STUDY UNIT 9 – PART 1

EXTERIOR BALLISTICS

DOWN-TO-EARTH CONSIDERATIONS

The basic purpose of any gun is to deliver energy, by means of a bullet, at various distances. We have learned through our study of internal ballistics that much of the *potential* energy of any powder charge is dissipated through recoil, bullet friction, and heat — resulting in a muzzle energy equal to only about 30% to 35% of the powder's *potential* energy.

External ballistics is concerned with *how much* of this muzzle energy is delivered to the target at various ranges, which in turn depends on how long it takes the bullet to reach the target. The faster the projectile moves, the more quickly it arrives, and the more of its initial energy it has to expend. The shape, weight, and speed of the bullet, and the distance to the target, determine trajectory — and unless trajectory is *known*, accurate shooting is impossible.

In short, external ballistics is the science of predicting both the flight path of any bullet and that bullet's residual or down-range energy at various distances from the muzzle. The variables involved in these predictions are muzzle velocity, ballistics coefficient, and range to the target. These factors may vary widely from cartridge to cartridge. *They are all, however, subject to one immutable and unbreakable law — the law of gravity.*

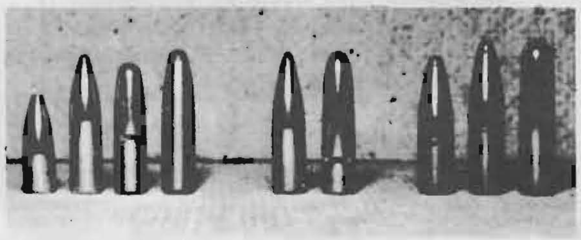


FIGURE 1 — Exterior ballistics is the science of predicting *bullet performance. Projectiles in groups shown — (from left) .257's, 6.5's, and .270's — all have individual velocity, energy, and trajectory characteristics. You'll soon know how to calculate the variables.*

TRAJECTORY AND GRAVITY

Two things happen immediately when a bullet leaves the muzzle: (1) the bullet starts slowing down because it has lost its propellant force, and (2) the bullet starts dropping because of the pull of gravity. Theoretically, if a rifle were fired from an absolutely horizontal position over a perfectly flat plain, and an identical bullet were dropped from gun height at the instant of firing, *both bullets would bite the dust at the same time.* Of course, the fired bullet would strike the ground at quite a distance from the rifle, with this distance primarily dependent on the bullet's velocity.

Another example of gravity's effect on a bullet would be to line up a rifle in a perfectly horizontal position, then bore-sight at an object 100 yards away. By firing the rifle, you would observe that the bullet hit *under* the bore-sighted target. The amount of bullet drop represents the pull of gravity on that particular bullet during the time it took for that bullet to travel 100 yards (see Figure 2).

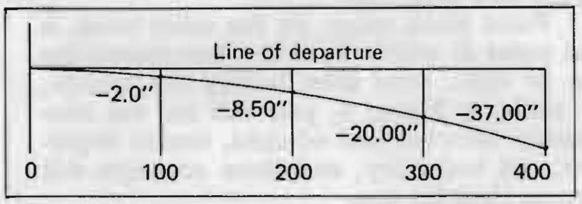


FIGURE 2 — When a bullet is fired from a bore *that is level, the drop figures at the various ranges represent the tug of gravity on the bullet during the time it took the bullet to reach these range points.*

The faster a projectile moves, the flatter its (parabolic) arc or trajectory over any given distance. This becomes apparent when you compare bullets of identical weight, sectional density, and ballistics coefficient, but moving at different velocities. If one bullet moves out at 2,000 fps and the other at 1,000 fps, the slower bullet will have a much higher mid-range trajectory over a given distance than will the faster bullet.

Because of the slow bullet's higher trajectory, which is necessary to offset the tug of gravity, it will take twice as long to reach the target. Trajectory is therefore determined by a bullet's flight time to the target, and flight time is primarily dependent on velocity. We say *primarily* because bullet shape, or B.C., *also* influences flight time.

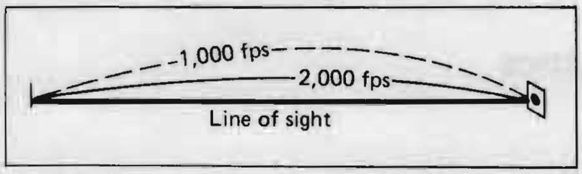


FIGURE 3 — When two identical bullets are fired the same distance, but at different velocities, the slower bullet must rise higher to overcome the force of gravity. The trajectory is thus higher and the flight time longer.

SIGHTS COMPENSATE FOR BULLET DROP

Mid-Range Rise and Point Blank Range. Now, then, before we go further, let's make *sure* we understand what is meant by *mid-range rise* and *point blank range.*

Does the bullet *rise* after leaving the muzzle? Certainly not. The bullet drops continually *from its line of departure* throughout its flight. But now, look at the bullet *trajectory* in relation to the *line of sight.* Here you will see the *curved trajectory line* to be one which starts below the line of sight, curves "upward" (or rises), and then drops back down. Thus, with respect to the *line of sight,* the bullet *appears* to rise in its flight. And the point that marks the halfway point *between the muzzle and zero,* above the line of sight, is your mid-range rise.

Point blank range, on the other hand, is that point at which the bullet first crosses the line of sight, soon after leaving the muzzle. By studying Figure 4, you will see the relationship between line of sight, line of departure, and trajectory, and these concepts will become clear for you.

But remember that all bullets, irrespective of their initial velocity, start dropping the instant they leave the support of the barrel, and a rifle's sighting equipment must compensate for this bullet fall-off. So, the three factors taken into consideration in any sighting-in procedure are: (1) the shooter's line of sight, (2) the trajectory of the bullet, and (3) the line of departure or angle of the barrel (see Figure 4).

You can see that the line of sight is the "straight line" from the shooter's eye to his target; the trajectory is the arc the bullet travels from the muzzle to the target; and the line of departure is an imaginary straight-line extension of the barrel, which determines the barrel elevation necessary to place the bullet at the zero point, where the line of sight and bullet impact coincide.

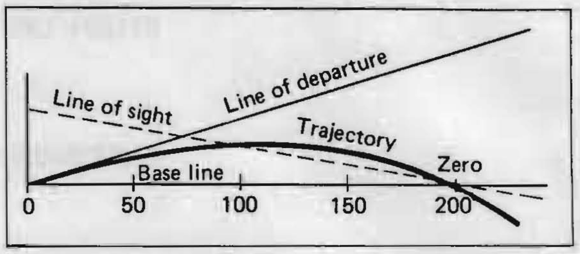


FIGURE 4 — Line of sight, line of departure, and trajectory are the three factors that must be taken into consideration in any sighting-in procedure.

The slower the velocity of a given bullet, the greater the disparity between the line of sight and the line of departure (barrel angle), and the higher the mid-range trajectory. It follows that the higher the trajectory, the more time gravity has to act on the bullet, and the more abrupt the bullet fall-off *beyond* the rifle's zero point. These two factors, mid-range "rise" and bullet drop beyond the zero point, determine a rifle's effective or "point blank" range. Point blank range is, of course, relative to the size of the target.

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.

PROGRAMMED EXERCISE

1

1. What two things happen immediately when a bullet leaves the muzzle of a gun?
2. Mid-range rise is the vertical distance halfway to zero between the bullet (trajectory) and the: (a) line of departure. (b) base line. (c) ground line. (d) line of sight.

Answers on Page 4

COMPUTING POINT BLANK RANGE

Let's say you plan to hunt deer with a .30/06 using 150-grain bullets with a muzzle velocity of around 2,900 fps and assuming a B.C. of .470. Using your Powley High-Velocity Trajectories Chart (see Study Unit 1), you determine that with a 200-yard zero, your mid-range (at 100 yards) bullet rise is little more than one inch; your bullet drop at 300 yards is just over 8 inches; at 400 yards, nearly 24 inches. If you are hunting in country where 300 yards is the longest shot you'll take, this 200-yard zero is fine. But let's say you're hunting in the West, you're an excellent marksman, and you'll take shots at up to 400 yards. That 24" 400-yard drop with your 200-yard zero is a bit too much. So let's see what happens with a 250-yard zero.

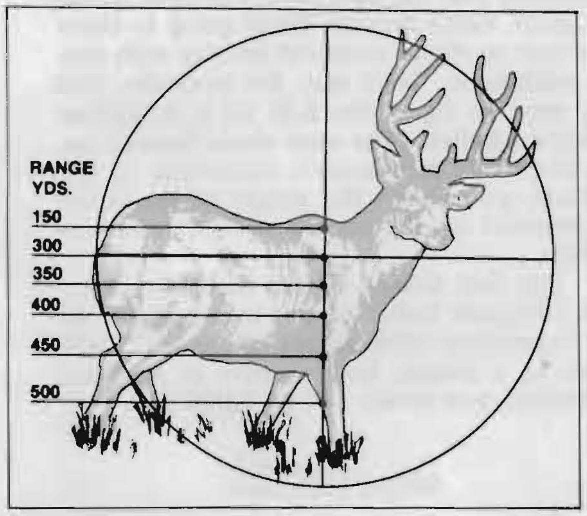


FIGURE 5 — Modern high-velocity magnums can have extremely long "point blank" ranges. Above, the rifle is sighted in for 300 yards. With the "hold" indicated, the bullet rise at 150 yards and the drop at 450 yards are within the target area. The point blank range of this rifle is therefore nearly 450 yards.

Using your Powley chart again, you see that your mid-range rise (at 125 yards) is about 3 inches; your drop at 300 yards, just over 4 inches; at 400 yards, about 17 inches (which is slightly less than the 18" shoulder-to-brisket measurement of the average deer). With a 250-yard zero, you thus have a point blank range from the muzzle to around 400 yards — meaning that your target is larger than the distance your bullet will rise or fall when you hold *on* your quarry at any distance up to 400 yards.

Generally, a mid-range rise of about 4 inches is considered maximum (the distance you will have to hold *under* your target to hit at mid-range). Most often, a 3" rise figure is used. By working with an acceptable rise figure, you can use your Powley chart to determine the point blank range of any rifle.

The size of the target determines your acceptable bullet "spread" (mid-range rise and maximum drop), which in turn determines point blank range. On elk, for example, a "spread" of 18 inches might be acceptable; on varmints, only 3 or 4 inches. Which is the reason ultra-high-velocity rifles with extremely flat trajectories (and bullet "spreads") are used for varmints at long range.

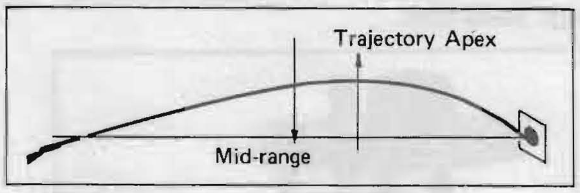


FIGURE 6 — The trajectory apex (highest point) is just forward of the halfway point from muzzle to target.

The mid-range of any trajectory is usually treated as being at the mid or halfway point to the target. Actually, and because a trajectory is a parabolic arc, the midpoint occurs a bit past the center point (see Figure 6). (A *parabolic* curve is the type of curve used on the surface of reflectors in giant telescopes, auto headlights, and solar furnaces.) For all practical purposes, however, most shooters use the halfway mark for simplicity in their ballistics calculations.

BULLET SHAPE AND WEIGHT AFFECT VELOCITY

You have seen how bullet velocity determines how far a bullet will strike the ground in front of our hypothetical horizontal rifle; and how the faster the bullet moves, the less time gravity has to act upon and pull down that bullet. The velocity of a projectile at any point in its trajectory is, of course, primarily dependent upon its muzzle velocity. How well a bullet *retains* its velocity after leaving the rifle depends on a bullet's sectional density *and* ballistics coefficient. We have discussed these two factors previously, but without explaining *how* the S.D. and B.C. numbers for a given bullet are calculated. The Powley computer and most loading manuals list S.D.'s and B.C.'s. However, as a gun pro you should *know* how to figure the S.D. and B.C. of any projectile as you may, on occasion, wish to use bullets you've swaged yourself or purchased from small manufacturers who do not normally list the S.D. and B.C. designations.

HOW TO FIGURE SECTIONAL DENSITIES

A sectional density number, which represents the weight of a bullet divided by its cross-section (diameter squared), is the first index of a bullet's ability to retain velocity. For example, a lead bullet of the same size and shape as an aluminum bullet would drop less over a given range when both bullets were fired at the same muzzle velocity. Pick up two small rocks of the same size and shape, but one heavy (high B.C.) and the other light (low B.C.). You'll be able to peg the heavier rock a lot farther with the same amount of energy. Same idea.

