of the short sight radius (Figure 19). A small holding or sight picture error with a rifle might throw the bullet an inch off the mark. The same error with a stubby-barreled handgun would move the bullet six or seven inches off target.

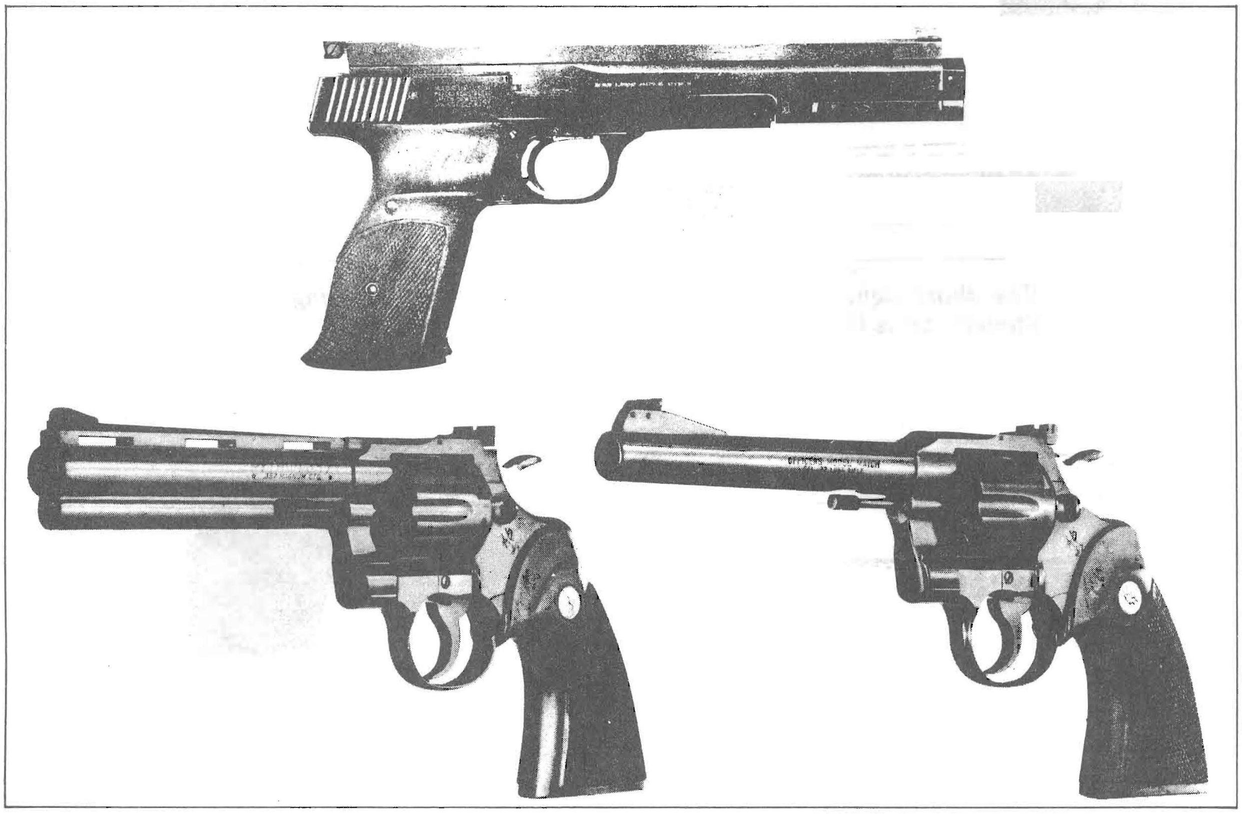


FIGURE 18 — Solid-ribbed S&W Model 41 with Bo-Mar sights is shown at top. Factory versions of the Colt Python (bottom) are available with or without a ventilated rib. The rear sights are identical. (Courtesy Stoeger Arms Corp.)

MUZZLE "JUMP"

Handguns also differ markedly from rifles in sight-to-bore axis relationship. In a rifle the bore axis appears to converge with the line of sight, thus angling the bullet upward to compensate for the drop of the bullet. The bore axis of a handgun is most often parallel to the line of sight, giving the impression that the bullet, under the pull of gravity, will strike far beneath the target (Figure 20). Not so. The handgun, being relatively lighter than the rifle in proportion to its bullet weight and energy, will tilt the barrel upward at recoil before the bullet leaves the muzzle. This muzzle jump compensates for the high front sight and "low" hole by raising the center of impact. Muzzle jump isn't solely vertical. Because the bullet is rotating as it exits the barrel, torque is generated which twists the gun in the opposite direction of the rifling twist. This phenomenon isn't particularly noticeable in small-caliber handguns, but the twist feels almost like a wrench when firing a big-bore magnum.

Handgun Sights Are Disarmingly Simple

Compared to modern rifle sighting equipment, handgun sights appear almost primitive. Few are adjustable, and those that are aren't nearly as complicated as the cheapest imported fixed-power scope. Nevertheless, there are experts around who shoot better with their handguns at 100 yards than many riflemen can at 50 yards. We wonder, though, how much sights *really* have to do with superlative pistoleering. Target shooting is one thing; however, modern exhibition shooters can drill a dime or a clay pigeon at 20 or 30 feet without even seeing the sights. The old-time gunfighters could lay an opponent low at 50 yards with a lightning draw and firing at hip level. The handgun is more an extension of the eye and the hand than a long gun, and the ability to point has as much to do with hitting as any talent for aiming.

Before going on, please do Programmed Exercise 2. Make sure you write your answers on a separate sheet of paper before looking at the answers on the page specified.

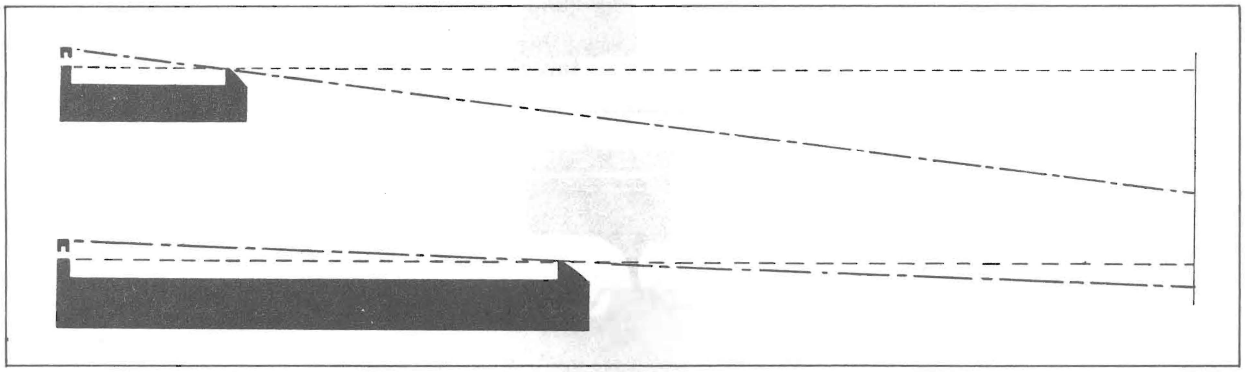


FIGURE 19 — The short sight radius of a pistol (top) complicates holding and adjustment problems. (Courtesy Stoeger Arms Corp.)

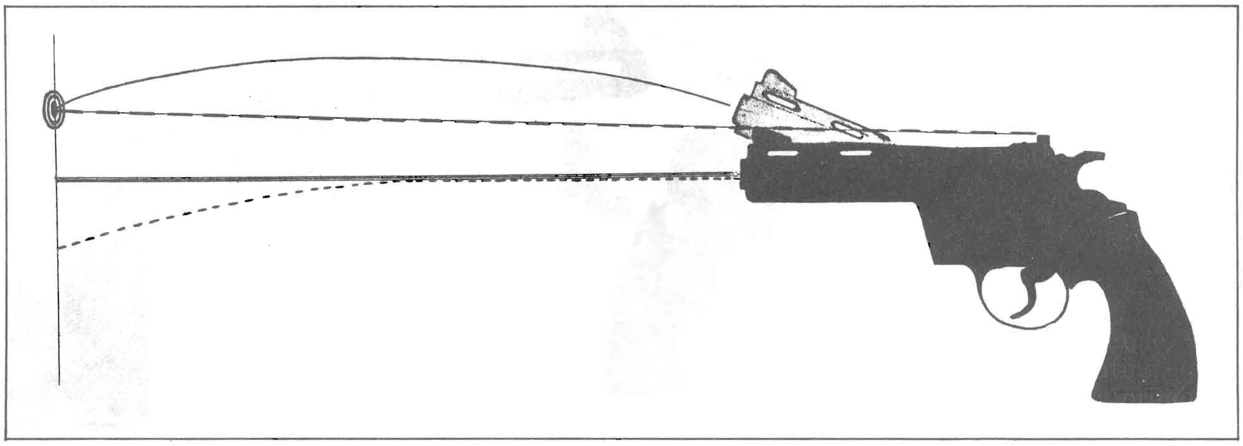


FIGURE 20 — A handgun's muzzle jumps before the bullet leaves the barrel, placing the bullet higher than the bore axis would indicate. (Lines are exaggerated for emphasis.) (Courtesy Stoeger Arms Corp.)

PROGRAMMED EXERCISE

2

1. Would you ever find an adjustable sight on a .22-caliber autoloader? YES

2. Why are peep sights almost never found on handguns? (a) too short a distance between the front and rear sights. (b) recoil prevents setting for accuracy. (c) incompatibility: a peep sight must be positioned close to the eye. (d) prohibitive costs.

3. True or false? A handgun tilts the barrel upward at recoil before the bullet leaves the muzzle. T

4. True or false? Muzzle jump is a totally vertical phenomenon. F

5. True or false? Adjustable handgun sights are apt to be very complex. F

Answers on Page 12

ANSWERS

2

1. Yes.
2. C.
3. True.
4. False.
5. False

TELESCOPIC SIGHTS: DESIGN AND APPLICATION

THE ORIGIN OF SCOPES ON RIFLES — JUST ISN'T ALL THAT CLEAR

The telescope, invented in the early 17th century by Galileo, was first used for studying the heavens. As there has always been some confusion as to what constitutes "up" and "down" in a celestial panorama, the fact that the image was inverted was of small consequence. When, however, early telescopes were used for window-watching or viewing other terrestrial bodies, there was a bit of a problem. One either got used to upside-down images or did a headstand. So an extra lens or prism was placed in the middle of the tube to invert (erect) the image and straighten things out.

No one knows who was the first rifleman to hang a scope on his gun (Figure 1). Some experts, basing their opinions on rather obscure references, believe that Sir Isaac Newton abandoned his falling apples long enough to experiment with telescopes and long-range shooting. This was undoubtedly true, but whether the reference pertained to mounting a scope on a rifle or to observing long-range artillery fire with a telescope is debatable. In view of the piddling performance of guns of the period, mounting a scope would be like using a radar sight on a modern slingshot.

THE FIRST SCOPES ARRIVED IN THE PRE-CIVIL WAR ERA

There are few historical references to telescopic sights up until about the middle of the 18th century, although some authorities believe scopes were first used for military purposes by Americans during the Revolutionary War. By 1840 several small manufacturers were making telescopic target sights. Production for each "factory" was only a few scopes a year, as the manufacturers were more or less feeling their way along, and each new scope incorporated improvements over the last model. By today's standards, early scope sights were both simple and crude. They usually consisted of a rolled brass or steel tube of 1/2" or 3/4" diameter with single objective (front) and ocular (rear) lenses, and an erecting lens in between. The reticle, usually a crosshair, was anchored solidly in the tube and focused at infinity, which tended to blur objects viewed at short range. There were no provisions for adjustment, either external or internal.

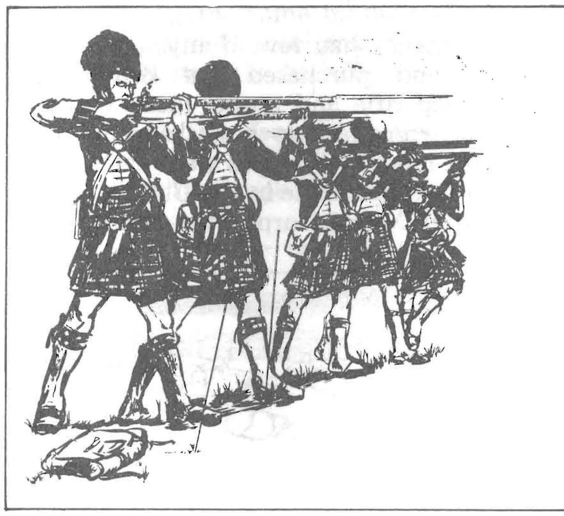


FIGURE 1 — When infantry fought like this, sights (much less a scope) weren't really necessary. (Courtesy Stoeger Arms Corporation, South Hackensack, New Jersey)

EARLY SCOPES WERE OF BARREL LENGTH

After a scope was assembled, it was temporarily mounted on the gun, bore-sighted, and necessary shims were affixed for correct tube alignment (Figure 2). The scope was then removed from the gun, all optics taken out of the tube, and the tube brazed or soldered into place on the barrel. Sometimes a rib was used. The scope usually extended the full length of the barrel, and after soldering the gun resembled a modern over-and-under shotgun. The optics were then reinserted into the tube, and the rifleman was ready to learn how much "Kentucky windage" was required to place his ball on target.

Primitive though they were, these early sights nevertheless provided a magnified and usually clear target image, and made possible a degree of long-range accuracy not possible with open sights. Eye relief was short by today's standards, but as the scopes were used with low-powered target loads, the danger of banging one's eyebrow wasn't all that great.

During the Civil War, the value of scope sights for sniping was recognized, and because of large military orders from the Union Army (as many as 100 scopes at a time) manufacturers received the encouragement and money necessary for crash research and development programs. The early and crude method of making a vertical adjustment, by pivoting the front end of the tube and raising or lowering the rear end by a threaded screw in the tang, gave way to more practical mount-type adjustments. The quality of workmanship improved, and many scopes were made shorter than barrel length for military compactness.

The Confederacy had few, if any, scope manufacturers, and purchased the British Whitworth sniping rifle and scopes made for the Whitworth from various English manufacturers. These imported scopes were essentially the same as those made in the U. S., but were much shorter. Most incorporated a clamp screw type of elevation adjustment and a graduated plate on the stock which measured the degree of scope tilt and provided an index for future adjustments.