FIGURE 7 — Some loading presses, such as the Hollywood model illustrated, have attachments that enable you to swage your own bullets. When you do, you'll have to calculate your own sectional density and ballistics coefficient figures.

140-grain round-nose
Sectional density: .287
Ballistic coefficient: .287

270-grain spire-point
Sectional density: .274
Ballistic coefficient: .485

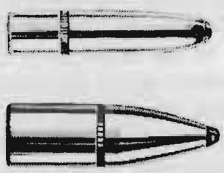


FIGURE 8 — Sectional density has no direct relationship to caliber or bullet shape. The 6.5mm and .375 bullets shown are different in bore diameter and shape, yet their S.D. is nearly the same.

ANSWERS

1

1. (1) The bullet starts slowing down because it has lost its propellant force, and (2) the bullet starts dropping because of the pull of gravity.

2. D

The formula for determining sectional density is:

$$SD = \frac{W}{d_2}$$

where: W = weight of the bullet
d = diameter of the bullet

If you're a math whiz, fine. The formula is self-explanatory. If, however, it looks like something that escaped from a bowl of alphabet soup, don't despair. We're going to show you how to figure sectional density with simple arithmetic. Let's say, for example, that you want to figure the S.D. of a .30-caliber 180-grain bullet. (The nose shape doesn't enter into S.D., remember?) According to the formula, you divide the weight of the bullet (in *pounds*) by the square of its diameter in *inches*.

The first thing you do, then, is convert that 180-grain bullet weight into pounds. As any conversion table shows, there are 7,000 grains in a pound. So, to arrive at a pound equivalent, you divide 180 by 7,000 . . .

$$7000 \overline{)180.0000} = .0257$$

The weight of your 180-grain bullet is thus .0257 of a pound.

154-grain spire-point
Sectional density: .273
Ballistic coefficient: .433

154-grain round-nose
Sectional density: .273
Ballistic coefficient: .225

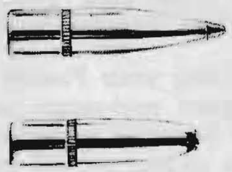


FIGURE 9 — The two 7mm bullets illustrated each weigh 154 grains. Although the bullet shapes are different, the S.D. numbers are identical.

Next, we square the diameter of the bullet. Its diameter is .308". To square a diameter, we multiply the diameter by the diameter . . .

$$\begin{array}{r} .308 \\ \times\ .308 \\ \hline .094864 \end{array}$$

The diameter of your bullet, squared, is thus .094864. For simplicity, let's round the number off to .0949. Now, to determine the sectional density number, we simply divide the weight of the bullet in pounds (.0257) by its diameter squared (.0949) . . .

$$\begin{array}{r} .270 \\ .0949.\overline{).0257.000} \end{array}$$

Thus, the sectional density for this particular bullet is .270. With a bit of practice you can easily figure the S.D. of any bullet. You need know only the bullet's weight and bore diameter — and remember that there are 7,000 grains in a pound.

HOW TO FIGURE BALLISTICS COEFFICIENTS

As you know, the ballistics coefficient or B.C. number designates a bullet's relative ability to overcome air resistance, which in turn determines how well or how poorly a given bullet retains its velocity down-range. Long, streamlined bullets have high B.C.'s and shed velocity slowly; short, stubby bullets with low B.C.'s lose velocity rapidly. This is why low-B.C. bullets which may start out faster than high-B.C. bullets are usually "overtaken" by the long, slender bullets at mid and long range (see Figure 10).

Now you're going to learn how to figure the B.C. of any bullet yourself (and it's no more difficult than computing S.D.'s, which you just learned to do). The first thing you must know is a bullet's coefficient of bullet form (CBF) number, which is *not* the B.C. number. The CBF number is a bullet shape "rating." The more streamlined the bullet, the *lower* the CBF number. The ballistics coefficient of any bullet is dependent on both its shape and its sectional density. And the CBF is the "shape" consideration. To determine ballistics coefficient, we must divide the sectional density number by the CBF rating or number. We'll get to that in a moment, but let's get back to figuring CBF numbers.

All bullets are rated (by people whose business it is to work out such things) on a head radius or ogive number basis. This is *not* the CBF number. The ogive number is, however, used in determining the CBF number. Blunt bullets are assigned a *low* ogive number (they have a smaller head radius); sharp spitzer bullets have a *high* ogive number (they have a larger head radius). The more pointed and streamlined the bullet, the higher the ogive number; the more blunt and stubby the bullet, the lower the ogive number.

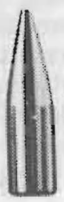
Now turn to Figure 11. This chart, drawn to scale, shows the various bullet shapes and their ogive numbers, in calibers .22 through .50. These shapes represent "normal" or spitzer-type bullets, *without* hollow-point or flat-nose tips. The first step in determining the CBF number for a given bullet is to match up the *actual bullet* with the chart in Figure 11.

For example, let's take that 180-grain .30-caliber bullet for which we have just figured the sectional density (.270). We'll say it's

7MM (.284" Dia.) 120 GRAIN HOLLOW POINT

SECTIONAL DENSITY: .213 BALLISTIC COEFFICIENT: .378

RANGE	MUZZLE	100 yds.	200 yds.	300 yds.	400 yds.	500 yds.
VELOCITY (fps)	3300	3029	2771	2525	2295	2080
ENERGY (ft. lbs.)	2902	2445	2046	1700	1404	1154
DROP: 100 yd. zero	−1.5"	0.0	−2.3"	−9.4"	−22.1"	−41.3"
DROP: 200 yd. zero	−1.5"	1.2"	0.0	−5.9"	−17.4"	−35.4"
DROP: 300 yd. zero	−1.5"	3.1"	3.9"	0.0	−9.6"	−25.6"
DROP: 400 yd. zero	−1.5"	5.5"	8.7"	7.2"	0.0	−13.6"
DROP: 500 yd. zero	−1.5"	8.3"	14.2"	15.4"	10.9"	0.0



7 MM (.284" Dia.) 162 GRAIN BOAT TAIL HOLLOW POINT

SECTIONAL DENSITY: .287 BALLISTIC COEFFICIENT: .725

RANGE	MUZZLE	100 yds.	200 yds.	300 yds.	400 yds.	500 yds.
VELOCITY (fps)	3000	2864	2732	2604	2479	2359
ENERGY (ft. lbs.)	3238	2952	2686	2439	2212	2002
DROP: 100 yd. zero	−1.5"	0.0	−2.8"	−10.4"	−23.2"	−42.3"
DROP: 200 yd. zero	−1.5"	1.4"	0.0	−6.1"	−17.4"	−35.1"
DROP: 300 yd. zero	−1.5"	3.5"	4.1"	0.0	−9.2"	−24.8"
DROP: 400 yd. zero	−1.5"	5.8"	8.7"	6.9"	0.0	−13.2"
DROP: 500 yd. zero	−1.5"	8.5"	14.0"	14.9"	10.6"	0.0

FIGURE 10 — A comparison of the above tables shows that the much heavier but more streamlined (high-B.C.) bullet catches up with the lower-B.C. bullet just past the 200-yard point. At longer ranges, the 162-grain bullet is moving faster and drops less than its lighter counterpart.

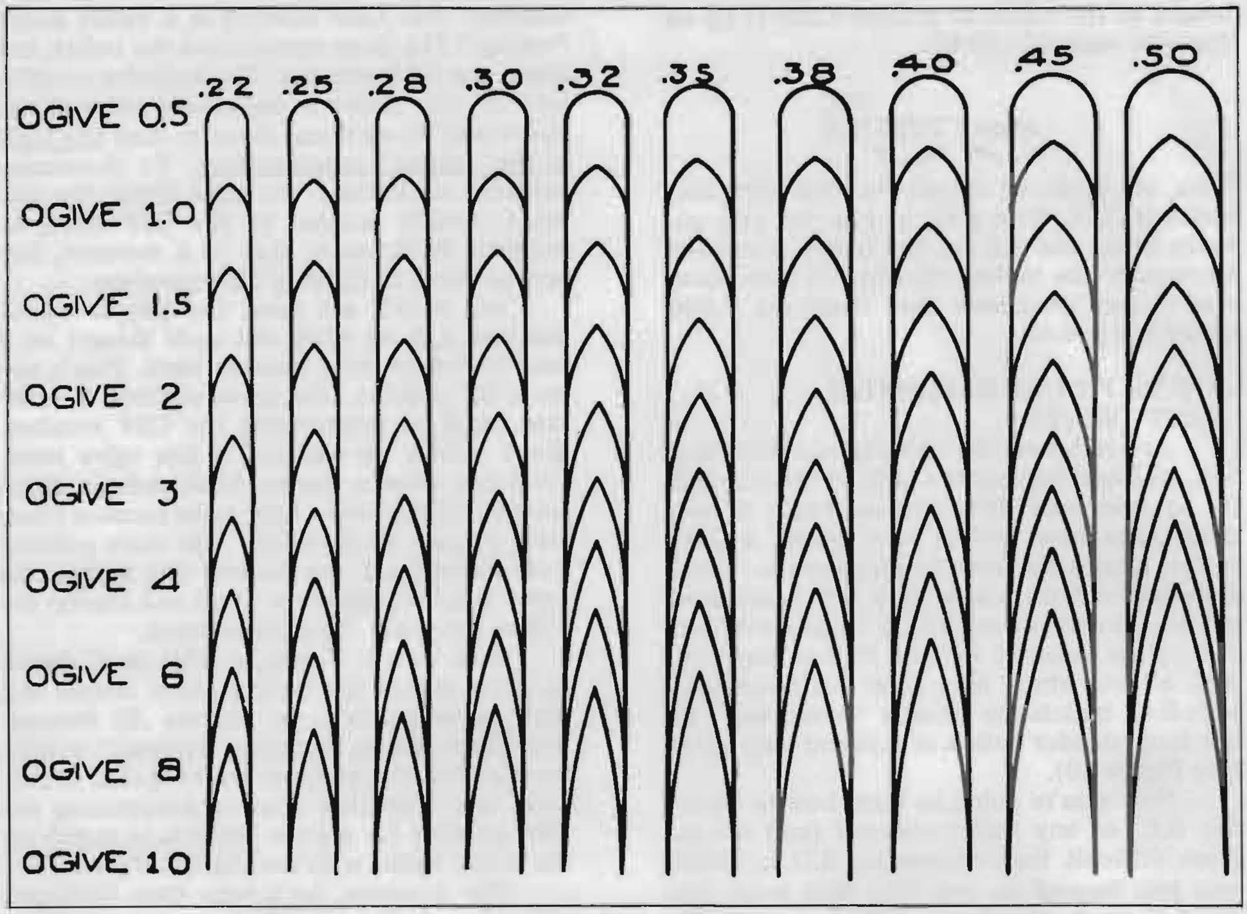


FIGURE 11 — The ogive chart. Fit your bullet to the ogive, then consult Table 1 to get the CBF number.

a flat-base Sierra spitzer that we will fire in a .30/06 at about 2,700 fps. By finding the .30-caliber column on the chart and shifting the actual bullet over the various shapes, we discover that this Sierra bullet most closely conforms to the shape appearing third from the bottom, with an "ogive 6" designation (see Figure 12).

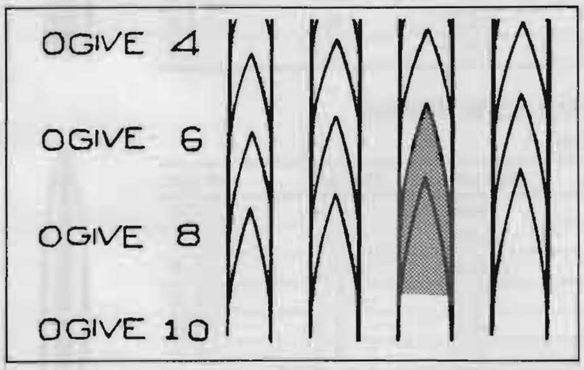


FIGURE 12 — By moving an actual 180-grain Sierra bullet over the "templates" in Figure 11, you discover that your bullet (shaded) most closely matches the "ogive 6" designation.

When we have the ogive number, we refer to Table 1 to locate the CBF number or value for this "ogive 6" bullet. You'll note that the table has, under the "Bullet Form" heading, "Head Radius" listings, followed by numbers which correspond to the various ogive numbers. You'll also see that the table lists two figures or CBF numbers for any bullet with a head radius (ogive number) higher than 2.0 (see Figure 13). One number is for a bullet driven at low velocity (under 2,000 fps), the other for the same bullet driven at higher velocity (2,000 to 3,500 fps). The reason for the different numbers for the same bullet has to do with the increased air resistance at higher velocities, which must be "balanced" with the S.D. number.

Okay, back to our 180-grain ogive 6 bullet, which we will load to a velocity of 2,700 fps. In Table 1, opposite "Head Radius of 6.0 Cal MV 2000-3500 fps," we find, under the "Normal Point" heading, the number .55. This is the CBF (coefficient of bullet form) number for your bullet. Now, to determine the *ballistics coefficient* of this bullet, we simply divide the sectional density number which

BULLET FORM	NORMAL POINT	VALUE OF i — Diam. of Hollow Point or Flat Nose in Calibers				
		0.1	0.2	0.3	0.4	0.5
Blunt Projectile, Cylindrical	2.30					
Blunt Projectile, Taper Sides 0.9 Cal	1.85					
Blunt Projectile, Taper Sides 0.8 Cal	1.50					
Blunt Projectile, Taper Sides 0.7 Cal	1.30					
Blunt Projectile, Taper Sides 0.6 Cal	1.10					
Head Radius of 0.5 Cal	1.40					
Head Radius of 1.0 Cal	1.10	1.15	1.20	1.25	1.30	1.40
Head Radius of 1.5 Cal	0.95	1.00	1.10	1.15	1.25	1.35
Head Radius of 2.0 Cal	0.85	0.90	0.95	1.00	1.10	1.25
Head Radius of 3.0 Cal. M.V. 2000–3500 f.s.	0.70	0.75	0.80	0.90	1.00	1.10
Head Radius of 3.0 Cal. M.V. under 2000 f.s.	0.75	0.80	0.85	0.95	1.05	1.15
Head Radius of 4.0 Cal. M.V. 2000–3500 f.s.	0.60	0.65	0.70	0.75	0.85	1.00
Head Radius of 4.0 Cal. M.V. under 2000 f.s.	0.70	0.75	0.80	0.85	0.95	1.10
Head Radius of 6.0 Cal. M.V. 2000–3500 f.s.	0.55	0.60	0.65	0.70	0.80	0.95
Head Radius of 6.0 Cal. M.V. under 2000 f.s.	0.65	0.70	0.80	0.85	0.95	1.10
Head Radius of 8.0 Cal. M.V. 2000–3500 f.s.	0.49	0.55	0.60	0.65	0.75	0.90
Head Radius of 8.0 Cal. M.V. under 2000 f.s.	0.60	0.65	0.70	0.75	0.85	1.00
Head Radius of 10.0 Cal. M.V. 2000–3500 f.s.	0.44	0.50	0.55	0.60	0.70	0.85
Head Radius of 10.0 Cal. M.V. under 2000 f.s.	0.55	0.60	0.65	0.70	0.80	0.95
Balls with M.V. under 1000 f.s.	2.00					
Balls with M.V. between 1000–1300 f.s.	1.70					
Balls with M.V. over 1300 f.s.	1.40					

TABLE 1 — CBF numbers (coefficient of bullet form).

Head Radius of 6.0 Cal. M.V. 2000-3500 f.s.	– 0.55
Head Radius of 6.0 Cal. M.V. Under 2000 f.s.	– 0.65

FIGURE 13 — Bullets of the same head radius or ogive number are assigned one of two possible ratings; the rating depends on the approximate velocity the bullet will be driven.

we have already established (.270) by the CBF number (.55) . . .

$$.55. \overline{)\,.27.000} = .490$$

By referring to the Sierra loading manual, you'll see that the listed B.C. number for this 180-grain .308 spitzer flat-base bullet is .501. We have come very close. The .011 difference is too slight to influence any further calculations based on its B.C. number.

FIGURING CBF'S FOR FLAT-NOSE AND HOLLOW-POINT BULLETS

You now know how to determine the coefficient of bullet form (CBF) for normal or spitzer-type bullets. However, many bullets have hollow-point cavities or flat noses, requiring a slightly different procedure for figuring CBF. Refer again to Table 1. The column of figures appearing to the *right* of the "Normal Point" column are concerned with bullets of flat or hollow-point tip configuration. Because of their greater air resistance, they have higher CBF numbers. The less streamlined the bullet, the higher the CBF number, which when divided into the S.D. number results in a lower B.C. number.

When working with such "blunted" bullets, you first find the ogive number (same as before). Next, you *actually measure* the diameter of the hollow point or the flat portion of the bullet's nose (see Figure 14), then find that diameter under the appropriate diameter heading — 0.1, 0.2, 0.3, etc. — at the top right of Table 1. Under the correct diameter heading, and opposite the appropriate head radius (ogive) and velocity heading, you will find the CBF number for your hollow-point or flat-nose bullet.

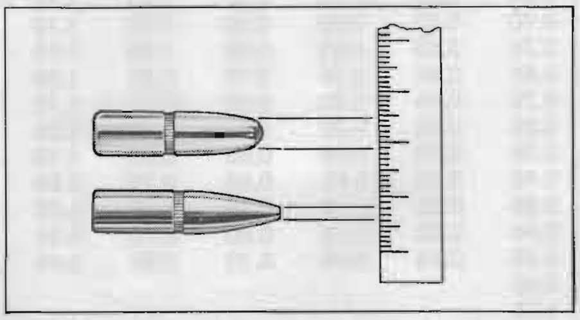


FIGURE 14 — After the basic ogive or head radius number is determined, the diameter of the cavity or the flat portion on "blunted" bullets must be measured and that measurement related to Table 1.

For example, if you were working with a 250-grain .35-caliber Speer bullet with an "ogive 4" designation and a semi-spitzer tip with a flat portion measuring 0.1" in diameter, and that bullet will be driven at about 2,400 fps, your CBF number would be 0.65 (see Figure 15).

To determine the B.C. of this bullet, you would divide its sectional density (.279) by the CBF rating number of 0.65 . . .

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        .429
.65.) .27.900
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A comparison with the Speer manual shows the B.C. value for their 250-grain .358-caliber spitzer bullet at .423. Again, we have come very, very close.

To sum up, the coefficient of bullet form (CBF) number is determined by comparing the shape of an actual bullet with the various configurations in Figure 11, which gives the ogive number. This ogive number, in connection with appropriate velocity (and diameter of the hollow-point or flat-nose tip of the bullet, if any), enables you to locate the CBF number in Table 1. The CBF number, when divided into the S.D. number, provides the ballistics coefficient (B.C.) number for that particular bullet.

	VALUE OF i				
	Diameter of Hollow-Point or Flat-Nose in Calibers				
Normal Point	0.1	0.2	0.3	0.4	0.5
2.30					
1.85					
1.50					
1.30					
1.10					
1.40					
1.10	1.15	1.20	1.25	1.30	1.40
0.95	1.00	1.10	1.15	1.25	1.35
0.85	0.90	0.95	1.00	1.10	1.25
0.70	0.75	0.80	0.90	1.00	1.10
0.75	0.80	0.85	0.95	1.05	1.15
0.60	0.65	0.70	0.75	0.85	1.00
0.70	0.75	0.80	0.85	0.95	1.10
0.55	0.60	0.65	0.70	0.80	0.95
0.65	0.70	0.80	0.85	0.95	1.10
0.49	0.55	0.60	0.65	0.75	0.90
0.60	0.65	0.70	0.75	0.85	1.00
0.44	0.50	0.55	0.60	0.70	0.85
0.55	0.60	0.65	0.70	0.80	0.95
2.00					
1.70					
1.40					

FIGURE 15 — Your measured value . . .

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. Why do bullets with identical shapes have different CBF numbers when driven at higher velocities than when driven at lower velocities?

2. What is the ballistics coefficient of a bullet with a CBF of .60 and a sectional density of .290? (a) .483. (b) .207. (c) .445. (d) .298.

3. Refer to Table 1. What is the CBF number for a normal .45-caliber bullet with less than 2,000 fps muzzle velocity and an ogive number of 6? (a) 0.60. (b) 0.65. (c) 0.80. (d) 0.85.

Answers on Page 10

UPHILL AND DOWNHILL SHOOTING

One of the more interesting and controversial aspects of exterior ballistics is where to "hold" on a target to assure a hit when shooting uphill or downhill — as is often the case when hunting in mountainous or hilly terrain.

Most shooters believe that a bullet fired uphill, working against gravity, somehow slows down — requiring one to hold *high* to avoid *undershooting* the target. By the same token, it is widely believed that a bullet fired downhill and assisted by gravity picks up speed like a rolling stone. Here, presumably, one must hold *low* to prevent *overshooting.*

As in most rumors and old wives' tales, there is a speck of truth in these theories. However, the effect of gravity relative to the *angle* of the bullet's flight path is so small as to be immeasurable. The truth is that riflemen have a tendency to overshoot the target whether firing uphill *or* downhill. The cause is gravity, but *not* in the context of a bullet's "fighting" uphill or "sliding" downhill.

Let's say that a Dall ram, standing on a bluff high above a hunter, is 400 linear or tape-measure yards from the rifle. Yet if that ram were on the same horizontal plane or level as the shooter, the actual distance between ram and rifle might be only 300 to 350 yards — depending on the steepness of the grade. The same situation would exist if the ram were 400 linear yards *below* the shooter and the grade equally steep. The actual distance between trophy and hunter would still be that 300 to 350 yards (see Figure 16).

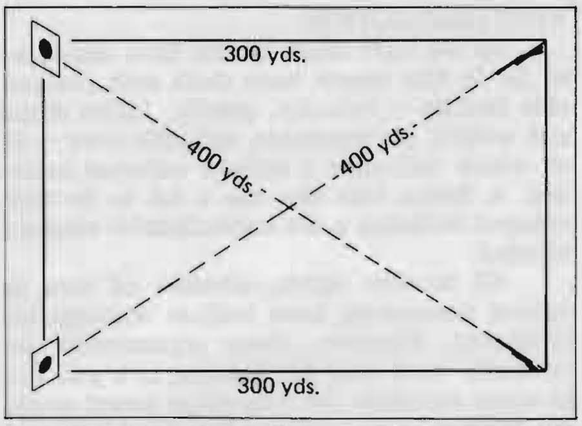


FIGURE 16 — When shooting uphill or downhill, estimation of linear distance is not as important as correctly estimating the horizontal distance to the target. Gravity only works on the bullet during the time it takes to cross the horizontal distance.

The thing to remember is that gravity works only on the horizontal plane, and pulls down the bullet proportionate only to the *horizontal distance* between the muzzle and the target, irrespective of whether the target is above or below the shooter. When faced with such uphill or downhill shots, remember that your target is always closer as far as gravity is concerned. Try to estimate the horizontal distance, hold low rather than high, and your chances of hitting will be much improved.

The common problem of overshooting at distant uphill or downhill targets is compounded by the fact that *less* target area is visible when the target is viewed from an angle. A deer's vital area on the horizontal plane usually constitutes a rectangle about 15 inches high by 10 inches long. Yet this same target rectangle, when viewed from above or below, may shrink to half of its apparent height — depending on the steepness of the grade (see Figure 17). And with a small target it's easy to overshoot *or* undershoot. Especially when winded, as is often the case when hunting uphill or in the mountains.

BULLET ROTATION

Any and all calculations involved in exterior ballistics are concerned with *predicting* a bullet's trajectory, and the point of impact and residual energy, at various ranges. Ballistically, you can nail down these figures with astonishing accuracy. But what good are the most accurate calculations if the rifle itself is so inaccurate that it shoots 4 MOA (12") groups at, say, 300 yards? In other words, if you calculate that your bullet will drop 7.5 inches at 300 yards, this figure is almost meaningless if your rifle scatters bullets over an area a square foot in size.

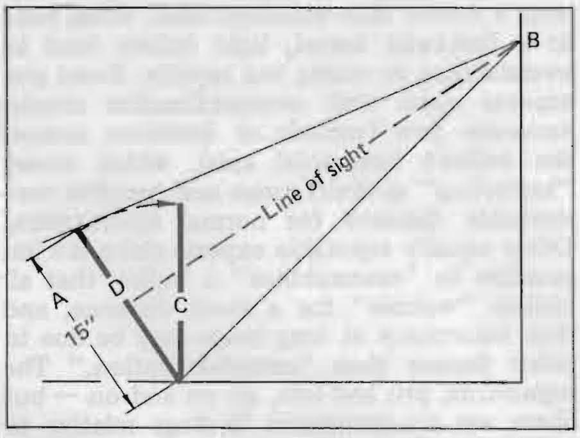


FIGURE 17 — A deer's vital area (A), about 15" high, actually appears smaller when viewed from above or below (B) because the animal is standing upright (C) and at an angle to your line of sight. If the animal stood at an angle perpendicular to your line of sight (D), it would be a rather strange-looking animal, but a "full" target.