THE CIVIL WAR POPULARIZED TELESCOPIC SIGHTS

The well-publicized exploits of Civil War snipers, some of whom felled opponents at ranges of 1,000 yards and more, plus the Westward Ho! movement which took hunters into plains areas where scopes had more justification than in the crowded Eastern forests, created a need and hunger for telescopic sights that brought a number of manufacturers into the field. Beautifully made instruments were turned out by such makers as Malcolm (Figure 3), Sidle, and Mogg, and by 1890 the industry was in full swing. Interestingly, the National Rifle Association, formed in 1871, initially prohibited the use of "magnifying" sights in any matches conducted by affiliated rifle clubs, presumably because such sights constituted an unfair advantage. Outraged rebels within the NRA soon brought an end to this hardnosed edict, and separate classifications were set up for open sight and telescopic sight competitive shooting.

GUN MANUFACTURERS GOT INTO THE ACT

Gun manufacturers, aware that many of their rifles were being equipped with scopes, took a long, hard look at the infant industry. At least one gunmaker, the J. Stevens Arms & Tool Company, decided that a few bucks could be made in this area, and in 1901 he bought out one of the largest of the scope-

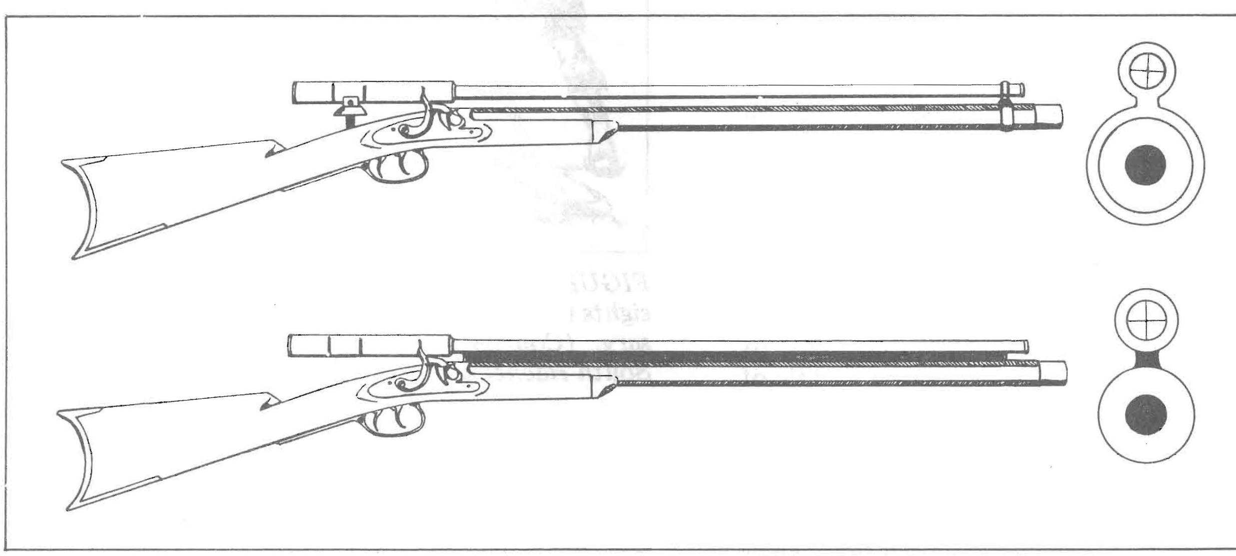


FIGURE 2 — Two early types of scope mounting. The primitive, vertically-adjustable mount at the top was weak and unwieldy. Most gunsmiths soldered the scope tube directly onto the barrel, with or without a rib, as shown at the bottom. (Courtesy Stoeger Arms Corp.)

making shops — the Cataract Tool & Optical Co. of Buffalo, New York. For the first time, the resources of a large and wealthy company were devoted to telescopic sight development.

Following a year of organization and design refinement, the Stevens line of scopes was introduced (Figure 4). Windage and elevation adjustments were contained in the mounts, and methods of minimizing recoil damage were incorporated. For the first time, emphasis was placed on the mechanical aspects of scope function, an area more or less neglected previously (Figure 5). The new scopes also boasted a number of optical refinements, including compound lenses (which we'll explain a bit later).

Finally, because of mass-production techniques, the price of a good scope was drastically reduced. The 4X "Ideal" cost $8.00, which was still a lot of money at the time. The first long-relief pistol scope was introduced by Stevens in 1902. In 1907, the first practical variable-power scope, the 6X-11X "Multiscope," was also marked by Stevens (Figure 6). (You thought handgun scopes and variables were new??) Stevens, more than any other company, provided the transition between the crude telescopic sights of the Civil War era and the modern scope sights of today.

In 1909, Winchester got into the scope-making business with its "A5" target scope (Figure 7), which was based on a rather impractical optical design. The scope never won much acceptance or popularity, and in 1928 Winchester sold the whole operation, including tools and fixtures, to the Lyman Gunsight Company.

Lyman had purchased the Stevens scope-making facility, just prior to World War I, and the company was well on its way to becoming the giant of the industry.

SNIPING SCOPES

The first "modern" sniping scope was the U. S. Model 1908 (and slightly refined Model 1913) "Telescopic Musket Sight," a bulky, heavy, prismatic sight made by Warner & Swazey, which saw some use during World War I (Figure 8). Because of its shortcomings, plans were afoot to equip some 50,000 M17 Enfields with the Winchester A5 scope, which really wasn't much better. The war ended before the project could get off the ground. Nothing much in the way of improved scope design resulted from that war.

Following World War I, Lyman dominated the scope industry, further refining the Stevens designs and improving the Winchester A5, which as a switch was tagged the 5A. About this time J. W. Fecker was building target-type scopes with the first objective lens focusing feature. One of his employees, John Unertl, subsequently opened his own shop and produced fine target and varmint-type scopes. The Fecker and Unertl scopes were light, short, and possessed excellent optical qualities. However, they still relied on bulky, cumbersome mounts which contained the adjustment mechanism. Scopes with internal adjustments hadn't yet edged over the horizon.

The "Fieldscope" produced by R. Noske in the early 1930's was probably the first true hunting scope. It incorporated an *internal*

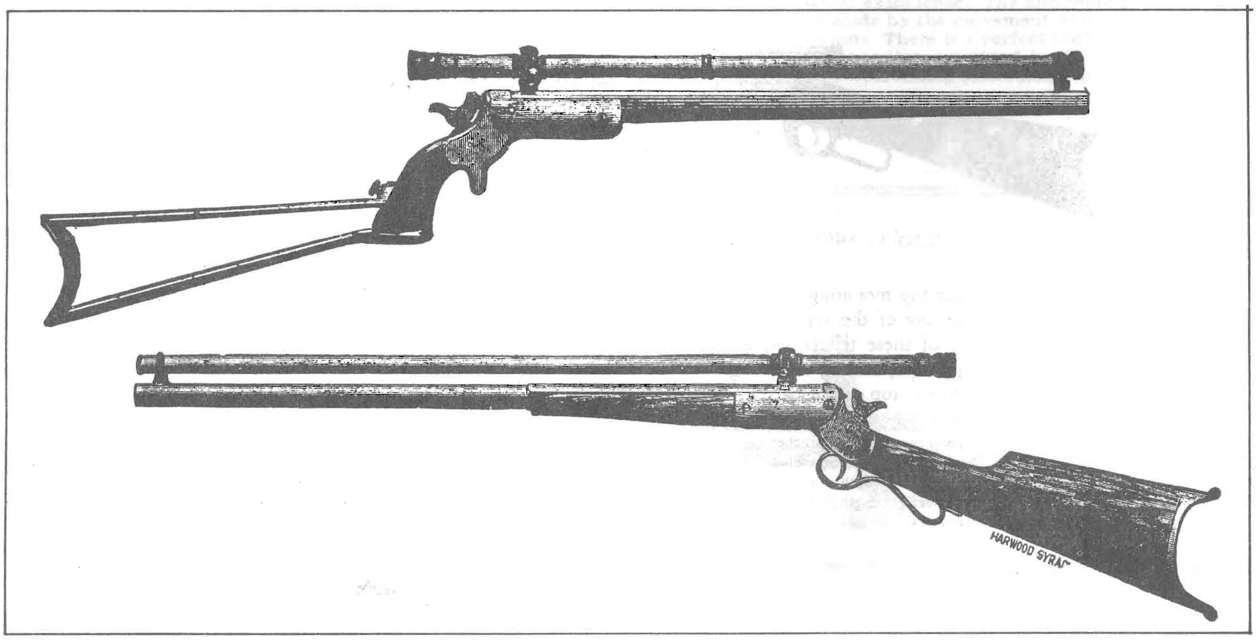


FIGURE 3 — Scopes made in the post-Civil War era usually extended the full length of the barrel.

Telescope Adapted for the "Winchester Single-Shot"

SHOWING "WINCHESTER SINGLE SHOT" AND MOUNTINGS

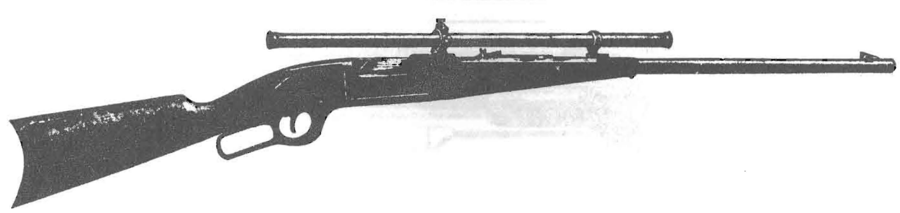
THE mountings on this telescope have adjustment for both windage and elevation and are fitted to regular sight grooves. Diameter of tube, ¾ inch. These scopes are full length, and should be 4 inches longer than barrel.

No. 620—Power 4 Diameters—Length 26, 28, 30, 32 inches	Price, including mountings, $ 9 00
No. 625—Power 6 Diameters—Length 26, 28, 30, 32 inches	Price, including mountings, 10 00
No. 630—Power 8 Diameters—Length 26, 28, 30, 32 inches	Price, including mountings, 11 00

Extra lengths by special contract.

20

Telescope Adapted for the "Savage"



SHOWING "SAVAGE" RIFLE AND TELESCOPE

ALTHOUGH the regular top mountings can be used on the "Savage" Rifle, some prefer the side mounts, as they do not interfere with the use of the regular open sights. When ordering please state the style of mounts wanted. Regarding the quality of these telescopes, we will only say that they are the best that the Stevens Company can make for the price. Sliding scope, resting on springs. Fine screw adjustment for elevation and windage. Both side and top mountings are screwed to the top of the barrel. Diameter of tube, ¾ inch.

No. 725—Power 4 Diameters—Length 19 inches	Price, including mountings, $13 00
No. 730—Power 4 Diameters—Length 19 inches	Price, including mountings, 16 00
No. 740—Power 6 Diameters—Length 20 inches	Price, including mountings, 17 00
No. 750—Power 8 Diameters—Length 24 inches	Price, including mountings, 18 00
No. 755—Power 12 Diameters—Length 24 inches	Price, including mountings, 19 00

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FIGURE 4 — Excerpts from the J. Stevens & Co. catalog, first published in 1902.

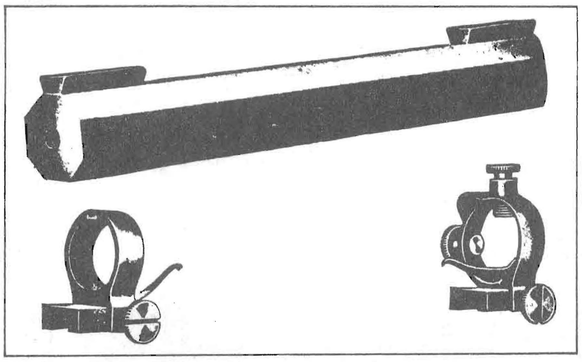


FIGURE 5 — Example of the early dovetail method of mounting scope rings to the barrel.

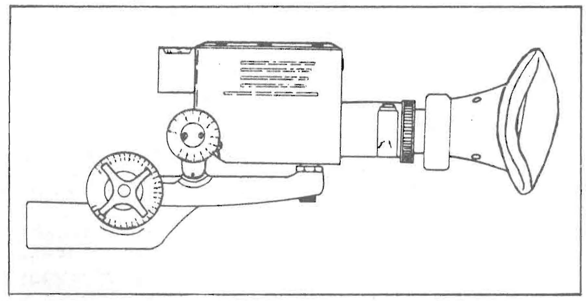


FIGURE 8 — The Warner-Swazey sniping scope that served as the U. S. sniper scope in the First World War. (Courtesy Stoeger Arms Corp.)

The Stevens Multiscope

Variable telescopes by means of changing the eye system have been in use for some time. Very little increase in power however, can be obtained in this manner, and there are other objectionable features besides. There is a constant demand for an improved, variable telescope, and we naturally take some pride in being the first to place on the market a variable telescope for the rifle of some practical value. This instrument is all that the name implies — six complete telescopes in one, and without the addition of extra lenses. The minimum power is six diameters, and the maximum eleven diameters. The change of power is made by the movement of one of the interior systems, and a graduated scale on the tube indicates the different powers. There is a perfect uniformity in point of excellence throughout the scale, each power being equal to the corresponding one listed in the "Stevens Special" series. The diameter of the tube is ¾ of an inch and they are furnished with sliding Micrometer mountings.

FIGURE 6 — The first variable-power scope, introduced in 1907! (Courtesy Stoeger Arms Corp.)

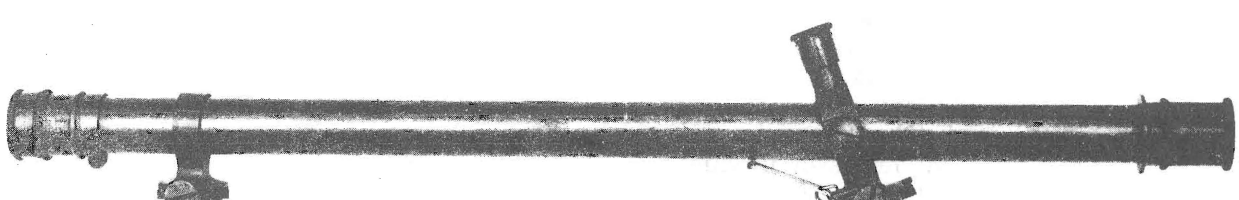


FIGURE 7 — The Winchester A5 target scope introduced in 1909. It was almost used as a sniper scope in World War I. (Courtesy Stoeger Arms Corp.)

elevation adjustment (windage was added in later models) and had sufficiently long eye relief (six inches) to permit mounting with the ocular lens *ahead* of the bolt handle (Figure 9). The scope was mounted low and, because of its forward positioning, no bolt alteration was necessary. The Noske was supposedly of 2-1/2X magnification (it was actually about 2X), weighed but nine ounces, and was 9-1/2" long. The diameter of the tube was 7/8" and field of view at 100 yards was 38 feet. The adjustment dials were calibrated in one-minute increments and capped with moisture-proof knobs. It was also expensive, retailing for $40 in 1932. In most respects, this scope was quite modern. In any event, it set the pattern for future hunting scope development.