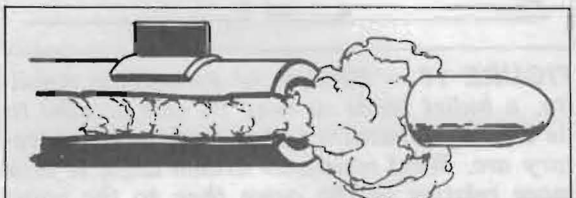


FIGURE 18 — The ratio of a barrel's twist determines the bullet's rotational speed. The longer the bullet, the faster it must spin to stabilize.

Assuming that you're using bullets of good quality and a reasonable (seldom maximum) powder charge, and that your barrel is properly bedded, the accuracy of a given rifle depends almost exclusively on the suitability of its rifling twist for a particular bullet. A bullet has to travel a certain distance from the muzzle before it stabilizes or is "put to sleep" (as the saying goes). *Before* it settles down to point-on concentricity, the bullet's gyroscopic spin (imparted by the rifling) resembles that of a poorly thrown football. Just how far the bullet has to travel before stabilizing depends on the twist relative to the bullet's ballistics coefficient.

Long, heavy, high-B.C. bullets require a relatively fast twist to spin the bullet's greater mass at the proper speed for stabilization. If the twist is *much* too slow, that bullet will never be "put to sleep." When the twist is only slightly slow (say, 1-12 instead of a proper 1-9), the bullet might require as much as 100 yards to stabilize.

On the other hand, light bullets of a given caliber generally deliver better accuracy with a slower than standard twist. When fired in a fast-twist barrel, light bullets tend to overstabilize or rotate too rapidly. Some gun experts claim that overstabilization creates excessive yaw (wobble or deviation around the bullet's horizontal axis), which causes "keyholing" at short range and requires considerable distance for normal stabilization. Other equally reputable experts claim it's impossible to "overstabilize" a bullet, that all bullets "wobble" for a short distance, and that inaccuracy at long range may be due to other factors than "overstabilization." The arguments, pro and con, go on and on — but there are no conclusive findings relative to light bullets and fast twist.

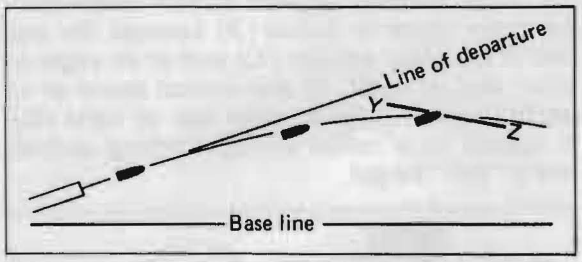


FIGURE 19 — Because of gyroscopic stability, a bullet tends to keep its axis parallel to its line of departure rather than to its trajectory arc. Wind resistance attack angle is thus more relative to the ogive than to the point (Line Y-Z), which also contributes to "keyholing" on long-range targets.

In any event, most rifles incorporate a twist ratio which is most suitable for the most popular bullet weight for that particular caliber. Accuracy is usually better with light bullets for which the twist is "too fast" than with long, heavy bullets for which the twist is "too slow."

ANSWERS

2

1. The increased air resistance met by bullets at higher velocities slows them down disproportionately when compared to lower-velocity bullets.

2. A. You divide sectional density by the CBF number — .290 ÷ .60 = .483 ballistics coefficient.

3. B

WIND DEFLECTION

As we have seen, all the facts discussed so far in this lesson have dealt with *predictable* factors — velocity, gravity, bullet shape and weight, air resistance, and rifle twist — all of which influence a bullet's external ballistics. A factor that also has a lot to do with external ballistics is the *unpredictable* element of wind.

All modern sights, whether of iron or optical persuasion, have built-in windage adjustments. However, these adjustments are normally used only for sighting in a gun and in some instances for long-range target work. No hunter in his right mind would tamper with his windage adjustment to compensate for a breeze or gale that could change or stop momentarily. No, the shooter must make a "guesstimate" on the force or speed of the wind and its angle in relation to his bullet path, then hold *into* the wind to compensate for bullet drift. His problem is further compounded by the fact that the wind may be blowing harder (or not at all) at mid-range or near the target, of which he is unaware. In short, all any shooter can do is estimate the wind force and angle and, by relating wind pressure to known drift figures, make the proper compensation in his sight picture.

Windage allowance can be predicted to a more accurate degree than one might imagine. If this wasn't the case, long-range artillery fire would be impossible.

FIGURE 20 — "Kentucky windage" is a must when shooting in a stiff wind. With a strong 3 o'clock breeze and a 7 x 57 rifle, this hold would be about right when your target is 300 yards away. (Drawing courtesy "Complete Book of Rifles and Shotguns" by Jack O'Connor)

BULLET SPEED VS. WIND DRIFT

The old brainbuster, "Does one get wetter by walking or running through a rainstorm?" is brought to mind by the relationship of bullet speed to wind drift. One could assume that the faster a bullet moves, the less time it spends in the air and the less time the wind has to influence its course. Right? Sorry.

A bullet can be compared to a powerboat crossing a river, with the current approximating the wind force. As long as the power is maintained, the distance the boat is carried downstream depends only on the speed of the boat and the distance to the other shore. Thus drift, relative to the force of the current, is dependent on velocity and distance. This example is analogous to the "the faster a bullet moves, the less drift" theory, which is wrong. Here's why . . . a bullet doesn't *have* a power source after it leaves the barrel. In effect, it is drifting.

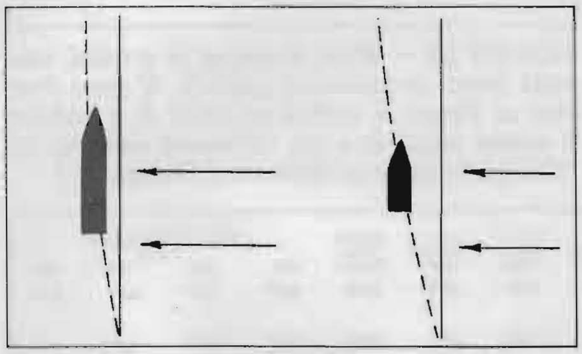


FIGURE 21 — A long, slender boat (or bullet) is less affected by the force of the current (or air) between two points than is a short, stubby object, even though the latter may be moving faster.

Now let's compare our bullet with the powerboat again, but with the power cut off. Like the boat, the bullet must drift to its destination. The amount of current or wind deflection is governed by the object's initial speed (before the power was cut) plus its *shape* — which determines the object's resistance to forward motion through water or air. A long, slender boat or bullet is less affected or delayed by the medium it is moving *against* than is a short, stubby boat or bullet.

In other words, bullets of high ballistics coefficients are deflected less by a given wind force than are bullets of a low ballistics coefficient — even though the high-B.C. bullet has more side area for the wind to push against and may take more time to get to its destination. This seemingly paradoxical phenomenon is explained by a "delay formula," worked out by ballisticians years ago. We're not going to bore into you with the details.

WIND DIRECTION RELATES TO THE DIAL OF A CLOCK

The direction a wind is coming *from* is always related to the face of a clock, with the shooter standing above the surface of the clock and in the 6 o'clock position (see Figure 22). A wind from the right is from "3 o'clock," from the left "9 o'clock." A quartering breeze from the right rear would be from "5 o'clock," from the right front "1 o'clock." A quartering wind from the left rear would be from "7 o'clock," from the left front "11 o'clock." Wind deflection tables such as Table 2 customarily list data for 3 and 9 o'clock winds only. Quartering winds, from 1, 5, 7, or 11 o'clock, deflect a given bullet only *half as much* as a 3 or 9 o'clock wind.

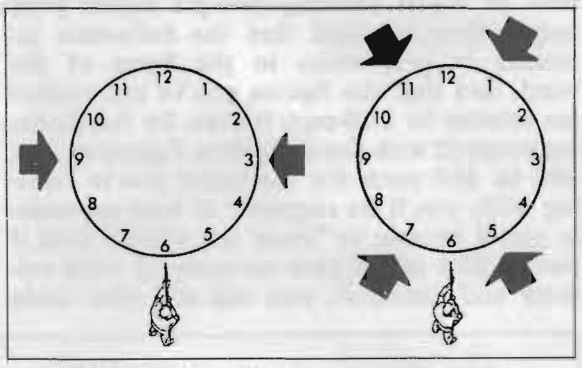


FIGURE 22 — Windage deflection clock.

10 MPH WIND AT 3 O'CLOCK OR 9 O'CLOCK				
Ballistic Coefficient	*Muzzle Velocity*	*Wind Deflection, inches* 200 yds.	300 yds.	400 yds.
0.15	2700	11.8	29.3	55.0
0.15	3100	9.4	23.3	47.0
0.15	3500	7.6	20.0	40.0
0.15	4000	6.2	16.0	32.3
0.15	4600	5.2	13.0	26.0
0.20	2700	7.9	20.0	36.7
0.20	3100	6.6	16.3	32.0
0.20	3500	5.3	13.3	27.0
0.20	4000	4.4	11.0	21.3
0.20	4600	3.6	9.5	17.5
0.27	2700	5.9	13.8	25.5
0.27	3100	4.8	11.0	21.5
0.27	3500	3.8	9.5	18.0
0.27	4000	3.1	7.7	14.5
0.27	4600	2.6	6.0	11.5
0.37	2700	4.0	9.6	17.3
0.37	3100	3.3	8.0	14.3
0.37	3500	2.5	6.0	12.4
0.37	4000	2.1	5.0	10.0
0.37	4600	1.9	3.7	8.0
0.50	2700	2.9	6.8	12.0
0.50	3100	2.4	5.7	10.0
0.50	3500	1.9	4.7	8.7
0.50	4000	1.7	3.8	7.2
0.50	4600	1.4	3.0	5.5

TABLE 2 — Windage deflection chart.

As you'll note from Table 2, and as explained in our powerboat analogy, bullets of a high B.C. are affected much less by the same wind force than are bullets of a low B.C. when both are moving at the same velocity.

Wind deflection tables are also usually concerned only with 10-mile-per-hour winds. Winds of 20 mph produce exactly *twice* the amount of deflection of a 10-mph wind; winds of 5 mph produce exactly *half* the amount of deflection, etc. Deflection can therefore be extrapolated for winds up to 30 miles per hour. In a gale of such gusto, you have no business shooting anyway — except perhaps at a belligerent and hard-charging bear.

When estimating wind, first try to determine the "clock" direction, remembering that quartering winds produce only half the deflection of winds blowing straight across your target. Bear in mind that the deflection increases in proportion to the force of the wind, and that the figures you've memorized are relative to a 10-mph breeze. By familiarizing yourself with the deflection figures at, say, 200 to 400 yards for the bullet you're hunting with, you'll be surprised at how accurately you'll be able to "dope the wind." Even if you're 25% off in your estimate of wind velocity and direction, you will still have made some correction — which can be the difference between a hit and a miss at medium or big game at moderate or long range (see Figure 23).

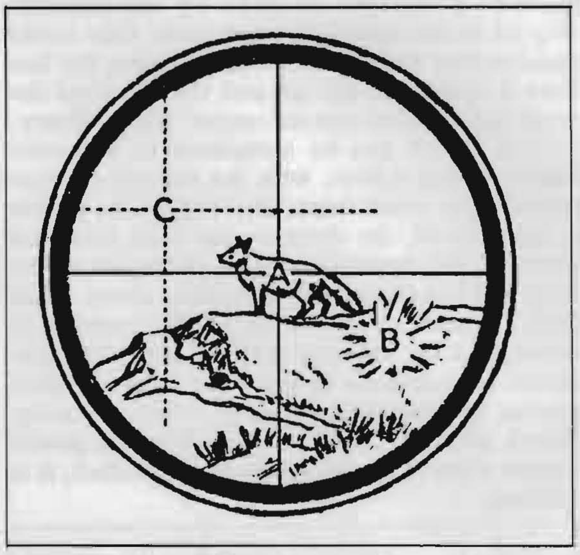


FIGURE 23 — When shooting in a wind, one must learn to calculate quickly. If your first shot at Target A landed at Point B, a hold at C would result in a hit. (Drawing courtesy of "Complete Book of Rifles and Shotguns")

Load	Representative Calibres	Diam.	Wt.	Type	Representative Manufacturer	Sectional Density	Coeff. Form	Ballistic Coeff.	Muzzle Veloc. Ft. Sec.	Drift in 10 MPH wind* Yards 100	200	300	400
1.	.264 Winchester 7mm Rem. Magnum .284 Jet Magnum	.263	140	Spitzer SP	Winchester Hornady Nosler	.290	.566	.512	3100	0.5″	1.9″	4.6″	8.6″
2.	7mm Weatherby 7mm Mashburn .284 BJ Express	.284	160	Spitzer SP	Nosler Remington Barnes	.284	.566	.501	3250	0.5″	2.1″	4.9″	9.0″
3.	.308 Norma .300 Ackley .30/.338 .308 BJ Express	.308	180	Spitzer SP	Barnes Remington Nosler	.271	.587	.462	3150	0.6″	2.5″	5.6″	10.4″
4.	.270 Winchester	.277	150	Spitzer SP	Barnes Nosler	.280	.566	.493	2950	0.6″	2.5″	5.8″	10.6″
5.	.270 Winchester	.277	130	Spitzer SP	Sierra Nosler	.242	.566	.428	3150	0.7″	2.6″	6.0″	11.1″
6.	Same as No. 2	.284	175	Semi-Spitzer SP	Nosler Remington	.310	.683	.454	3050	0.7″	2.7″	6.1″	11.2″
7.	.257 Jet .257 Robert Imp.	.257	115	Spitzer SP	Nosler Sierra	.249	.608	.410	3150	0.7″	2.7″	6.3″	11.4″
8.	.224 Jet .220 Swift Imp.	.224	63	Spitzer SP	Sisk	.180	.566	.318	3700	0.7″	2.8″	6.5″	12.0″
9.	.243 Winchester .244 Remington	.243	100	Spitzer SP	Hornady Remington Sierra	.242	.608	.398	3100	0.8″	2.9″	6.7″	12.2″
10.	.30/06	.308	180	Spitzer SP	Speer Nosler Remington	.271	.587	.462	2700	0.8″	3.1″	7.0″	12.7″
11.	.30/06	.308	150	Spitzer SP	Hornady Speer	.226	.587	.385	3000	0.8″	3.2″	7.2″	13.2″
12.	.338 Winchester	.338	200	Semi-Spitzer SP	Winchester Barnes Hornady	.250	.710	.352	3000	0.9″	3.3″	7.6″	14.1″
13.	6mm International .243 Winchester .244 Remington	.243	85	Spitzer SP	Sierra	.206	.632	.326	3250	0.9″	3.5″	7.9″	14.4″
14	.22/250 .220 Swift	.224	55	Spitzer SP	Sierra Speer Sisk	.157	.608	.258	3700	0.9″	3.6″	8.3″	15.1″
15.	6mm International 6mm-.222 Magnum	.243	75	Spitzer SP	Sierra	.182	.656	.277	3400	0.9″	3.7″	8.6″	15.8″
16.	.222 Rem. Magnum .219 Wasp .219 Improved Zip.	.224	53	Spitzer HP	Sierra	.151	.632	.239	3300	1.1″	4.6″	10.6″	19.5″

*Drift is proportionate to Wind Velocity; Double values for 20 MPH wind, etc.
For a factual discussion of drift see "Bullets and the Wind," by William C. Davis, American Rifleman, Jan. '56, page 45.

TABLE 3 — Windage deflection for representative handloads.

Shooting directly into the wind, or with the wind at your back, has no appreciable effect on whether your bullet will strike low or high. A bullet moving at around 3,000 fps is, in effect, bucking a 1,800 to 1,900-mph "headwind." Adding or subtracting 10 to 20 mph to or from this figure will make less difference in bullet impact than the variation between one "identical" cartridge and another.

TERMINAL BALLISTICS

Terminal ballistics is concerned with a bullet's performance at *impact*, after it has completed its trajectory. As there is no particular "performance" involved in a bullet's punching a neat hole in a paper target, the science of terminal ballistics, realistically, relates to a bullet's killing power. To put it another way, it deals with how efficiently a bullet transmits its remaining energy to the target, and evaluates that energy in terms of stopping or knock-down power.

Assuming that for a given game animal a reasonable bore diameter is used, and a reasonably heavy projectile is propelled at a reasonable velocity, then the question of lethality depends almost exclusively on bullet construction and placement of that bullet in the quarry. (What constitutes "reasonable" concerning the foregoing factors has been proved over the years.) Out of, say, four possible bullets of equal weight, but of different construction (see Figure 24), and driven into different parts of the animal's anatomy, one might zip clean through, expending its energy in the ground beyond; another might blow up on the surface or flatten against a large bone; the third might penetrate deeply, expand properly, and kill cleanly. It is for this reason that manufacturers strive to make bullets which are matched to a given gun and game animal. Under most conditions, they succeed.

The point is, all mathematical methods (and there are several) of evaluating the killing power or terminal ballistics of a cartridge/bullet combination do *not* take bullet construction or placement into consideration. Velocity and bullet weight always enter into an "energy transfer" equation; bore diameter is sometimes part of the formula. Yet how well the bullet — the heart of the matter — will perform never figures into the computation. Nor could it, unless there was such a thing as a "standard" bullet which, of course, there is not. Different game species, and varying velocities and distances, require different bullet construction.

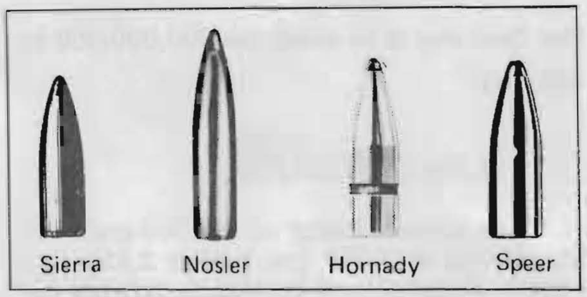


FIGURE 24 — Manufacturers' specifications (and concepts) vary considerably. The four .30-caliber 150-grain spitzers shown, of different makes but designed for the same type of game, may perform quite differently, all else being equal.

BALLISTICS "SECOND-GUESSING"

Ballisticians don't pinch, probe, and otherwise evaluate the vitality of a given game animal, compute the foot pounds of energy necessary to dispatch it, and then design a cartridge that will accomplish this objective. No. New cartridges always take up where a lesser cartridge left off. When Winchester brought out the .300 Winchester magnum, for example, they knew it would drive bullets of the same weight faster than did the old .30/06. The '06 was a splendid killer; ergo, the .30-caliber magnum would be even better.

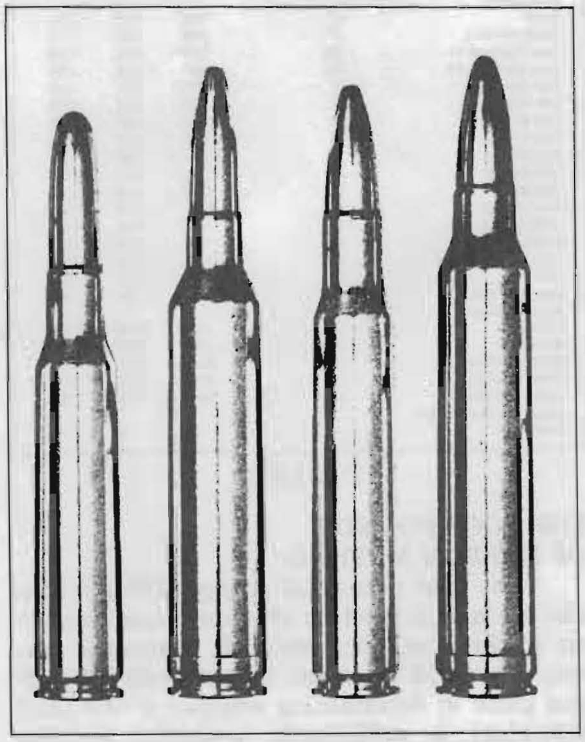


FIGURE 25 — New magnum cartridges aren't "tested" for lethality. If a smaller cartridge "worked," the new addition, firing the same bullet at a higher velocity, will do its job even better. Sometimes, however, thicker jackets are required for the faster-moving projectiles. From left: 7mm Mauser and 7mm Remington magnum, .30/06, .300 Winchester magnum.

In other words, the various methods of measuring a bullet's (or cartridge's) killing power constitutes ballistics "second-guessing," proving mathematically what has already been proved *physically* — in the game fields, or in terms of superiority over an older, proven game-getter. At best, the various ballistics yardsticks provide a comparison basis between diverse cartridges, enabling the shooter to *predict* what rifle and cartridge combination is best for his purpose. And predicting is what ballistics, whether interior, exterior, or terminal, is all about!

There are a number of formulas and systems, many of them controversial, used in evaluating killing power. However, there are three main schools of thought which we'll now discuss.

.357 Magnum Velocity Variation in Different Guns (fps)

Gun Description	Barrel Length	Ammunition used in Test 125-Gr. JHP	140-Gr. JHP	158-Gr. JSP
S&W M19 #1	2½"	1190	1132	1034
Colt Python	2½"	1205	1418	989
S&W M19 #2	2½"	1209	1118	1018
Ruger Security Six	2¾"	1233	1154	1075
Colt Trooper Mark III	4"	1317	1175	1101
S&W M66	4"	1385	1225	1117
S&W M19 #1	4"	1368	1227	1153
S&W M19 #2	4"	1374	1242	1146
Ruger Security Six #1	4"	1370	1242	1130
Ruger Security Six #2	4"	1380	1267	1151
Dan Wesson W12	4"	1358	1280	1160
Ruger Blackhawk #1	4⅝"	1361	1266	1159
Ruger Blackhawk #2	4⅝"	1480	1336	1196
Ruger Security Six	6"	1436	1311	1210
S&W M19 #1	6"	1400	1282	1179
S&W M19 #2	6"	1372	1281	1154
S&W M19 #3	6"	1603	1417	1284
S&W M28 #1	6"	1307	1246	1080
S&W M28 #2	6"	1499	1353	1178
S&W M27	6"	1547	1358	1248
Colt Python #1	6"	1227	1142	1002
Colt Python #2	6"	1477	1373	1251
Colt Python #3	6"	1468	1364	1207
Ruger Blackhawk (new)	6½"	1471	1375	1262
S&W M27	8⅜"	1501	1342	1221
Ruger Blackhawk	10"	1738	1544	1365
Thompson Center Contender	10"	1944	1726	1587
Martini Rifle	17½"	2121	1906	1678
Winchester 92 Rifle	20"	2153	1967	1824
Marlin 1894 Rifle	24"	2212	1994	1835
Velocity Test Barrel	10"	1866	1732	1591
Velocity Test Barrel Extreme Variation-fps		48	26	38

TABLE 4

THE FOOT POUNDS OF ENERGY METHOD

The foot pounds of energy (FPE) or kinetic method is used by all ammo manufacturers in their ballistics tables. It is also the system observed by most departments of fish and game in determining whether a rifle (and cartridge) is sufficiently powerful for big game, with 1,000 foot pounds of energy at 100 yards usually the minimum requirement. (Some departments okay *all* center-fire rifles, but prohibit specific calibers such as all .22's, the old .25/20, etc.)

The FPE system is perhaps the most realistic as it deals with a specific, the actual energy delivered to the target (which can be calculated when muzzle and down-range velocities are known). *If* properly constructed bullets are used, it is probably the most definitive measure of a gun's lethality. Other methods, as we shall see, are concerned only with the *comparison* of various cartridges or are based on theory.

In Study Unit 6 we included a table that enables you to compute the muzzle energy of any bullet once the velocity and bullet weight are known. However, as part of your education as a gun pro, you should know how to figure muzzle energy without resorting to this table. There are a number of ways of calculating muzzle energy, but the following is perhaps the easiest.

To determine muzzle energy, the formula is:

$$ME = \frac{WV^2}{450{,}000}$$

where: W = weight of bullet in grains
V = velocity

Let's reduce this to simple math. To find muzzle energy, you square the velocity, multiply the result by the bullet weight in grains, then divide that figure by 450,000. For example, let's say we want to determine the muzzle energy of a 100-grain bullet moving at 3,000 fps. First we square the velocity, which means that we multiply the velocity by the velocity:

$$\begin{array}{r} 3{,}000 \\ \times\ 3{,}000 \\ \hline 9{,}000{,}000 \end{array}$$

Next we multiply this 9,000,000 by the bullet weight in grains (100):

$$\begin{array}{r} 9{,}000{,}000 \\ \times\ 100 \\ \hline 900{,}000{,}000 \end{array}$$

Our final step is to divide the 900,000,000 by 450,000:

$$450{,}000 \overline{)\,900{,}000{,}000} = 2{,}000$$

The muzzle energy of this 100-grain bullet, moving at 3,000 fps, is thus 2,000 foot pounds. Regardless of the muzzle velocity and bullet weight, you always divide by the 450,000 value.