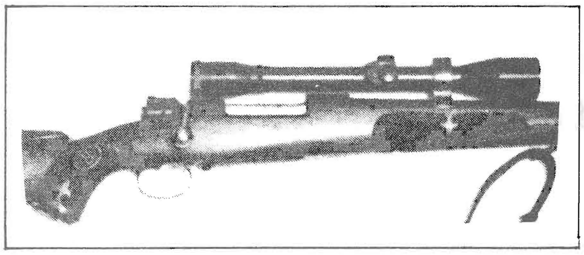


FIGURE 9 — The first honest hunting scope, the Noske "Fieldscope," was mounted in this manner — far forward to eliminate the need for bolt alteration.

One of the largest — if not *the* largest — scope manufacturers in the world today also got started about the same time. In the early 1930's, W. R. Weaver produced his first *inexpensive* hunting scope — a 3X model (the M330) which sold for only $19. The Weaver scope had all the basic features of the Noske, plus a few more, and in 1933 sold for one-third the price of the Noske. The immediate success of the M330 encouraged Weaver to offer other models of varying magnification, but in the same price range. Acceptance was immediate, and Weaver can be regarded as the originator of the low-cost rifle scope. More than any other man, W. R. Weaver (Figure 10) placed the previously expensive telescopic sight within reach of the average rifleman.

The reason for Weaver's low prices, then and now, is that the company makes its own scope components and the tooling necessary for manufacture. All facets of production are integrated in one factory (Figure 11).

About the only other outstanding telescopic sight produced during the 1930's was the famed Lyman Alaskan, a 2-1/2X instrument with crystal-clear optics that retained its popularity long after manufacture was discontinued. In the late 1930's, as World War II approached, many scope manufacturers switched to other optical products required by the U. S. government and its allies, and never returned to scope-making. By the end of the war, few firms remained in the scope business. Companies which departed the field included Belding and Mull, Pechar, Marlin, Noske, Wollensak, and many others.

FIGURE 10 — W. R. Weaver at his Texas plant (1961 photo). (Courtesy Shooting Times)

Manufacturers such as Weaver and Lyman (who supplied the M330 and "Alaskan" as sniper scopes during the war), Fecker, Unertl, and Mossberg were able to pick up where they left off. As a result of the war effort, many improvements were apparent in post-war rifle scopes (Figure 12). Better production and quality control methods evolved. Technical innovations such as fluoride coatings, better sealing compounds, and anti-fogging processes (most of which were developed for other than scope application) appeared for the first time. As a result, the post-war scopes of the late 1940's and early 1950's were far superior to instruments of the late 1930's. Since those days there have been no revolutionary improvements in basic scope design. Refinements and gimmicks have proliferated, with everything from battery-powered, lighted reticles to automatic rangefinders offered to the prospective buyer.

What can a scope manufacturer come up with that's *really* new? Scope-makers of the

FIGURE 11 — Partial view of the Weaver scope assembly room. (Courtesy Shooting Times)

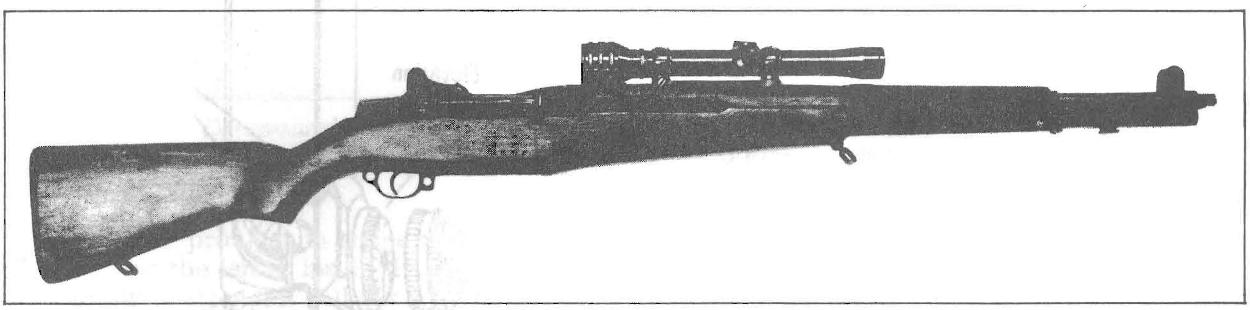


FIGURE 12 — The Springfield 1903 rifle with a Lyman Alaskan or Weaver 330 scope was used for sniping during World War II. The Garand M1 rifle, shown here with a Redfield scope, was tested after the war but never officially approved as a sniping combination. (Courtesy Stoeger Arms Corp.)

1890's undoubtedly asked themselves the same question. Modern scope-makers will no doubt continue to come up with innovations as startling to today's shooters as were the first internal scope adjustments to riflemen of the 1930's.

LET'S TAKE A LOOK INSIDE A TELESCOPIC SIGHT

You undoubtedly know what a telescopic sight *does* — it provides a magnified, better-lighted view of the target, with the reticle providing an aiming point *against* that target. You know that the aiming point and target are on the *same* focal plane, so you only have to "focus" on one image — the target with the crosshairs, dot, or post plastered against it. This is about as far as the "knowledge" of most shooters goes concerning a telescopic sight. As a gun pro, you should know *how* and *why* a scope does what it does. The subject is vast enough to warrant a couple of tomes the size of St. Peter's record book. However, you're not going to be designing or repairing scopes (those are jobs for the factories), so we'll just touch on the high points.

Basic Design of the Rifle Scope

As you'll note from Figure 13, a scope is made up of a sturdy housing or tube which

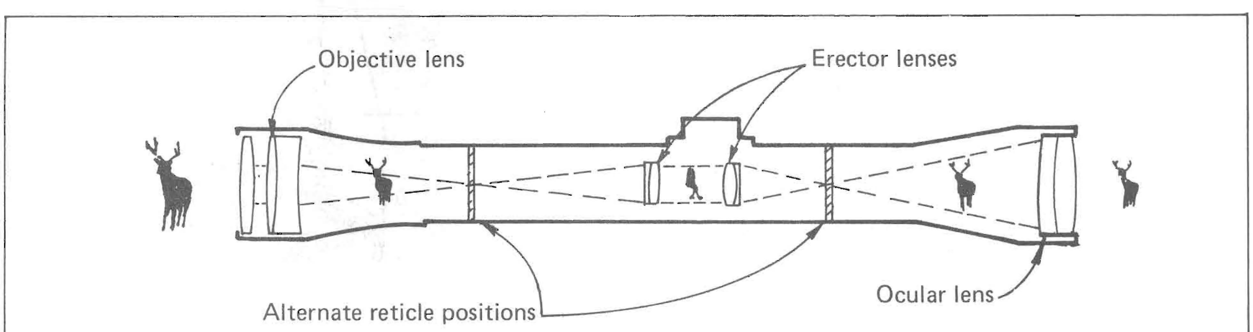


FIGURE 13 — Schematic drawing of the Weaver K-type scope, showing how the erector lenses present an upright image to the eye.

contains the optical elements and holds them in proper relation to each other. The front or objective lens is concave, which causes the parallel light rays that enter the lens to converge. The distance from the objective lens to this point of convergence is the focal length of the lens. Once the rays have converged, they start *diverging*, which is a fancy way of saying that beyond the conversion point the image is upside-down. The image or rays are then turned right-side-up or erected by the erector lens. From there, the image is presented to the eye through the ocular lens in the form of parallel rays.

In a fixed-power scope, the reticle can be placed at either of the two points at which the rays converge (refer to Figure 13), which represent the center of the lenses and the center of the scope. For all practical purposes, when the reticle is centered on the target, the optical axis of the telescope is centered on the target. By extension, when the axis of the scope is perfectly parallel to the axis of the bore, the bore is centered on the target and only the pull of gravity prevents the bullet from centering on the target. This is the principle on which a scope operates (Figure 14). Hypothetically, when a scope is properly centered over the bore, only elevation adjustments are necessary.

In practice, this isn't true — due to small errors in alignment of the scope or in the optics themselves, which make lateral (or windage) adjustments a necessity.

Manufacture and Mounting of the Lenses

The primary purpose of any scope is to project an optical image of the target into the shooter's eye. The clarity of this image is termed *definition*, which depends on the quality of the lenses. There is no such thing as a perfect lens, due more to inherent deficiencies in the glass than to any manufacturing shortcuts. All lenses, no matter how skillfully and carefully made, have deficiencies or aberrations. Therefore, rather than searching for one near-perfect lens (and throwing out maybe a dozen lenses with more pronounced defects), compound lenses formed of two or three lens segments or layers are used (Figure 15). A defect in one segment is *corrected* or balanced out by its opposing segment, much as glasses correct optical defects in the human eye. By skillful selection of the segments in a compound lens, aberration is all but eliminated.

The bearing surfaces of these lens segments must mate perfectly, with no air space between them to distort the light rays. For many years compound lenses were cemented

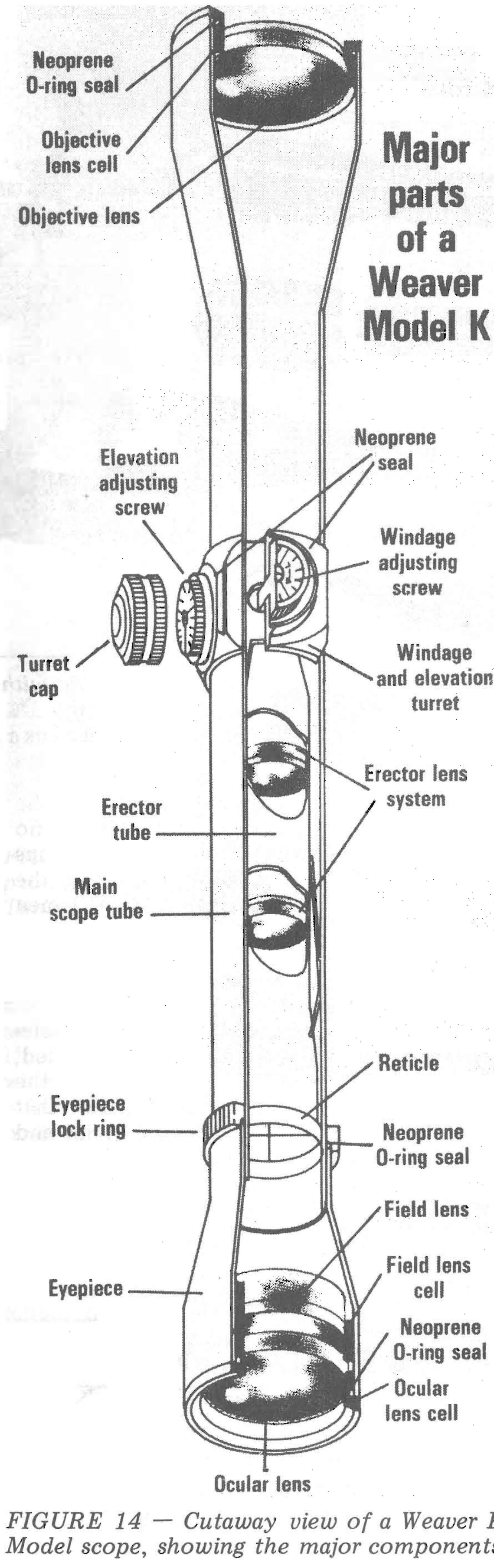


FIGURE 14 — Cutaway view of a Weaver K Model scope, showing the major components.

together with Canada Balsam, an adhesive that sometimes failed due to recoil shock, age-clouding, and temperature extremes. Following World War II, synthetic resins were developed that overcame the shortcomings of Canada Balsam. Tests proved that an extremely sharp blow would cause the lens to break before the resin bond gave way.

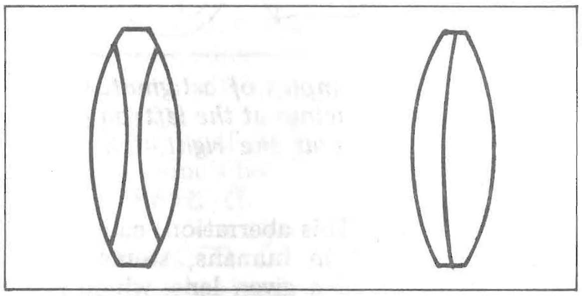


FIGURE 15 — Compound lenses are made up of two or three segments cemented together with a resin bonding agent.

A major problem in scope manufacture is mounting the lenses inside the tube. While optical glass is strong, it will not tolerate much stress on a small area, which eliminates the idea of anchoring the lenses with clips. Attempts to cushion the lenses with absorbent or elastic material didn't work either, as the force of recoil compressed the "shock absorbers" and tilted the axis of the lenses. In the best modern scopes, the lenses are protected by cells fitted into machined recesses in the tube (Figure 16). Extremely close tolerances must be maintained for this fitting.

FIGURE 16 — After grinding and polishing, the lenses are placed in circular rings or cells. (Photo taken at the Weaver plant) (Courtesy Shooting Times)

Let's go back for a moment to the subject of lens aberration, which deserves further discussion. When compound lenses are made, there are six aberrations or defects which must be corrected — not only in a given lens, but in the scope as a whole. In other words, the segments that make up a compound lens, and then all the lenses that go into a scope's optical system, must be balanced so that no significant aberrations are obvious to the shooter. Let's briefly discuss these six aberrations . . .

Chromatic (Figure 17). No single lens can focus all the color rays that make up "white light" at the same point or distance from that lens. For this reason, the red part of an image may be of a slightly different size than the violet part of an image. This results in the "whole" image, which is made up of different colors and wave lengths, being somewhat blurred. The problem is compounded by the fact that several different lenses with different focal lengths are used in a given scope. Chromatic aberration can be corrected by proper lens selection, but the procedure is time-consuming and costly. Such corrected scopes are called *achromatic;* cheap imported scopes, when advertised as "achromatic," seldom are.

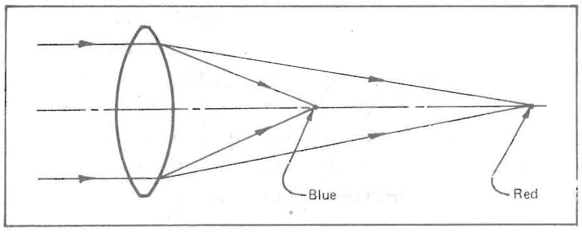


FIGURE 17 — Chromatic aberration. (Courtesy Shooting Times)

Spherical (Figure 18). Rifle scopes use convex lenses, meaning that a lens is thicker in the center. If the lens isn't ground correctly, the center portion will have a longer focal length than the tapering sides and the rays won't converge at the same point — resulting in a multitude of separate images, each a different distance from the optical center of the lens. The effect is that of a badly blurred image which cannot be focused. Some lens defects can be tolerated; a spherical aberration cannot.