As another example, let's take a 7mm 120-grain bullet with a muzzle velocity of 3,300 fps. The velocity squared is 10,890,000 (3,300 x 3,300). Next we multiply this figure

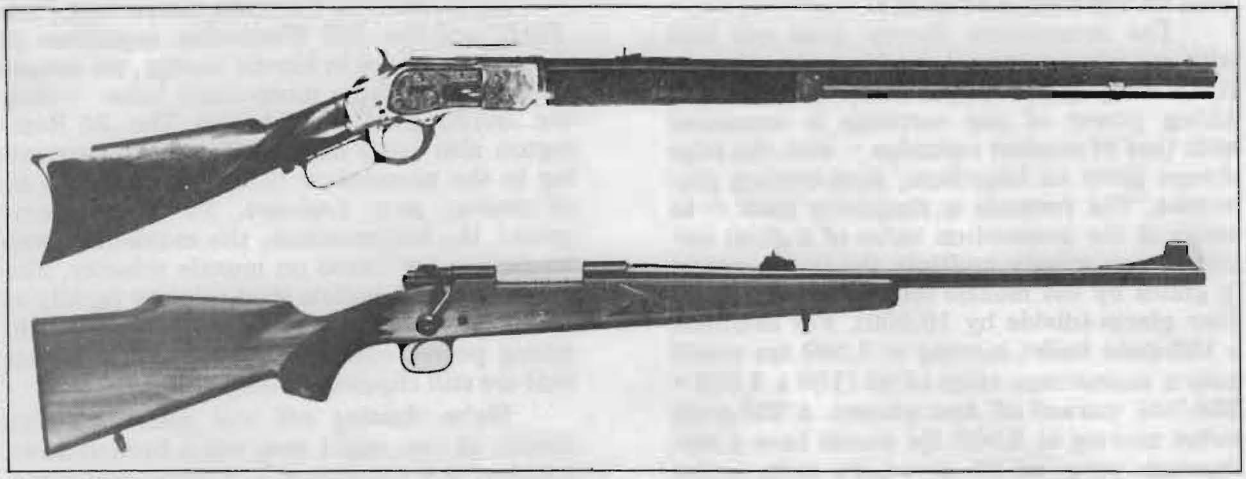


FIGURE 26 — Both of the above rifles are of .257 caliber, but there the similarity ends. The old M73 in .25-20 chambering, because of low velocity and energy, is now illegal for deer in most states. The M70, in .25/06 caliber, shoots the same weight bullets at ultra-high velocity and is capable of taking elk.

by the bullet weight (10,890,000 x 120 = 1,306,800,000). Our last step is to divide the 1,306,800,000 by the value of 450,000:

$$450{,}000 \overline{)\,1{,}306{,}800{,}000} \quad = 2{,}904$$

Checking our result against Speer, we find an answer within one foot pound of our own. Right on!

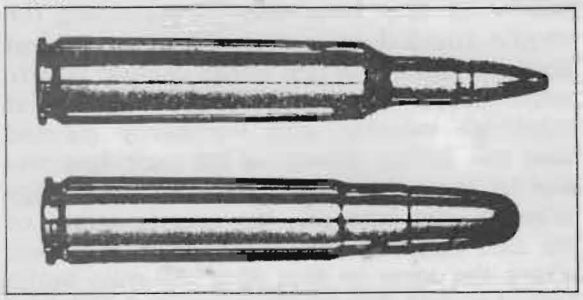


FIGURE 27 — With the kinetic or foot pounds of energy method of evaluating stopping power, bore diameter isn't important. The 6mm and .35 Remington cartridges shown have about the same muzzle energy, even though their respective calibers, velocity, and trajectory vary widely.

This formula can also be used to compute remaining energies. When the velocity is known at a down-range point, the formula is based on the velocity *at that point.* (Very soon we'll show you how to figure remaining or residual velocities.)

As you'll note, the foot pounds of energy method does not take bore diameter into consideration. We've pointed out previously that bore or bullet diameter changes drastically once a bullet impacts. However, many experts, particularly of the old school, believe that large-caliber bullets moving at slower speed have greater killing and stopping power than fast-moving, light bullets, even though the kinetic energy delivered by the fast bullet is greater. This system of evaluating killing power is known as the momentum theory.

Before going into this theory, however, 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.

PROGRAMMED EXERCISE

3

1. How much would you estimate the deflection of a .30/06 .308 180-grain spitzer SP to be at 200 yards with a 20-mph wind at 3 o'clock? (a) 1.55 inches. (b) 3.1 inches. (c) 6.2 inches. (d) 12.4 inches.

2. When you convert a 180-grain bullet to pounds, you get: (a) .026. (b) .013. (c) .046. (d) .097.

3. What is the muzzle energy of a 180-grain bullet moving at a muzzle velocity of 3,000 fps? (a) 3,000 foot pounds. (b) 3,200 foot pounds. (c) 3,400 foot pounds. (d) 3,600 foot pounds.

Answers on Page 16

THE MOMENTUM THEORY

The momentum theory does not deal with specific energy released in a given target. It is a comparative system whereby the alleged killing power of one cartridge is compared with that of another cartridge — with the edge always given to large-bore, slow-moving projectiles. The formula is simplicity itself — to arrive at the momentum value of a given cartridge, you merely multiply the bullet weight in grains by the muzzle velocity and mark off *four* places (divide by 10,000). For example, a 100-grain bullet moving at 3,000 fps would have a momentum value of 30 (100 x 3,000 = 300,000, marked off four places). A 200-grain bullet moving at 2,500 fps would have a momentum value of 50, etc. Let's make a few comparisons of various cartridges, moving bullets at standard "factory" muzzle velocities, by the foot pounds of energy and momentum value methods:

Cartridge	Bullet Weight	Muzzle Energy Ft. Lbs.	Momentum Value
.220 Swift	55	1,764	21
.30/30	170	1,827	37
.257 Whby.	100	2,878	36
.35 Rem.	200	2,000	40

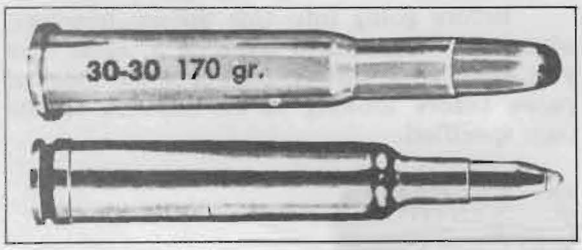


FIGURE 28 — According to the once *widely accepted momentum theory, the old .30/30 cartridge (top) was almost identical in stopping power to the fairly recent .257 Weatherby magnum (bottom).*

ANSWERS

3

1. C. The table gives a cross wind (3 or 9 o'clock) deflection for 10 mph; double it for 20 mph, so it would be 6.2 inches.

2. A. Divide 180 by 7,000 and you get .026 pounds.

3. D. ME = $\frac{180 \times 3000 \times 3000}{450{,}000}$ =

   3,600 foot pounds.

As is obvious from the above table, the .30/30 and the .257 Weatherby, regardless of the wide variance in kinetic energy, are assigned about the same momentum value — with the .30/30 given a slight edge. The .35 Remington also beats out the Weatherby, according to the momentum theory. *This theory is, of course, pure hogwash.* To further compound the ludicrousness, the momentum value figures are based on muzzle velocity. The tapered, heavy bullets shed velocity rapidly at over 150 yards, and can't begin to compare in killing power with the smaller-caliber bullets that are still clipping smartly along.

We're dusting off and presenting this theory as one might drag out a broken-down antique. It's interesting, but of no real value. Surprisingly, a large number of supposedly knowledgeable shooters still stoutly claim that the momentum theory is the best measure of a rifle's knock-down power. In the old days, before high-velocity cartridges came into being, the theory had some validity in comparing one big-bore cartridge with another. Today, comparing muzzle energy with momentum value relative to killing power is a case of comparing "apples and oranges."

HYDROSTATIC SHOCK THEORY

The phenomenon of hydrostatic bullet shock is a *theory* introduced or at least popularized by Roy Weatherby in explaining the terrific knock-down power of his then wildcat magnum rifles. The first (small-caliber) Weatherbys drove comparatively light bullets at ultra-high velocity, and Weatherby claimed that the killing power of his cartridges was due to more than the foot pounds of energy released. For example, the muzzle energy of his .257 cartridge with a 100-grain bullet was about the same as that of a 180-grain bullet out of a .308 Winchester (around 2,800 foot pounds), yet the lighter bullet usually killed much faster. The reason, Weatherby claimed, was hydrostatic shock — the violent expansion of an animal's body fluids and tissues when struck by the lightning-fast bullet. Massive hemorrhage and shock followed, which were out of proportion to the energy delivered.

Bullet velocity alone isn't responsible for hydrostatic shock. Rotational speed of the bullet is a contributing factor. In a barrel of a given twist, say 1-10, a bullet moving at 3,500 fps rotates far more rapidly than one loping along at 2,500 fps. The terrific whirling or rotational force of the bullet is also energy, literally exploding body fluids and tissues upon impact.

The phenomenon of hydrostatic shock had been observed and commented on prior to the introduction of Roy Weatherby's explanation. The .220 Swift, for example, when used in the 1930's with properly constructed bullets, proved an incredibly efficient one-shot killer on all manner of big game. The light 50 to 55-grain bullets, with a muzzle energy of under 2,000 foot pounds, were not the reason. The combination of nearly 4,000 fps velocity and terrific rotational speed (over 200,000 rpm) was undoubtedly responsible.

All modern high-velocity, small-bore cartridges, such as the .25/06, 7mm Remington magnum, .264 Winchester magnum, etc., kill as much by hydrostatic shock as by energy, in the usual sense.

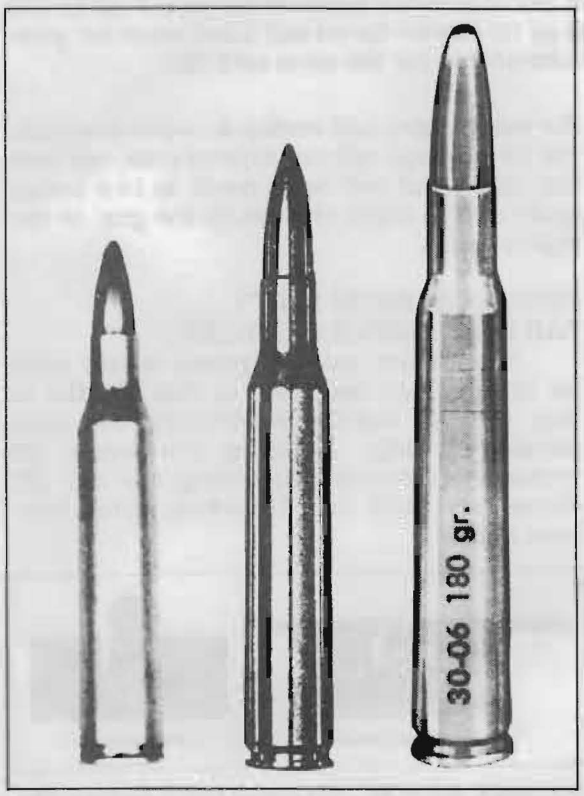


FIGURE 29 — None of the above, the .220 Swift, .270 Winchester, or .30/06, are "new" cartridges. In all, hydrostatic shock is as much responsible for lethality as the actual energy delivered to the target.

EXTERIOR BALLISTICS — HANDGUNS

The exterior ballistics of a handgun are very similar to those of a rifle as they are both rifled arms. A pistol, however, is subject to more variations of external factors as applied to projectiles because it normally uses bullets with very poor sectional density and ballistic coefficient ratings. Pistol bullets are usually short, blunt, and light for their caliber or bore diameter. The fact that most handguns have extremely short barrels compared to rifle barrel length also affects their exterior ballistics to a marked degree.

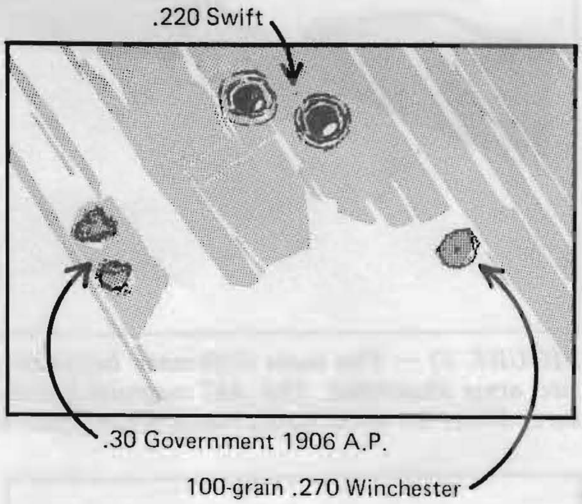


FIGURE 30 — At short range, the .220 Swift with a 48-grain bullet completely penetrated a half-inch of armor plate, while the heavier .270 and .30/06 bullets made only shallow craters. The Swift, with its faster bullet rotation, bored through like a dentist's drill.

Handguns do not attain the high velocities attained by most center-fire rifle cartridges because of lower chamber pressures and shorter barrel lengths. With the exception of a few high-pressure "hand rifles" such as Remington's bolt-action single-shot pistol firing the .221 Remington cartridge, and other comparable single-shot handguns, 1,800 to 2,000 fps is about all the velocity that can be squeezed out of a pistol, even a magnum. Handgun projectiles usually travel in the vicinity of 1,000 fps or less. Most target shooting is done with with "mid-range" loads with a velocity of 700 or 800 fps, and some are hand-loaded to the point where the shooter can actually see the bullet travel down-range.

HANDGUNS AND HYDROSTATIC SHOCK

Due to lower velocity, pistols do not have the devastating effect upon tissues of projectiles from high-velocity rifles. Most authorities agree that the minimum velocity for dependable hydrostatic shock (killing power) is approximately 2,000 fps.

Few pistols even approach this velocity, and most depend upon heavy slugs traveling slowly to more or less tear their way through the target, basing stopping power more on hemorrhage than on bullet expansion and shock.

Pistol sights, like those on rifles, permit the muzzle to be elevated to compensate for

FIGURE 31 — The main difference between rifle and pistol exterior ballistics is pointed up by the two arms illustrated. The .357 magnum pistol, because of its shorter barrel and lower chamber pressure, drives the same bullet much slower than the rifle chambered for the same cartridge.

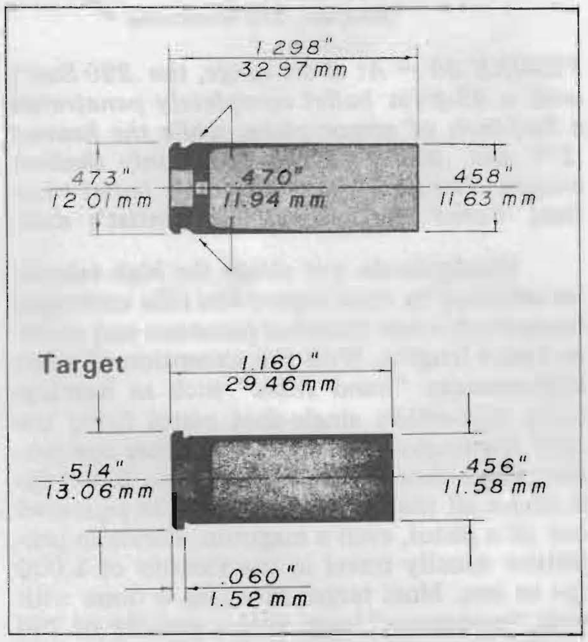


FIGURE 32 — The high-velocity .44 Auto Mag cartridge, top, is one of the few handgun loads that "stops" by energy and hydrostatic shock. The .44 long Colt bullet, bottom, relies more on massive hemorrhage to put the target down for keeps.

bullet drop. Most sight settings in pistols, particularly those used for target work, permit the shooter to hold below the target. The effect of recoil then raises the center of impact into the center of the target. For hunting, most shooters adjust their pistol sights for a so-called "dead-on" hold, in that the projectile will strike where the sights are pointed.

Since the pistol is normally held with one hand, it is much more sensitive to variations in grip (holding), sight picture, and trigger movement. Many target shooters have noted that when firing two five-shot strings at the same target, and resting in between strings, the two groups will not superimpose one over the other, but will be as much as two inches apart due to slight changes in the grip or the sight picture.

PISTOL CALIBERS DON'T PARALLEL RIFLE CALIBERS

The caliber range in pistols is very similar in the lower spectrum to that of rifles in that the .22 rim-fire is probably the most popular cartridge. There are also several .22 center-fire cartridges, including the old .22 Hornet and .218 Bee, for which pistols have been made.

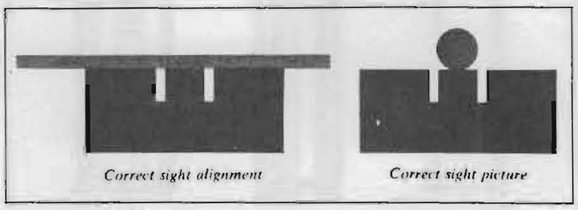


FIGURE 33 — In a handgun sight picture, the aiming point at let-off is usually 6 o'clock. Recoil then brings the bullet impact center up.

FIGURE 34 — Small cartridge rifle rounds have been used in handguns for years. The Thompson Contender shown is chambered for the old .22 Hornet.

The next bullet size is the .25, of which two cartridges are currently manufactured. One is the .256 Winchester magnum and the other is the .25 ACP.

In .30-caliber, there are no American pistols as such, although Ruger does make a revolver chambered for the .30-caliber carbine round. There are also the old .30-caliber Luger and Mauser handguns. There are various .32-caliber revolvers and automatics made today, usually chambered for the .32 ACP. Next to the .22-caliber rim-fire, the .38 Special and its longer brother, the .357 magnum, are the favorites of American handgun enthusiasts. Some of the older, obsolete blackpowder cartridges such as the .38-40 and .44-40 are well on their way out. The new .41 magnum, .44 magnum, and .44 Auto M-51 have pretty well pre-empted the large-bore handgun field, although Colt is still manufacturing their aged Model 1873 in the .45 long Colt cartridge.

HANDGUN BARREL LENGTHS

Most handguns come with a choice of barrel lengths. One must remember when reading factory ballistic charts that published velocities are usually taken with six-inch barrels. Also, ballistics for revolvers are very often taken with special barreled actions which do not allow gas to escape (as do all revolvers). Not too many years ago, a company brought out a new center-fire pistol cartridge with a published muzzle velocity of over 2,000 fps. When this cartridge was fired in the revolver for which it was designed, the company was embarrassed to discover that the bullet chronographed at only 1,700 fps. The reason was that their test gun was of solid-barrel design, which allowed no gas to escape at the juncture of the cylinder and the barrel. The gun writers had a field day with this "goof."

The velocity lost by shortening handgun barrels ranges from 50 to 100 fps per inch. Therefore, the velocity taken with a six-inch barreled .357 magnum will vary greatly from that of a two-inch barreled handgun firing the same cartridge. It's all a matter of expansion ratio, as you learned in your lesson on interior ballistics.

FIGURE 36 — An oldtimer that refused to die is the Colt M73 shown, which has had one of the longest production runs of any firearm.

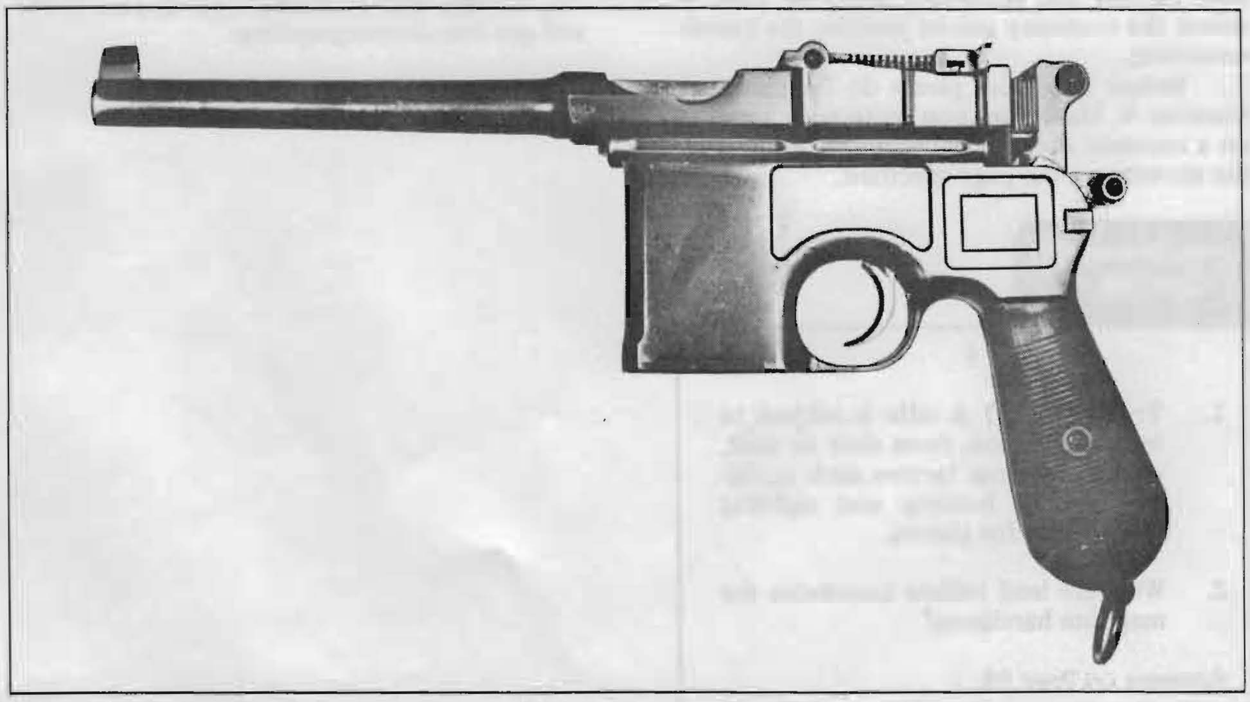


FIGURE 35 — Other than Ruger and Thompson pistols chambered for the .30-caliber carbine round, the only .30-caliber pistols are old foreign makes such as the Mauser "Broomhandle" illustrated.

HANDGUN BULLETS

Most handgun bullets are lead since they are cheaper and easier to manufacture. Such projectiles are generally unsuitable for magnum handguns because of the higher velocities and subsequent leading and melting problems. For the .357 magnum, .41 and .44 magnums, and the center-fire .22's, both half-jacketed and full-jacketed bullets are offered.

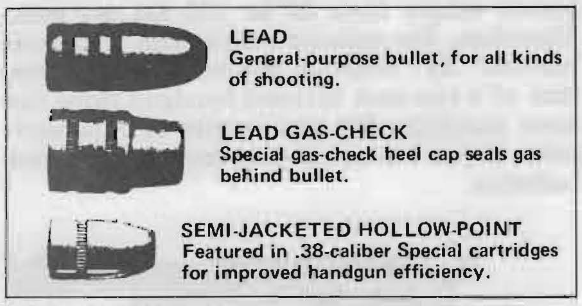


FIGURE 37 — In many given pistol calibers, bullets of the cast lead, lead with gas check, and jacketed varieties are available. The choice of bullet depends on the velocity at which it will be driven.

A velocity of about 1,000 fps seems to be about the maximum at which lead bullets, unprotected in any fashion, can be used. With the addition of a gas check, lead bullets (for handgun or rifle) can be driven at up to 1,600 fps. At moderate velocities, meaning about 1,200 fps and over, handgun barrels firing unprotected lead bullets have a tendency to lead very rapidly and shouldn't really be used — unless the economy gained justifies the barrel-scrubbing.

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.

PROGRAMMED EXERCISE

4

1. True or false? A rifle is subject to more variations, from shot to shot, due to external factors such as differences in holding and sighting than is true for pistols.

2. Why are lead bullets unsuitable for magnum handguns?

Answers on Page 22

SUMMARY

The normal flight of any bullet is in a parabolic curve. For this reason, when sighting in handguns or using handguns for anything other than measured-distance firings such as 25-yard target work, the shooter should know his bullet impact area in relation to his sight settings at the various ranges. This is particularly true if the gun will be used for hunting. Quite often the shooter will find that a sight setting which permits a 6 o'clock hold at 25 yards will, with high-velocity ammunition, give a dead-on hold at 50 yards, and show a drop of 8 to 12 inches at 100 yards. This is good information for the hunting handgunner to store away in his memory bank, as quite often he will be forced to shoot at targets at different ranges than his zero point, and to hit he must know his trajectory.

Normally, since pistol barrels are shorter than rifle barrels and operate at much lower velocity levels, the shortening of a pistol barrel does not have as much effect, proportionately, upon the bullet's striking point. Handguns are vastly affected by differences in grip (holding), changes in sight picture because of sight radius, and the lack of efficient ballistics bullet form. Also, their lower velocities contribute to a reduced or non-existent hydrostatic shock effect.