Coma (Figure 19). When light passes through a lens at an angle, and the image is slightly smeared (like a comet with a nebulous tail), the aberration is known as coma (Latin for "comet"). This is a type of spherical

BLURRED EDGES

aberration which, when corrected, is labeled "aplanic."

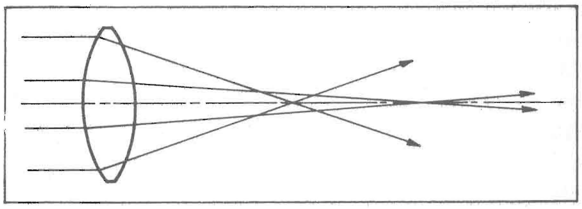


FIGURE 18 — Spherical aberration. (Courtesy Shooting Times)

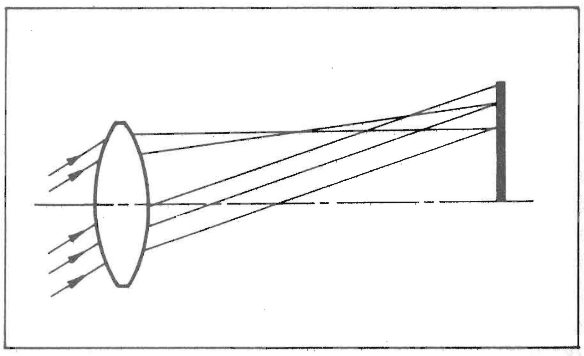


FIGURE 19 — The coma aberration. (Courtesy Shooting Times)

Curvature (Figure 20). This condition is present when the center of the image is sharp and the edges blurred, or vice versa. The general effect is that the image has been formed on the inside of a bowl. Either the center or the edges of the "picture" may be brought into focus; *both* cannot be focused simultaneously. This aberration is usually caused by a defective erector lens.

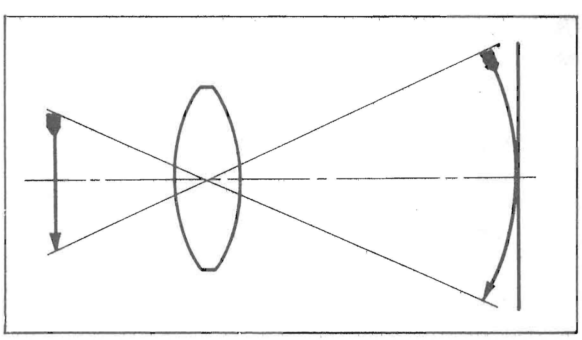


FIGURE 20 — Curvature aberration. (Courtesy Shooting Times)

Distortion. This aberration is characterized by a non-uniform magnification in the field of view. If the magnification is greater in the center and decreases toward the edges, then a round object at the edge will appear somewhat elongated (Figure 21). If the magnification is strong at the edges and weakens

LOOSE LENS MOUNT

toward the center, then that same square object will appear rounded. When the magnification is the same throughout the lens, the lens is described as "orthoscopic."

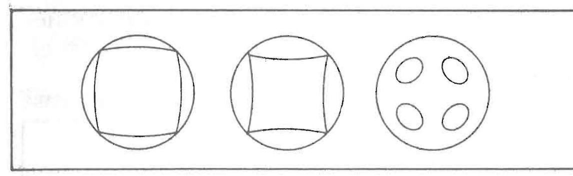


FIGURE 21 — Examples of astigmatism appear in the two drawings at the left; an example of distortion is at the right. (Courtesy Stoeger Arms Corp.)

Astigmatism. This aberration, caused by "bumpy eyeballs" in humans, stems from uneven curvature of a given lens, which prevents the lens (or eyeball) from focusing on the entire object being viewed. When focusing on a brick wall, for example, the mortar lines would tend to "bend" in or out (Figure 21). This condition often results from a loose lens mounting, or from lenses of different diameters having slightly different contours when all contours should be identical.

How well a given scope corrects these six aberrations "describes" to a large extent its quality. Of all the aberrations mentioned, the chromatic and spherical varieties are the most serious because they cause distortion at the center of the field, with a critical loss of accuracy. Imperfections and loss of definition and detail at the edges of the field aren't nearly as important.

Before going on, please do Programmed Exercise 1. Make sure you write your answers on a separate sheet of paper before looking at the answers on the page specified.

Resolution or Resolving Power

This is a term which is little understood. It means, essentially, the ability of a scope to pick up detail. One scope may be able to "grow" antlers on a deer at 500 yards; another may not, even though both scopes are of the same magnification and both are focused properly. The first scope therefore has better resolving power. Two factors determine a scope's resolution. The first is how well the aberrations mentioned have been corrected. The second factor has to do with the size or diameter of the objective (front) lens. To understand why this size is important, consider that the human eye can only distinguish detail, under ideal lighting conditions, of one minute of angle. In other words, you *should* be able to see a 1" black square at 100 yards, a 2" square at 200 yards, etc. One minute of angle is 60 seconds of arc. Scopes with even a

PROGRAMMED EXERCISE

1

1. How many reference points are there in a scope sight? 1
2. In normal practice, are lateral or windage adjustments necessary with a scope sight? YES
3. "Definition" refers to what aspect of a scope's function? IMAGE CLARITY
4. How is lens aberration eliminated? BALANCED OPTICS
5. With what are compound lenses bonded? SYNTHETIC RESINS
6. A lens with a corrected coma condition is called: (a) aplanic. (b) comatic. (c) comatasic. (d) symbiotic.
7. Why are chromatic and spherical aberrations the most serious? CAUSE DISTORTION IN CENTER OF FIELD

Answers on Page 12

small 20mm objective lens will resolve about six seconds of arc — which is ten times the resolving power of the human eye. The greater the diameter of the front lens, the greater the resolving power. The eye can use only so much of this resolving power, so the size of that objective lens is really more important relative to the amount of light it lets into the scope and its influence on the size of the field of view. More on that later.

Scope Brightness

"Brightness" is another term that few shooters really understand. And the manufacturers haven't helped much in advertising "brightness," "luminosity," "light-gathering" ability, etc. — terms which have specific meanings for an optical engineer, but only confuse the average guy. The brightness of a given target (or image) is dependent on two factors: (1) light transmission, which is a measure of the amount of light that reaches the shooter's eye as opposed to the amount that entered the scope; and (2) relative brightness, which depends solely on the diameter of the exit pupil.

Not all the light that enters a scope through the objective lens is utilized. Lenses have a habit of reflecting about 5% of the light that reaches them, whether they are exterior or interior lenses. Many scopes utilize five lenses with a total of ten reflecting surfaces, so with a 5% reflection loss per surface much of the light entering the scope is wasted by reflection alone. Further light loss is caused by each lens surface *absorbing* a small amount of light. What's more, the light that is reflected bounces back and forth in the tube, causing poor image quality and in some cases "ghost" images. Actually, only a small portion of the light that enters a scope would leave through the exit pupil if it weren't for lens coatings.

Modern lenses are coated or "bloomed" with a hard magnesium fluoride film about six-millionths of an inch thick, which reduces light loss from reflection and internal light "scattering" by as much as 90%. The fluoride film is colorless, but under the action of light rays it appears to be of a purplish cast. The fact that the "color" is apparent on the external lens surfaces doesn't mean that the internal lenses are also coated. Some of the cheap imported lenses have only the outside lenses coated. As a result, images at dawn and at dusk are sometimes barely visible.

Defining Relative Brightness. The relative brightness of a scope is only indirectly related to its light-transmitting ability. Relative brightness is *directly* related, however, to the size of the objective lens, which in turn affects a scope's "light-gathering" ability. Let's see how this works.

First, "relative brightness" is expressed as a figure, which is the diameter of the exit pupil of the scope squared and expressed in millimeters. To find this diameter, you don't just lay a ruler across the eyepiece. A simple way to determine this diameter is to place a sheet of thin paper against the eyepiece, then hold the scope to the light. You'll see a bright spot of light on the paper. Move the paper back farther and the circle will start enlarging. The point where the circle is the smallest, and the size of that circle, is the size of the exit pupil. It can be measured with a ruler.

By squaring this size or diameter, we determine the relative brightness. For example, a scope with a 5mm exit pupil would have a relative brightness of 25; one with a 7mm exit pupil would have a relative brightness of 49. (Remember, in squaring a number we multiply the number by itself.) Manufacturers usually list the relative brightness number on a scope's specification sheet; the higher the number, the more light transmitted to the shooter's eye. However, this figure doesn't mean an awful lot (Figure 22). Here's why: The human eye is part of a scope's optical system. Under normal light conditions, the

ANSWERS

1

1. One.
2. Yes.
3. Clarity of image.
4. By combining appropriate segments into a compound lens.
5. Synthetic resins.
6. A.
7. They cause distortion at the center of the field.

pupil of the eye opens to about 5mm; in dim light, the pupil expands or dilates to about 7mm. This means that under most hunting conditions the maximum relative brightness the eye can utilize is 25, from a 5mm scope exit pupil; at twilight, a relative brightness of 49, based on a 7mm scope exit pupil, is all the brightness the eye can use. However, most scopes have an exit pupil larger than 5mm or 7mm, and for a reason that has nothing to do with image brightness.

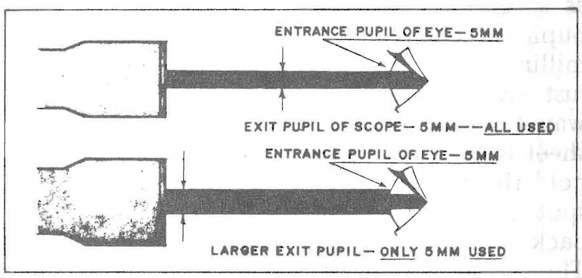


FIGURE 22 — The eye can only use so much light. (Courtesy Stoeger Arms Corp.)

From an optical standpoint, a scope exit pupil of 5mm or 7mm would be adequate. However, in order to sight quickly, the exit pupil of the scope must be considerably larger than the entrance pupil of the eye. If the two pupils are of about the same size, the shooter has to align his eye precisely to see the target. The larger scope exit pupil gives him some leeway and makes for faster aiming and shooting. For this reason, many scopes have exit pupils as large as 10mm. Much of the light is wasted, but the shooter gets on target more quickly.

Before going on, please do Programmed Exercise 2. Make sure you write your answers on a separate sheet of paper before looking at the answers on the page specified.

PROGRAMMED EXERCISE

2

1. What two factors determine a scope's resolution?
2. About what percentage of light will be lost to reflection through a single lens? (with both surfaces taken into consideration.)
3. A scope's relative brightness is expressed in millimeters based on: (a) diameter of the objective lens, squared. (b) diameter of the exit pupil, squared. (c) distance from the objective lens to the converging point, squared. (d) distance between the exit pupil and the erector lens, squared.
4. True or false? The "exit pupil" is another name for the objective lens.
5. A scope with a 6mm exit pupil would have a relative brightness of: (a) 12. (b) 30. (c) 36. (d) 54.

Answers on Page 14

Determining a Scope's Magnification

By viewing the same object through a scope with one eye and the same object with the other naked eye, an approximation of magnification or power can be made (Figure 23). A more exact method of determining magnification is to divide the diameter of the objective (front) lens by the diameter of the exit pupil (which you've already measured with your sheet of paper). The diameter of the objective lens can be measured with a millimeter ruler, but be sure to take only the clear area into consideration. Lens mounts and other internal features diminish the apparent diameter. Thus, a scope with a 40mm objective lens and a 10mm exit pupil would have a 4X magnification; a scope with a 20mm objective lens and a 5mm exit pupil would also have a 4X rating. Now you know how to check the manufacturer's claims on power ratings. It's surprising how many scopes, especially the cheap imported variety, have slightly less than advertised magnification.

FIELD OF VIEW

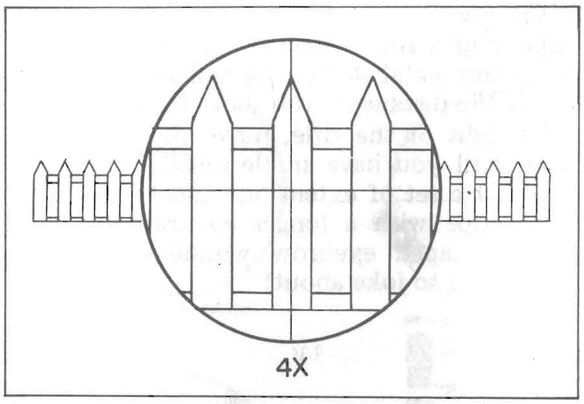


FIGURE 23 — A simple but not very precise method of checking magnification: comparing the magnified image to the same object viewed with the unaided eye. (Courtesy Stoeger Arms Corp.)

Magnification is accomplished by the placement, curvature, and size of the lenses, and the *relative* sizes of the objective and ocular (eyepiece) lenses.

Field of View

The field of view is the width of the "picture" you see through the scope and is always expressed as so many feet at 100 yards (Figure 24). The width of this field, for all practical purposes, is determined by the angle formed between the shooter's eye and the exit pupil of the scope (Figure 25). The wider the exit pupil of the scope and the closer the eye is to the scope, the wider the viewing angle and field of view will be. When the scope has a narrow exit pupil and the shooter's eye is farther back, the viewing angle *and the field of view* narrow. (The distance between the shooter's eye and the eyepiece of the scope is eye relief — which we'll discuss in a moment.)

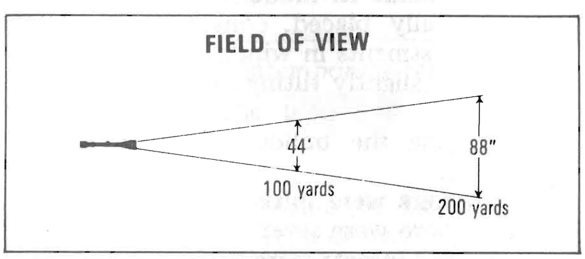


FIGURE 24 — A field of view is always expressed in width at 100 yards. At 200 yards the field is proportionately wider. (Courtesy Stoeger Arms Corp.)

For this reason, scopes mounted on handguns, and scopes mounted far forward on rifles, have a narrow viewing angle and consequently a narrow field of view. Another factor that determines the width of a field is the magnification of the scope. Assuming that the angle formed between the eye and the exit pupil of two scopes, one a 2.75-power and the other a 4-power, is the same, the low-power scope will have a wider field. Why? Because the width of the field is determined by the *angle of view, divided by the magnification,* times 10. For example, if the angle of view is 12°, the 4X scope would have a field of 30 feet at 100 yards (12 ÷ 4 x 10 = 30). The 2.75X scope would have a field of 44 feet (12 ÷ 2.75 x 10 = 44). This is the reason low-powered scopes have wide fields and are best for large running game. And why high-power scopes have small fields of view which are satisfactory for *stationary* targets and varmints.

Unfortunately, the wider the viewing angle, and the wider the field, the shorter the relief (Figure 26).

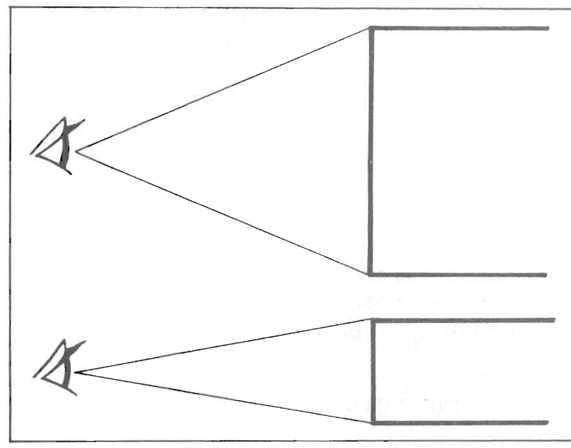


FIGURE 25 — The wider the exit pupil of the scope (top), the wider the viewing angle and the wider the field of view; the narrower the viewing angle, the narrower the field of view. (Courtesy Stoeger Arms Corp.)

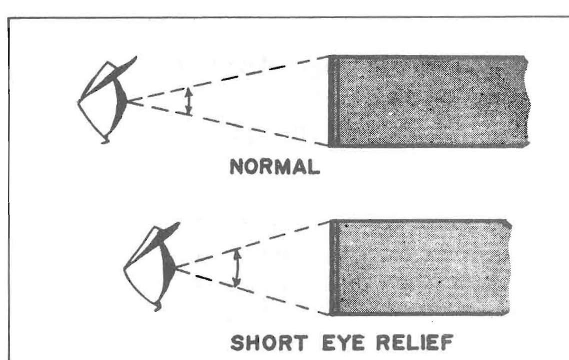


FIGURE 26 — Unfortunately, the wider the field of view (and viewing angle), the shorter the eye relief. Careful "juggling" is necessary to provide as wide a field as possible with adequate and safe eye relief. (Courtesy Stoeger Arms Corp.)

ANSWERS

2

1. How well the aberrations are corrected and the size of the objective lens.
2. 10%.
3. B.
4. False.
5. C.

Eye Relief

The viewing angle, which together with magnification decides the size of the field of view, is based on the distance of the eye from the eyepiece of the scope (Figure 27). And the distance at which the largest picture is visible is known as eye relief. Moving the eye too far to the rear, or hunching forward, diminishes the size of the field. Ideally, a hunting scope should be positioned so that when the rifle is swung to the shoulder, proper eye relief is automatic without conscious stock crawling or backing off.

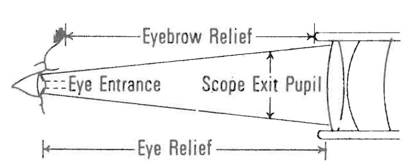


FIGURE 27 — Factors which influence eye relief. (Courtesy Stoeger Arms Corp.)

Eye relief isn't critical on .22-caliber and other low-recoil rifles. It is extremely important when firing a hard-kicking critter and shooting in a hurry, when you don't have time to think about positioning your eye. A scope driven forcefully into the eye or forehead can produce a very serious injury. Generally, a scope used on a high-recoil rifle should have at least three inches of effective eye relief, taking the rim that protrudes beyond the lens and any hinged scope cover into consideration.

Eye relief is usually adjusted by moving the scope back and forth through the loose mounting rings until the image "looks right" to the owner. Before tightening down those scope ring screws, measure the distance between the metal scope ring and the shooter's eye. If the distance is too short for the caliber and weight of the rifle, move the scope forward until you have ample relief. Or sell the customer a set of extension rings (Figure 28) or a scope with a longer eye relief. Those crescent-shaped eyebrow wounds and scars are nothing to joke about!

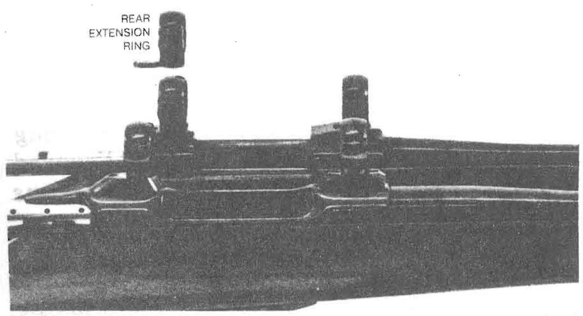


FIGURE 28 — When eye relief is too short, and standard rings won't permit the scope to move forward, a rear extension ring is usually the answer. (Courtesy Shooting Times)

Reticles

There are a great many different types of reticles, as can be seen in Figure 29. Generally, the crosshair variety, of different thicknesses (and tapers) for different hunting and target conditions, is the most popular. Next are the various post and crosshair combinations, which do a fair job of framing the target in dim light.

In the early days, the reticle itself, in internal-adjustment scopes, was moved to zero a rifle, and any errors in aligning the scope to the barrel were glaringly apparent. With a poor mounting job, the intersection of the hairs sat somewhere off to the side, up or down, you name it. Modern scopes utilize a fixed, centrally placed, constantly centered reticle. Adjustments in windage and elevation are made by slightly tilting the erector lenses, which moves the field against the reticle, thus changing the bullet's point of impact (Figure 30).

Crosshairs were initially made of spider web, and there were several spider ranches in the U. S. The insects were "milked" for their silk, which presumably required very small hands and very low stools. Anyway, spider silk wasn't very satisfactory. The hairs were fragile, sagged in damp weather, and often snapped like a too-taut violin string when the thermometer rose. Human hair was tried, but because of its coarseness was used only for the thickest reticles (vertical adjustments were hair-raising?).

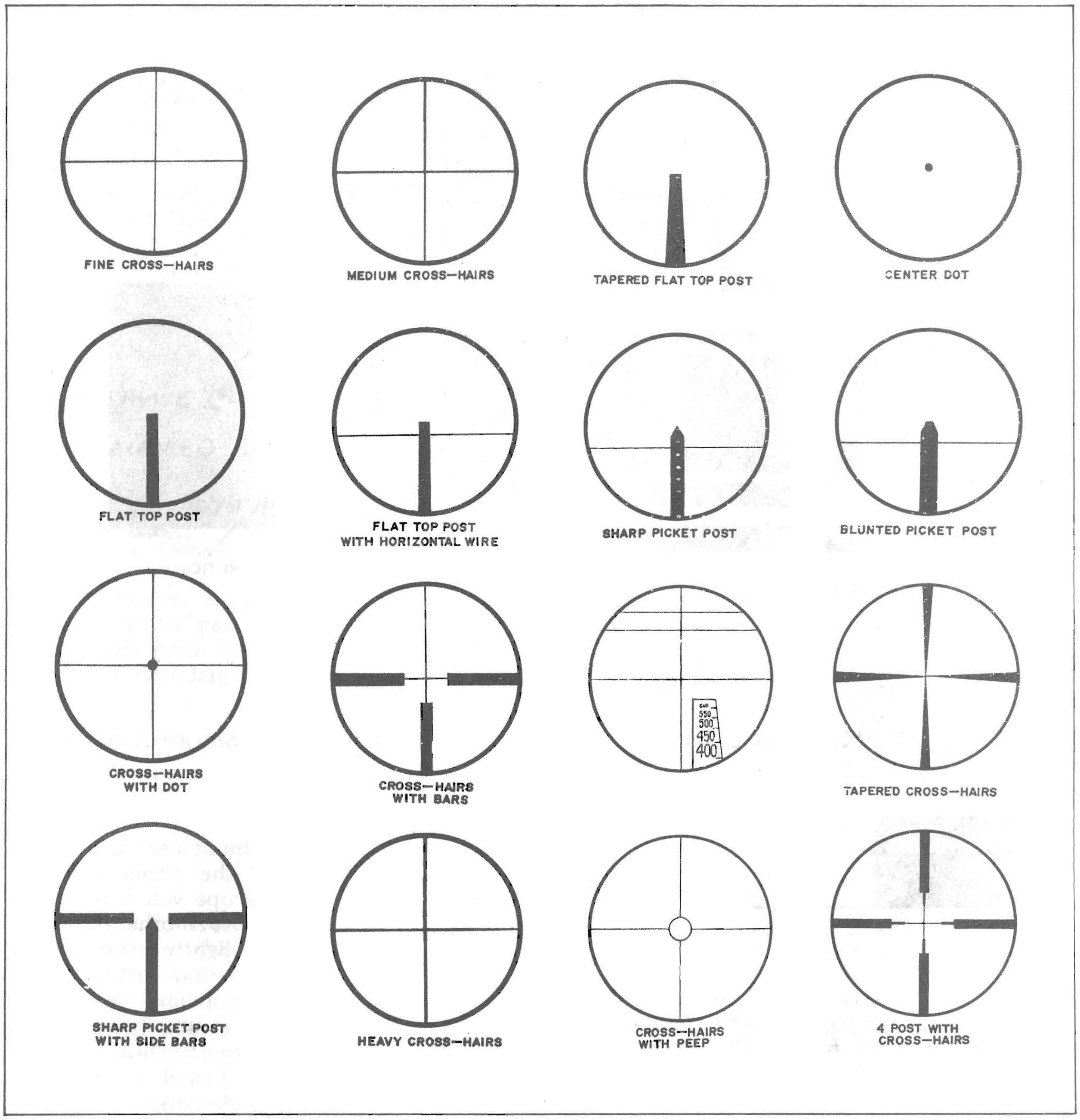


FIGURE 29 — Contemporary reticle designs. The tapered crosshair design (lower right) is usually used with variable scopes having the reticle in the first focal plane (see text). (Courtesy Stoeger Arms Corp.)

Tungsten wire could be drawn exceedingly fine, was strong, and was very uniform in diameter. It automated the spiders out of business and is still used in some scopes. Whether spider silk, human hair, or wire, the strands were tightly stretched and positioned across a metal reticle frame or ring, then crimped or cemented into place. Most reticles today are chemically milled, with acid eating away all but the desired reticle conformation on a thin sheet of metal alloy. In this way, complex tapered crosshairs and posts, hairs and dots, rangefinding increments, etc. can be formed without handwork. In the past, post reticles and dots had to be meticulously hand-soldered into place. The process was time-consuming and expensive, and the most skilled hands couldn't duplicate the precise tolerances of the chemical-etching method.

Before going on, please do Programmed Exercise 3. Make sure you write your answers on a separate sheet of paper before looking at the answers on the page specified.

CHECK FOR PARALLAX

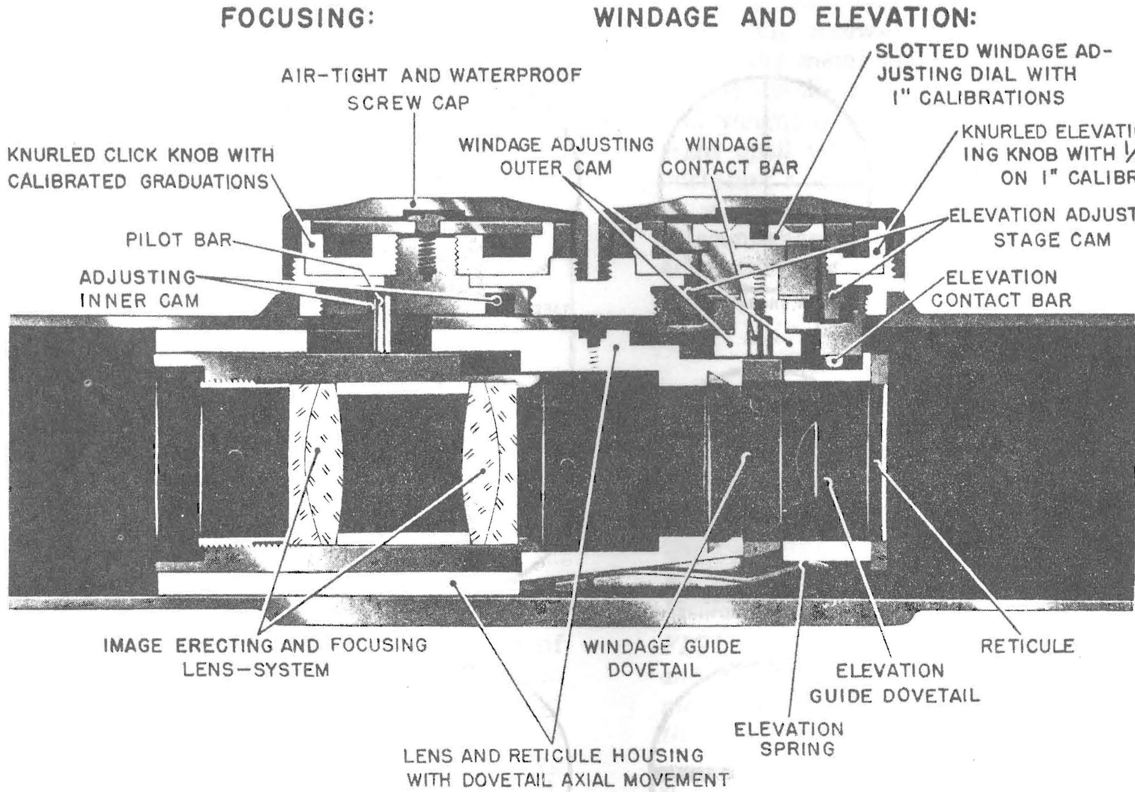


FIGURE 30 — Cutaway view of the Weatherby Imperial Scope. (Courtesy Stoeger Arms Corp.)

PROGRAMMED EXERCISE

3

1. What formula would you use to determine a scope's magnification?
DIV. DIA OF OBJ BY DIA OF EXIT PUPIL
2. A field of view is expressed as feet at how many yards? 100 YDS
3. Which has the wider field of view at the same angle — a 4x scope or a 2x scope. 2X
4. You are adjusting eye relief for a customer. You determine that the distance he says is right for him is too short for the caliber and weight of the rifle. What do you do? MOVE SCOPE FWD OR USE EXT RINGS
5. Which is the most popular type of reticle? CROSSHAIR

Answers on Page 18

Parallax

Because of the nature of a scope's optical system, the center of the reticle and the optical center of the scope will coincide at only *one* point or range. At all other distances the reticle will appear slightly off-center of the optical center in relation to the target, and a condition called "parallax" exists (Figure 31). The deviation is usually so slight, affecting accuracy less than the normal bullet spread at a given range, that it is considered unimportant except with target rifles and scopes.

To check for parallax, the scope is mounted firmly in V blocks or a vise, with the crosshairs centered on an object placed at the distance at which you want to check for parallax (Figure 32). The eye is then moved slowly from side to side and up and down across the rear of the scope's eyepiece. Parallax exists if the reticle appears to move against the target image — the amount depends on how much the reticle "moves," which in turn depends on the quality of the scope. Excessive parallax can usually be tuned out for a given range by moving the reticle carrier longitudinally. But remember, the fact that a scope is parallax-free at 100 yards or at any point means that it will have *some* parallax

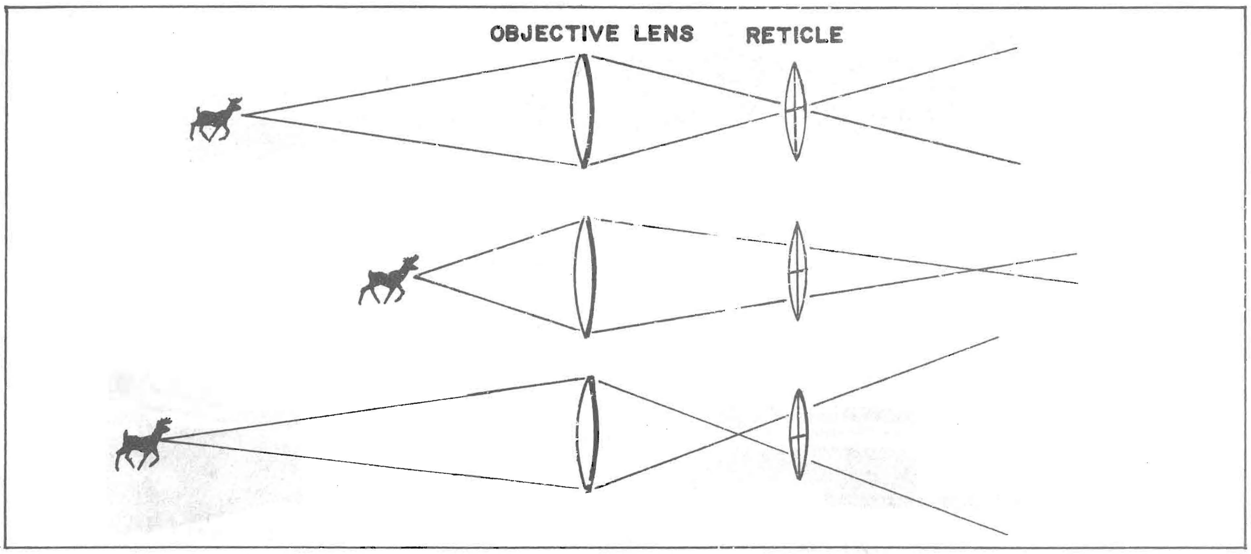


FIGURE 31 — In the top drawing, no parallax exists because the deer is at the range for which the scope is adjusted. When the animal is at different ranges, parallax enters the picture. (Courtesy Stoeger Arms Corp.)

at other ranges. Factory scopes are usually adjusted to be parallax-free at 100 yards; beyond that point the parallax-induced accuracy error isn't large enough to make much difference.

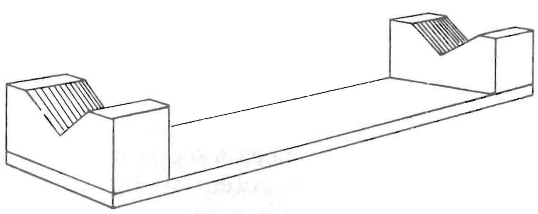


FIGURE 32 — Parallax can easily be checked with a scope off the rifle through a simple V-block set-up. (Courtesy Stoeger Arms Corp.)

Target scopes with large objective lenses and of high magnification have a proportionately larger parallax problem, so they are often equipped with an adjustment ring around the objective lens, calibrated for various ranges (Figure 33). By turning the ring, the objective lens is slightly shifted, thus aligning the reticle center with the optical center at that particular range.

Focusing

It's surprising how many scopes aren't focused properly by the shooter, which nullifies one of the biggest advantages of the telescopic sight — a water-clear view of the target with the aiming reference point sharply etched against that target. If the target is clear and the crosshairs fuzzy, or vice versa, you only have a larger "iron sight" picture. Proper focusing can only be achieved by the person who will use that scope, since no two people have exactly the same type of eyeball, and the eye is part of any scope's optical system.

The usual arrangement consists of a threaded eyepiece which moves in and out on the scope housing and is tightened down with a lock ring after focusing (Figure 34). Ideally, both the target and the reticle are sharp and clear. This phenomenon can only be achieved when the eye is relaxed. To concentrate on the target *or* the reticle will bring one element into focus while blurring the other element. Take it easy; thread the eyepiece back and forth with no attempt at concentration. When the focusing seems right, lock it down. But check your setting a bit later when your eye is fresh, and preferably when viewing an object at hunting range. If you don't, the setting that seemed "right" in your workshop may in the field have all the clarity of a pretzel viewed through the bottom of a highball glass.

Fogging

Some scopes are filled with nitrogen or other inert gases; others are merely well sealed, and for an important reason — to keep any moisture or dirt from getting inside the scope. A little dirt or dust doesn't mean the end of the world, but if dust can get in, so can moisture — which can ruin a hunt faster than leaving the toilet paper in the glove compartment. When a scope has even a small amount of water inside, taking it out of a warm car or cabin and into the cold air will fog the lenses on the inside, making the instrument worthless. Also, the water droplets can freeze up moving parts, making any in-the-field adjustments impossible.

CHECKING SCOPE FOR LEAKAGE OR MOISTURE INSIDE

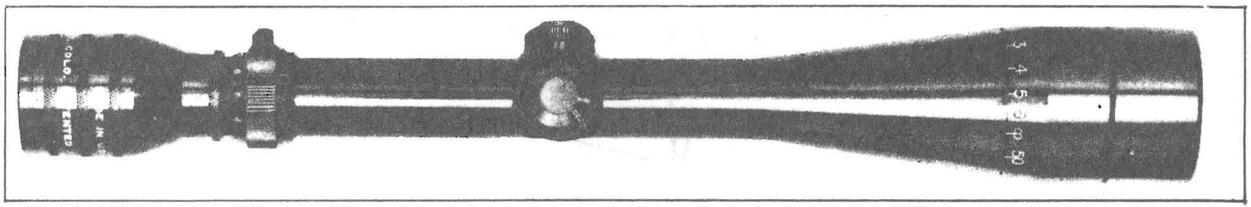


FIGURE 33 — High-power target and varmint scopes usually have a parallax adjustment ring on the objective bell of the scope. In some models the parallax adjustment is in the windage or elevation turrent. (Courtesy Stoeger Arms Corp.)

Weatherby Imperial Variable, 2 - 7X Variable Scope

Maker and Model	Magn.	Field at 100 yds. (feet)	Relative Bright-ness	Eye Relief (in.)	Length (in.)	Tube Diam. (in.)	W & E adj.	Weight (oz.)	Other Data
Weatherby									
Mark XXII	4	25	50	2½-3½	11¾	⅞	Int.	8¾	Focuses in top turret
Imperial	2¾	47½	90	3¼-5	10½	1	Int.	9¼	¼ MOA adj. for e.,
Imperial 4X	4	33	81	3¼-4½	11⅛	1	Int.	10¼	1 MOA for w. in all
Imperial 6X	6	21½	62	3¼-4½	12½	1	Int.	12⅜	models. Reticles: CH,
Imperial Variable	2-7	48-17¾	324-27	4.3-3.1	11-3/16	1	Int.	12	post and CH or Lee
Imperial Variable	2¾-10	37-14.6	296-22	4½-3½	12½	1	Int.	14⅛	

FIGURE 34 — The Weatherby Imperial, shown with specifications, focuses in the top turret. (Courtesy Stoeger Arms Corp.)

ANSWERS

3

1. Divide the diameter of the objective lens by the diameter of the exit pupil.
2. 100.
3. 2x.
4. Move the scope forward to adequate relief or sell him a scope with a longer relief.
5. Crosshair.

It isn't imperative that a scope be gas-filled; it *is* important that the seals around the adjustment turrets, lenses, etc. be waterproof. Some sealants used in cheap scopes are plain grease that can freeze solid and "freeze" any moving parts.

You can easily check a scope for leakage (and internal moisture potential) by warming it for 30 seconds or so in a pan of clean water heated to no more than 135° F. As the air inside the tube expands, it will escape through any leaks and rise to the surface as bubbles. Small bubbles around the threads and joints that don't break free aren't caused by leaks, but by air trapped in the tiny fissures. A steady flow of bubbles, as from a punctured inner tube, could mean big trouble in the field.

To find out if a scope *already* has moisture in its innards, warm it *slightly* above room temperature over a hot air vent, then place it in the freezer compartment of your refrigerator. Wait ten minutes, then check to see if beads of water have formed on the inside of the front and back lenses, or if any fogging is present.

If any of the foregoing leakage or moisture problems exist, send the scope back to the factory for new seals. Scope repair is *not* within the province of the gun pro.

Before going on, please do Programmed Exercise 4. Make sure you write your answers on a separate sheet of paper before looking at the answers on the page specified.

LOSS OF ACCURACY WITH SCOPE

PROGRAMMED EXERCISE

4

1. In which kinds of equipment is parallax considered a problem? HI-PWR TARGET & VARMIT SCOPES
2. Factory scopes are usually adjusted to be free of parallax at how many yards? 100
3. What is common equipment for parallax correction in a target scope? OBS PARALLAX ADJ. RING
4. If a little dust has gotten into a scope, what more serious problem does it signify? LOSS OF NITROGEN INTERNAL DAMAGE.
5. What is a common problem of sealants used in cheap scopes? CAN FREEZE UP.
6. A customer brings you a scope with a leakage problem. How should you take care of it? SEND IT TO FACTORY.

Answers on Page 21

Checking Scope Adjustments

Sometimes a splendidly tuned rifle will go sour, with its former one-MOA groups expanding to four or five inches or more. Is something wrong with the scope or does the trouble lie elsewhere? One *sure* way to tell is to first check for a loose scope mount or rings. If they're okay, fire a careful three-shot group. Mark the center of that group, miserably though it may be. Next, make a substantial windage and elevation shift (say, five inches up and five inches left) and fire another three-shot group at the same aiming point. If the group center shifts accordingly, the trouble is probably with the barrel or action bedding. If there is no discernible change in bullet impact, the scope is defective and should be returned to the factory.

A good, properly operating scope should move bullet impact the distance indicated by the clicks (usually 1/4", 1/2", or 1" MOA), then return the impact area to zero when the click sequence is reversed. To determine if the manufacturer of your scope is true-blue honest, and/or the scope is performing as it should, fire five sequences of three shots at the same aiming point (Figure 35). After the first three shots, raise the elevation adjustment for a five-inch bullet rise. Fire another three-shot group. Then move the windage adjustment the same number of clicks to shift bullet impact to the right. Continue firing until you've described a square with the final group overprinting your first group. Your group pattern, providing the scope is "on," should resemble Figure 35.

If your scope or a customer's doesn't return the bullet impact to zero after making adjustment, that doesn't mean the instrument is worthless. As long as a setting holds, the scope can provide good service. Just don't make any adjustments in the field for a different bullet weight or charge unless you've got the time, place, and ammo to rezero the rifle.

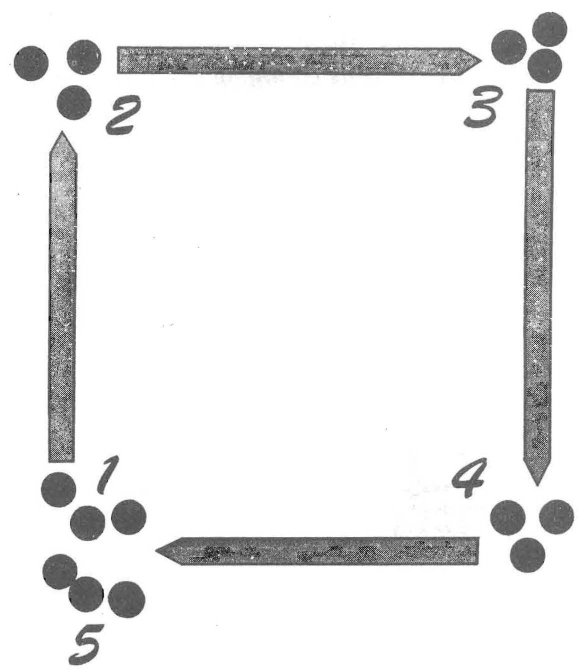


FIGURE 35 — A test pattern fired to determine whether a scope's adjustment mechanism is working as it should looks like this (see text). (Courtesy Stoeger Arms Corp.)

VARIABLE-POWER SCOPES

Variables differ from fixed-power scopes in that the magnification can be increased or decreased by rotating a "power ring" at the ocular end of the scope (Figure 36). The change in magnification is accomplished by moving the erector lens (or a pair of them) back and forth within a tube by means of a cam arrangement (Figure 37). The tube containing the erector lenses (the erector housing tube) moves longitudinally within another tube (the cam tube), which is connected to and rotated by the power ring. When the power ring is rotated, helical grooves in the cam tube engage studs protruding from the erector housing tube, thus moving the housing tube (and lenses) back and forth and changing the magnification. In short, the inner tube holds the lenses in alignment; the outer tube provides the movement (and magnification).

The problem has always been to keep the moving erector lenses in perfect optical alignment with the other lenses, in a system rugged enough to withstand heavy recoil, assorted hard knocks, and prevent leakage and/or entry of moisture. To accomplish this, many more parts are required than in a fixed-power scope, and manufacturing tolerances are much more precise. Variables cost more than the fixed-power models, but it's a wonder the price gap isn't much greater!

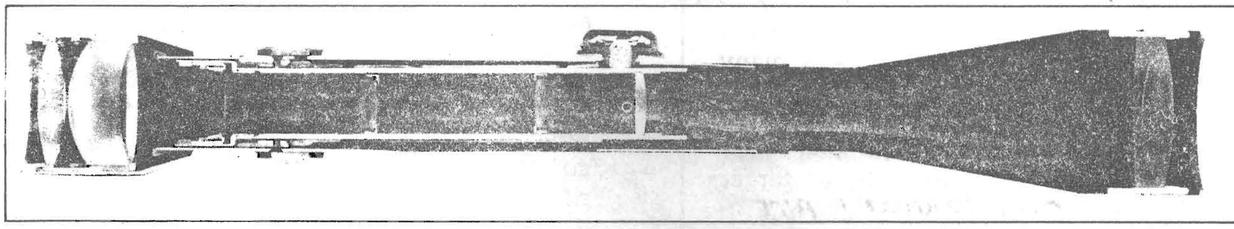


FIGURE 36 — Cutaway view of the Redfield 3X-9X variable. Turning the power ring rotates an outer tube which, through a cam arrangement, moves an inner tube containing the erector lenses back and forth — thus changing the magnification. (Courtesy Stoeger Arms Corp.)

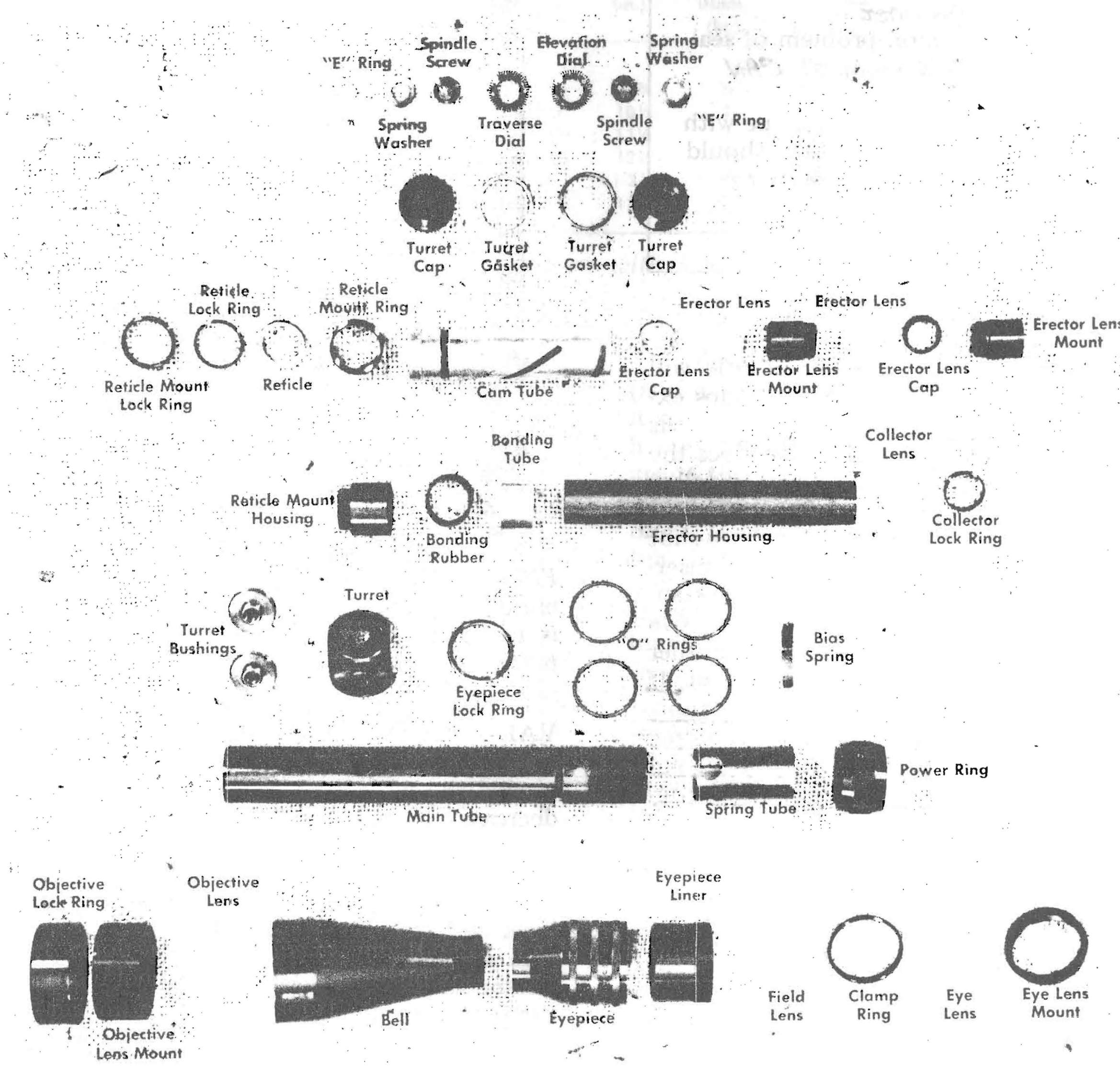


FIGURE 37 — Component parts of the Redfield 3X-9X variable scope. (Courtesy Stoeger Arms Corp.)

ANSWERS

4

1. Only in target rifles and scopes.
2. 100.
3. A calibrated adjustment ring around the objective lens.
4. That water can also get in.
5. Sealants are plain grease, capable of freezing and of freeze-locking moving parts.
6. Return it to the factory for new seals.

Adjusting the Variable Scope

Windage and elevation adjustments in a variable scope are made by deflecting the front end of the erector housing tube, which moves the erector lenses and target image against a fixed reticle. There are two alternate positions for the reticle in a variable scope. When the reticle is placed in front of the erector tube in the first focal plane, the size of the crosshairs or post increases or decreases in proportion to the size of the magnified image. At 9-power, for example, the crosshairs would also be magnified 9 times; at 3-power, 3 times, etc. The first variables were made with the reticle in the first focal plane, and Bausch and Lomb, pioneers in variable-scope development, still use this "magnifying reticle" placement. However, the B&L variables employ a crosshair reticle which tapers toward the center, thus minimizing apparent change at the center as the magnification changes (Figure 38).

Most variables place the reticle in the second focal plane, just ahead of the ocular lens. In this position, the size and thickness of the reticle remain the same, regardless of the magnification. This arrangement is the most popular primarily because the crosshairs don't become "ropey" at a high-power setting.

Also, a reticle placed in the second focal plane can be made relatively thick and strong. It may be a bit too heavy at the low-power setting, but at medium and high-power, the settings most frequently used, the crosshair thickness is medium or fine in relation to the target. When the reticle is positioned in the first focal plane where it will be magnified, it must be thin (and weak) to begin with, to avoid a stretched-cable effect at the higher-power settings.

The "Rule of Three"

Incidentally, because of inherent optical laws and limitations, the magnification range of a variable is always three times its lowest power. This is obvious when you consider that most variables are advertised as 3X-9X, 2X-6X, 4X-12X, etc. Those labeled 1-1/2X-5X, 2-1/2X-8X, 2X-7X, etc. are stretching things a bit.

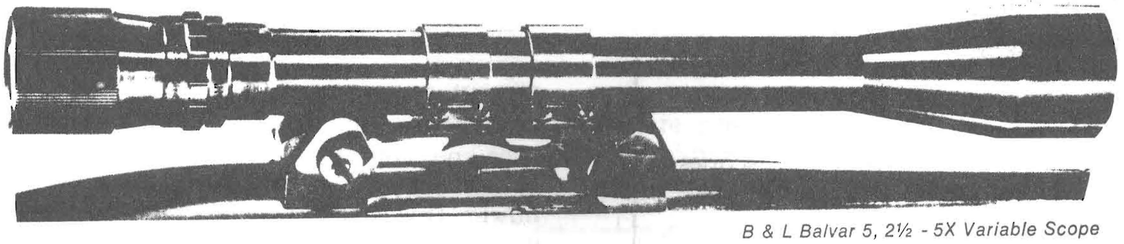
Variabies, like fixed-power scopes, have parallax problems. The difference is that the fixed scope will have some parallax at all but a specific range. The variable can't help but develop some parallax as magnification varies. Some variables, like the Weatherby Imperial, incorporate a parallax adjustment. Most do not. In a good variable, as in a good fixed-power, the degree of parallax is seldom serious enough to warrant concern — unless that scope will be used for serious target work, and variables are seldom used for this purpose.

Variable scopes necessarily represent a compromise, trading the "perfect" optics of a fixed-power scope for the "acceptable" optics at both ends and in the middle of a fairly wide magnification scale. Generally, variables perform best in the middle range setting, and provide slightly less optical excellence at the low and high magnifications. However, the disparity in performance between a 3X or 9X fixed-power scope, and a variable at the same settings, is so slight that it can't be detected by the average user.

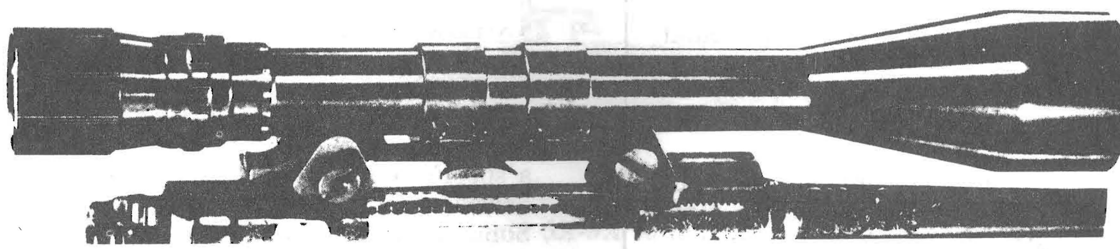
RANGEFINDING SCOPE DEVICES

The earliest rangefinding "device" was the reticle itself, which could "tell" the distance to a target providing the shooter knew a couple of things. First, he had to know how much space his crosshair covered or subtended at a given range. If it blanked-out a two-inch object at 100 yards, he knew it would cover four inches at 200 yards, six inches at 300 yards, etc. by minute-of-angle (MOA) interpolation. Second, he had to know the size of his target, which is required in all rangefinding (except when "non-scope" triangulation-type devices are used).

Let's say our early scope user, with the known 2-MOA crosshair, is a Civil War soldier. He knows that a man measures about half of his target's body, or about 8 inches. This tells our marksman that the range is 400 yards (4 x 2 MOA = 8"). If he knows the drop of his bullet at that range, and can hold steady, he'll hit. If the enemy soldier isn't cooperative, persists in hiding, and shows only parts of his anatomy briefly, the sniper may



B & L Balvar 5, 2½ - 5X Variable Scope



B & L Balvar 8A, 2½ - 8X Variable Scope

Maker and Model	Magn.	Field at 100 yds. (feet)	Relative Bright-ness	Eye Relief (in.)	Length (in.)	Tube Diam. (in.)	W & E adj.	Weight (oz.)	Other Data
Bausch & Lomb									
Baltur A	2½	43	64	3¼	12¼	1	Ext.	9½	Must be used with
Balfor A	4	30	56	3¼	12¼	1	Ext.	9½	B&L or other adj.
Balvar 5	2½-5	40-20	164-41	3½	12¾	1	Ext.	9½	mount. Baltur A,
Balvar 8A	2½-8	40-12½	256-25	3½	12¾	1	Ext.	10½	Balfor A, come with
Balvar 24	6-24	18-4½	40-2½	2¼	22	1	Ext.	36	tapered post or cross-

hairs. Dot $10 extra. Tapered crosshairs $5 extra for Balfor A. Variable scopes have tapered crosshair..

FIGURE 38 — The Bausch & Lomb variables position the reticle in the first focal plane. A tapered crosshair is used to minimize apparent change through the magnification range. (Courtesy Stoeger Arms Corp.)

calculate the range by viewing, through his scope, other objects of known size which are close to his enemy, such as a wagon wheel, ammo box, horse, etc. This sets up his quarry for an unpleasant, if brief, surprise.

Range Estimation On Game

This same system of relative known reticle size to known target size can be used on game. Deer, for example, are supposed to measure 18 inches through the brisket; if you know how much area your reticle subtends (and if you're not sure you can check it at 100 yards with various small objects), you can "guesstimate" the range (Figure 39).

Dots and posts were (and are) also used in the same manner. A one or two-MOA dot positioned at the crosshair intersect, or a post with the top subtending one or two MOA's, will, when related to the size of a known target, provide the range. The only drawback is that dots and posts cover a considerable amount of the target.

Over the years, many different types of rangefinding reticles have been invented, some with a number of different-sized dots placed within one reticle, others with a myriad of bars or graduations placed at right angles to both the horizontal and vertical crosshairs. Regardless of the configuration, these reticles (or graticules, as they're called in rangefinding scopes) were all designed to do one thing — relate fixed-MOA reference points within the scope to known target sizes and thus "compute" range (Figure 40).

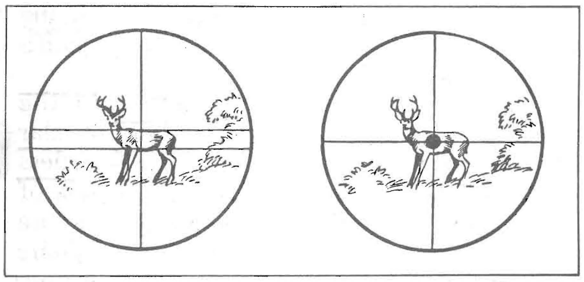


FIGURE 39 — Double crosshairs and dots are used to determine range. The 6-MOA double crosshair spacing at the left shows that the deer is at 300 yards. A 4-MOA dot would look like the drawing at the right, when the same animal is at the same 300 yards. (Courtesy the Complete Book of Rifles and Shotguns, by Jack O' Connor)

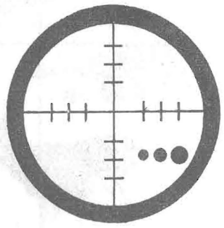


FIGURE 40 — Some awfully complicated "graticules" have been tried, some nearly as cluttered as the one shown above. They'll indicate the range — if you can see the target!

A rangefinding reticle design that has proved quite popular and effective is the double horizontal crosshair setup shown in Figure 39. A second, finer crosshair is spaced above or below the main horizontal crosshair, with the spacing representing a known measurement at 100 yards. If, for example, the spacing is equal to 18 inches at 100 yards (the vertical height of a deer's body), and a deer occupies only half of this area when viewed through the double wires, then the hunter knows the animal is at 200 yards. Actually, most double-wire setups have 4 to 12-MOA spacing, depending on whether the scope will be used on varmint-sized or big-game targets.

"Automatic" Rangefinding Scopes

A more sophisticated approach to the double-wire system is incorporated in the Redfield "Accu-Range" variable-power scope (Figure 41). The system utilizes thin, fixed, double wires positioned near the top of the scope field and spaced on that 18" deer body depth. The deer is bracketed within the double wires, and the magnification is increased until the animal's body "fills" the space between the two wires. Magnification here is proportional to range, so as magnification increases the range is "read out" on a printed scale incorporated into the lower half of the field. (The largest number visible is the range.) When the shooter has calculated his bullet drop at that range, he switches from the double wires to the regular crosshairs to make his shot (Figure 42). The only problem with such a device is that one really needs three hands. The rifle must be held steady when bracketing the target, and trying to hold the gun motionless with one hand while the other rotates the scope's power ring requires the nerves and expertise of a Barnum and Bailey juggler.

The Leatherwood "Automatic" Range-Compensating Scope

The Leatherwood range-compensating scope (Figure 43) is similar to the "Accu-Range" in that fixed double horizontal wires are used to bracket the target. Also, as the power ring is rotated, magnification increases until the target fills the space between the double wires. The difference is that the power ring is coupled to a cam which tilts up the rear of the scope. This raises the bullet impact to coincide with the target, irrespective of range. The cam is individually made for a given cartridge, and its shape conforms to the trajectory of the bullet. At comparatively

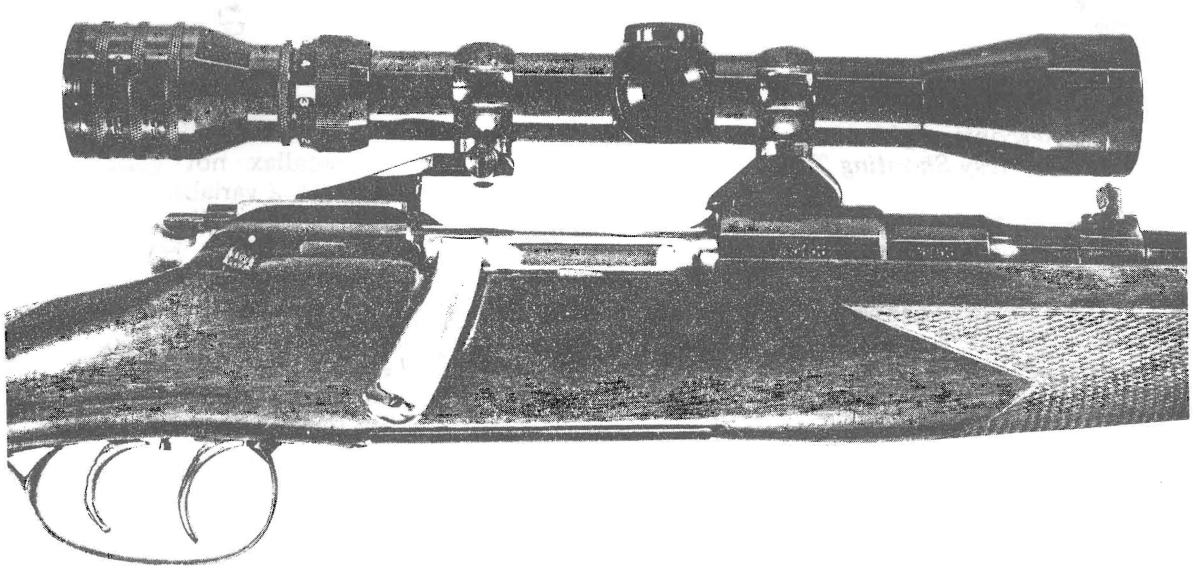


FIGURE 41 — The Accu-Range feature is available on Redfield variables like the 2X-7X shown on a Mannlicher-Schoenauer rifle as an extra-cost option. (Courtesy Stoeger Arms Corp.)

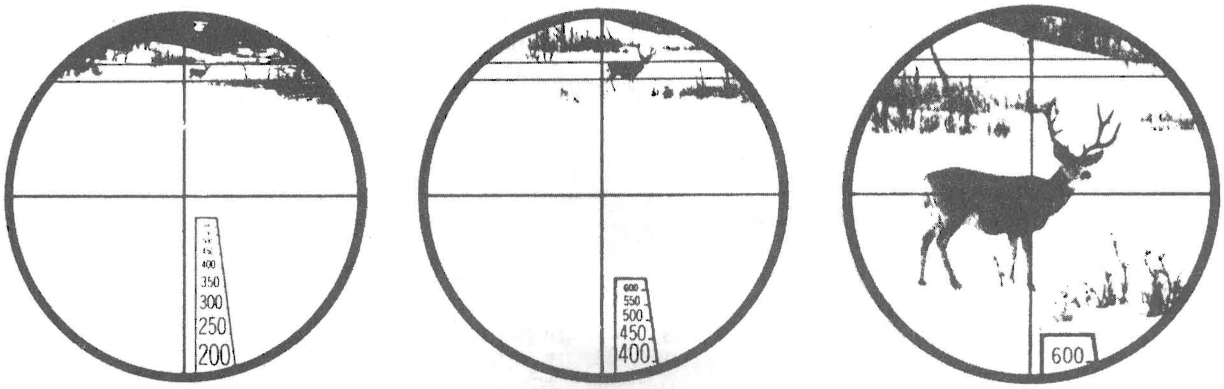


FIGURE 42 — Steps in using the Redfield Accu-Range reticle. (Courtesy Stoeger Arms Corp.)

short ranges, where bullet drop is slight, the scope tilts only slightly; at longer ranges, where the bullet drop is extreme, the scope tilts to a much greater degree. In short, the shooter doesn't *have* to know the range. His rifle does, and shoots accordingly. The magnification required to bracket the target (the spacing of the fixed double wires is relative to a *known size* of target) requires X amount of rotation of the power ring, which in turn brings X amount of cam surface to bear against and tilt the scope against spring pressure.

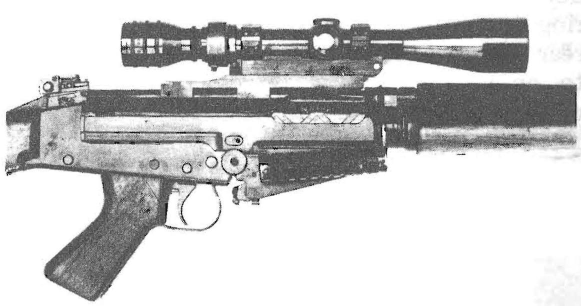


FIGURE 43 — The Leatherwood Range-Compensation telescopic sight mounted on an LIAI rifle. (Courtesy Shooting Times)

Here, rangefinding and trajectory compensation are automatic when the target is bracketed.

The Leatherwood scope (invented by Lt. J. Leatherwood, U. S. Army) isn't practical for sporting use because a differently contoured cam is required for each load or bullet weight in a given caliber. Only standard cams for standard cartridges are available, and the device is quite expensive. Custom cams are available, but the cost is high; in addition, if trajectory data are incorrect, so is the cam, thereby making the efficiency of the instrument nil.

The Leatherwood scope was, however, used successfully in Vietnam, where the cam was matched to the 7.62 Nato cartridge.

Before going on, please do Programmed Exercise 5. Make sure you write your answers on a separate sheet of paper before looking at the answers on the page specified.

PROGRAMMED EXERCISE

5

1. How do variable-power scopes differ from fixed-power scopes? CHANGE MAGNIFICATION UP OR DOWN
2. How many tubes are used in a variable scope? 2
3. In what focal plane is the reticle placed in most variable scopes? SECOND
4. Why is parallax not generally a problem with a variable scope, even though it exists at all magnification levels? NOT USED FOR TARGET WORK
5. Most double-wire rangefinding set-ups have what MOA spacing? 4-12 MOA
6. Why is the Leatherwood scope impractical for sporting use? COST

Answers on Page 26

ANSWERS

5

1. Magnification is increased or decreased by rotating a "power ring."
2. Two — the cam tube and the erector tube.
3. In the second focal plane.
4. Variables are seldom used for serious target work where it would matter.
5. Four to twelve, depending on use for small or big game.
6. A differently contoured cam is needed for each load or bullet weight in a given caliber.

NORTH AMERICAN CORRESPONDENCE SCHOOLS
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EXAMINATION FOR STUDY UNIT 14

When you have finished this Study Unit, complete the examination, then:

1. transfer your answers to an EXAMINATION ANSWER SHEET, and
2. mail your EXAMINATION ANSWER SHEET to the Education Service Center for grading.

KEEP THIS ORIGINAL EXAMINATION in your files. **MAIL ONLY YOUR ANSWER SHEET** for grading.

I. MULTIPLE CHOICE QUESTIONS. Select the answer which best completes the statement or answers the question. Write its letter (a, b, c, or d) in the blank to the right of the question. (3 points each)

1. An elevator rear sight is adjustable vertically by moving the: (a) tapered wedge. (b) sight mount. (c) aperture bar. (d) windage adjuster. A

2. Which type of front sight is most commonly used for precision target work? (a) hooded globe. (b) fixed blade. (c) dovetail. (d) vernier. B

3. All of the following are advantages of standard aperture (peep) sights <u>except one</u>. Which one is <u>not</u> an advantage? (a) the tang mount gives a longer sighting radius. (b) the eye-to-aperture distance minimizes sighting errors. (c) it has fewer reference points than an open sight. (d) the rear sight aligns directly with the target. D

4. Characteristics of the Patridge sight are: (a) square-notch rear, plain blade front, (b) V-notch rear, triangular front. (c) V-notch rear, plain front. (d) inverted V rear, triangular front. A

5. The sight-to-bore axis relationship in a handgun: (a) is usually parallel to the line of sight. (b) usually appears to converge with the line of sight. (c) usually drops off before converging. (d) usually angles upward to compensate for bullet drop. A

6. When a handgun bullet exits the barrel, the gun is twisted in which direction in relation to the rifling twist? (a) same. (b) opposite. (c) over. (d) below. B

7. A scope's definition depends on what? (a) quality of the lenses. (b) length of the scope. (c) thickness of the erector lens. (d) distance between the objective lens and point of convergence. A

8. Chromatic aberrations result in what kind of distortion? (a) red light. (b) whole image blurring. (c) violet light. (d) image size reduction. B

9. Curvature results in an image in which: (a) only the center can be brought into focus. (b) only the edges can be brought into focus. (c) a curved blur appears across a clear image. (d) only the edges or center can be brought into focus at one time. D

Exam 14 continues →

10. Lens astigmatism is an aberration caused by: (a) uneven lens curvature. (b) clouding. (c) scratches. (d) a cracked lens. A

11. A scope with four lenses (a total of eight reflecting surfaces) will have what percentage of light loss through reflection? (a) 20%. (b) 40%. (c) 60%. (d) 80%. B

12. Why are lenses coated with magnesium fluoride? (a) to reduce light loss. (b) to avoid glare. (c) to prevent scratching. (d) to sharpen focus. A

13. Why would a scope have an exit pupil as large as 10mm? (a) to increase the relative brightness. (b) for fast aim. (c) if it cannot be made smaller due to scope size. (d) to exit reflected light from inner lenses. B

14. The diameter of the objective lens is 30mm; the diameter of the exit pupil is 5mm. What is this scope's magnification power? (a) 3X. (b) 6X. (c) 15X. (d) 1.5X. B

15. All of the following <u>except one</u> are factors in magnification. Which one is <u>not</u> a magnification factor? (a) placement and curvature of the lens. (b) the size of the lenses. (c) relative sizes of the objective and ocular lenses. (d) astigmatic measure of the lenses (in millimeters). D

16. Measuring a field of view takes into account what element (s) of the view through the scope? (a) width. (b) height. (c) width and height. (d) width, height, and depth. A

17. Eye relief means: (a) the distance between the shooter's eye and the eyepiece. (b) distortion adjustment. (c) fine focusing. (d) the ratio of exit pupil size to viewable field. A

18. The angle of view is 10°. The scope has a magnification of 2X. The field of view is how many feet at 100 yards? (a) 5. (b) 20. (c) 50. (d) 200. C

19. What is needed to achieve optimum scope focus with both target and reticle clear? (a) relaxed eyes. (b) double lock ring. (c) threaded eyepiece. (d) finest crosshairs. A

20. You are checking a scope for leakage. You've warmed it for 30 seconds in a pan of clean water at 135° F. Which of the following is the sign of a real leakage problem? (a) granules of dirt floating to the surface. (b) a steady flow of bubbles. (c) dots of grease floating to the surface of the water. (d) bubbles clinging to threads and joints. B

21. To determine if a scope has moisture inside, you warm it slightly above room temperature and then: (a) put it in the freezer for ten minutes. (b) hold a lighted candle near the lens for 30 seconds. (c) dip it in cold water. (d) inspect it with a pinhead light. A

22. A formerly satisfactory rifle has expanded MOA groups to four or five inches. You have fired a three-shot group, marked its center, then refired a three-shot group with a major windage and elevation shift. You find that the group's center has shifted proportionately. The rifle's problem is probably: (a) the scope fails to rezero, but is otherwise usable. (b) a defective scope; return it to the factory. (c) due to bore build-up. (d) in the barrel or action bedding. D

23. In variable scopes, the reticle is usually placed in the second focal plane so that the: (a) crosshairs will magnify in proportion to the image. (b) crosshair reticle can taper toward the center to minimize visible change. (c) size and thickness of the reticle will remain constant despite magnification. (d) reticle may be made thin and fine. C

24. The magnification range of a variable scope is always how many times its lowest power? (a) 2. (b) 3. (c) 6. (d) 9. B

25. Variable scopes generally perform best at what magnification range? (a) middle. (b) low. (c) high. (d) equally at all. A

26. What difference in performance can your customer with average shooting requirements expect between a fixed-range scope at 9X and a variable set at 9X? (a) virtually none. (b) the fixed is superior. (c) the variable is superior. (d) there is a noticeable parallax in variable. A

27. The size of the target must be known for all rangefinding except when: (a) bullet drop at range is known. (b) the proportion of the target's width to height is known. (c) dots and posts are used. (d) a non-scope triangulation device is used. D

28. All of the following <u>except one</u> are functions of a rib. Which of these is <u>not</u> a job for the rib? (a) to dissipate heat waves. (b) to regulate barrel weight. (c) to provide a base for adjustable sights. (d) to provide a secondary sight line. D

29. Which of the following describes a short barrel when compared to a long barrel? (a) much more accurate. (b) less accurate. (c) as accurate. (d) slightly more accurate. C

30. A compound lens is made up of: (a) a concave-convex lens. (b) several, or a series of, concave and/or convex lenses used in combination. (c) molded and fired Canadian Balsam. (d) a double-cut glass round. B

31. How are lenses usually fitted in the best modern scopes? (a) with clips. (b) into cell-lined, machined recesses. (c) sealed with a resin bond. (d) with rings cushioned with a thin layer of plastic foam. B

32. Spherical aberration results in what kind of images? (a) badly blurred. (b) haloed. (c) overly rounded. (d) two-dimensional. A

33. An orthoscopic lens is one with: (a) strong magnification at the center and weak edges. (b) strong magnification at the edges and a weak center. (c) any non-uniform magnification. (d) uniform magnification. D

★★★