And now, with this introduction to *exterior ballistics*, we will get into a most interesting and *exact* method of determining velocity, energy, etc. in Study Unit 9, Part 2. We will get into *chronographing*.

ANSWERS

4

1. False.
2. The higher velocities of these guns cause leading and melting problems.

NOTES

NOTES

STUDY UNIT 9 – PART 2

EXTERIOR BALLISTICS – HOW TO MEASURE VELOCITIES AND DOWN-RANGE ENERGIES

TODAY'S BUFFALO BILL — NO BULL!

Picture Buffalo Bill patiently waiting for a wary bull to wander into range of his black-powder rifle; compare this scene with your vision of the varmint hunter, glassing a distant rock chuck through a 12-power scope. Different? Not entirely. The two share at least one common concern — the effective range of their respective arms. And effective range, the farthest point where a gun's trajectory and stopping power are adequate for the game and distance involved, *always depends on projectile velocity*.

As guns have become more efficient and as comparatively high-velocity *rifles* have replaced the centuries-old smooth-bore musket, ballisticians — then and now — have set their minds to finding ways and means of determining bullet velocity and *projecting* trajectory and maximum range for given guns. Probably the earliest "measurement" of velocity was simply eyeballing how far a bullet skidded into the dirt under a target at a given range. Today a refined version of this measurement, relating bullet drop to velocity, is still used, and with surprising accuracy — as you shall see a bit later.

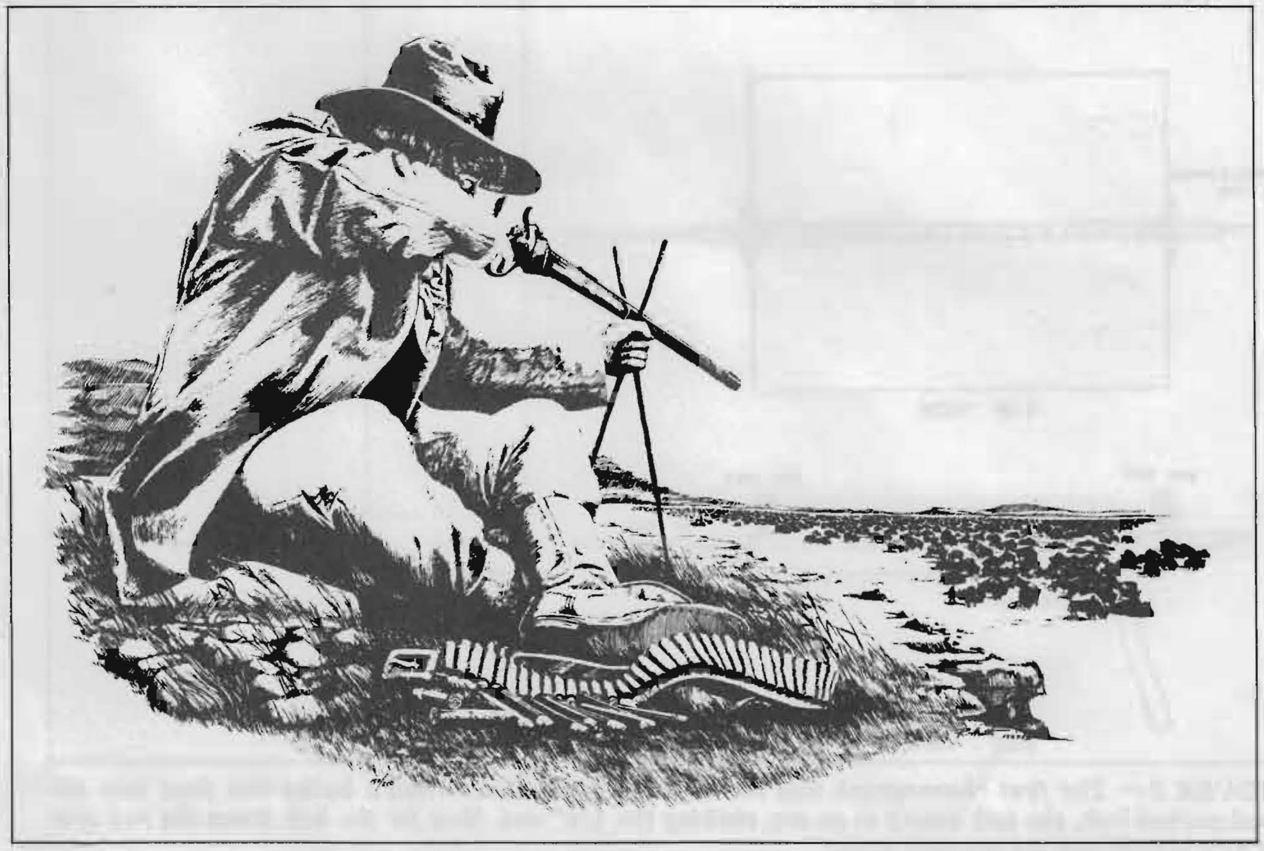


FIGURE 1 — "The Buffalo Hunter" by Robert R. Auth. Such frontier marksmen had the effective range of their rifles down to a gnat's nose, and seldom missed. (Courtesy The Rifle magazine)

THE FIRST CHRONOGRAPHS

Velocity is *always* relative to the *time* it takes for a projectile to reach its target. Thus, instruments for measuring bullet flight time (velocity) are known as chronographs, from the Greek "chrono," meaning "time." Probably the first precision "chronograph" was the ballistics pendulum invented by an Englishman, Benjamin Robins, about 1740. The pendulum's bob or weight was a heavy block of wood into which the bullets were fired. As the length of the pendulum and the weight of the bob and bullet were known, the velocity of the bullet could be calculated by measuring and timing the swing of the bob (see Figure 2).

Over the years, the ballistics pendulum was perfected to the point where it rivaled modern electronic chronographs in accuracy. However, its use was tedious and time-consuming, and the device was generally "retired" shortly after the turn of the 20th century.

THE BOULENGE CHRONOGRAPH

The first chronograph, as we know the instrument today, followed the discovery of electricity and was invented by Le Boulenge, a Belgian army officer, about 1870. Like modern chronographs, the Boulenge device relied upon the breaking of two electrical circuits to time the bullet's flight. The first circuit consisted of a thin wire which was stretched about three feet in front of the gun's muzzle — far enough away to escape the muzzle blast. When the wire was broken by the bullet, the circuit was also broken, permitting an electro-magnetized rod to start falling away from its anchor point.

The target was usually placed 100 feet distant and mounted just in front of a heavy steel plate. When the bullet struck, the plate moved to the rear, thus breaking the second circuit and allowing an electro-magnetized knife to drop and mark the still falling rod (which had a replaceable soft zinc jacket). The relative position of the knife cut on the jacket, when measured by a special rule, provided the flight time of the bullet to the target — which by further calculations produced the muzzle velocity.

THE ROTARY CHRONOGRAPH

Another early but still used chronograph was the "rotary," invented in the early 1900's. The instrument consists of an electric motor

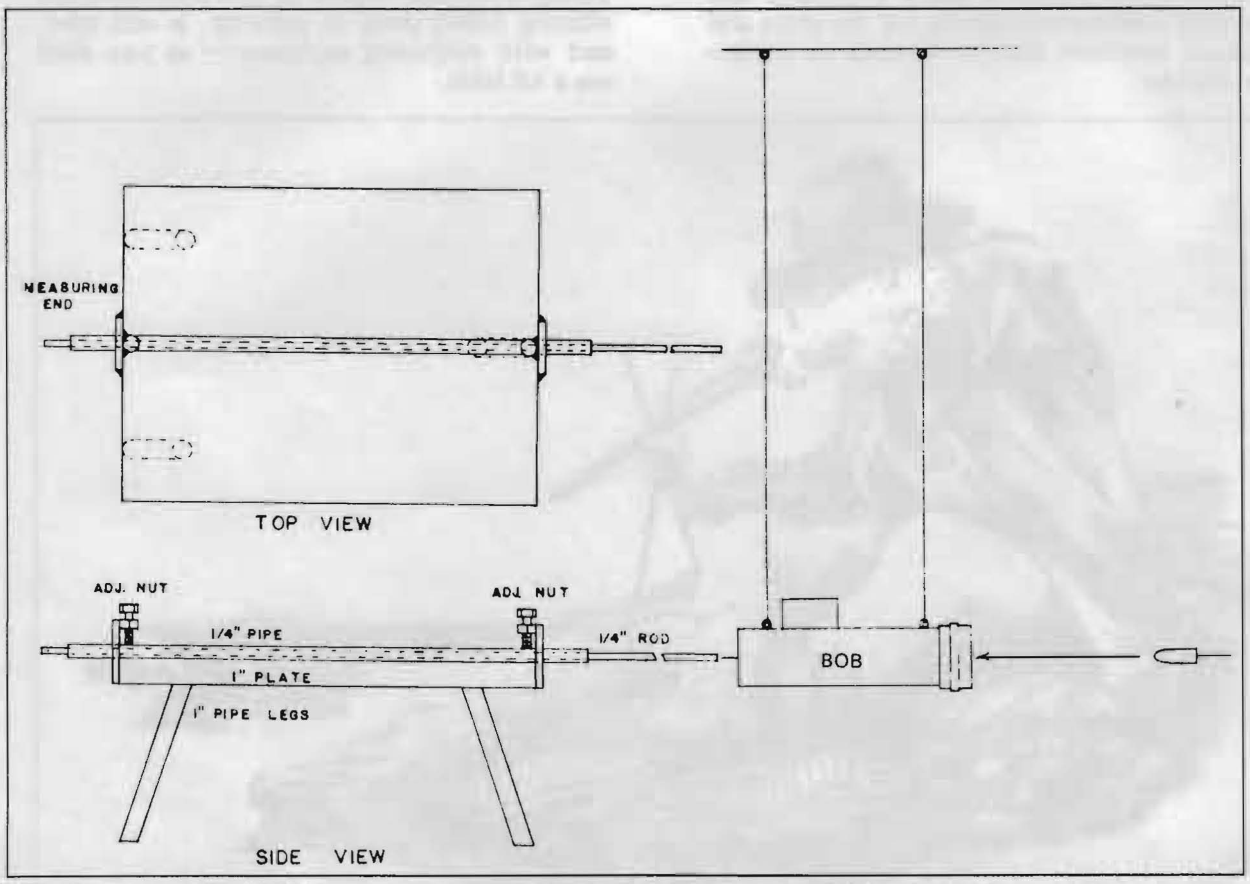


FIGURE 2 — The first chronograph was the ballistics pendulum. When a bullet was fired into the sand-packed bob, the bob swung in an arc, striking the 1/4" rod. How far the bob drove the rod into its pipe sheath was the velocity index.

with a long shaft to which are attached two paper discs of the same size. The discs are lined up with each other by index lines. When the shaft and discs are rotating, the bullet is fired through the discs. As the distance between the discs and the rotational speed of the motor are known, the space between the bullet holes, relative to the index lines, provides the means of calculating velocity. The greater the spread between the two holes, the lower the velocity; the smaller the distance, the higher the velocity. Here, the distance between the holes is related to bullet flight time, which in turn relates to velocity.

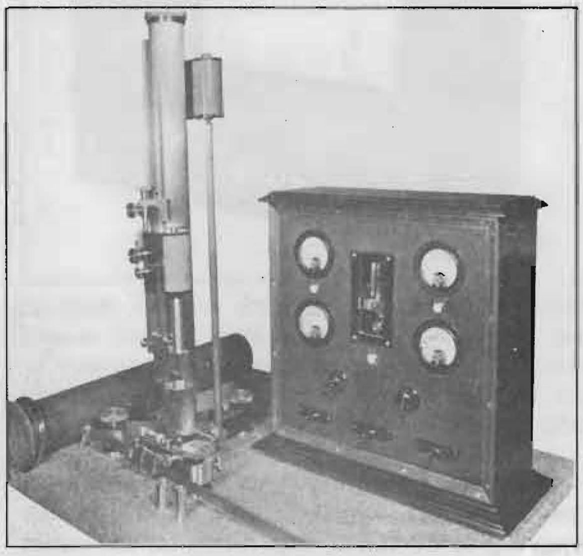


FIGURE 3 — The Le Boulenge chronograph, still in use. When the first circuit was broken by the bullet, the slender rod at the left started falling. When the bullet struck the target, a second circuit was broken, permitting a "knife" to drop on the falling rod. The relative position of the knife mark on the rod was the velocity or time index.

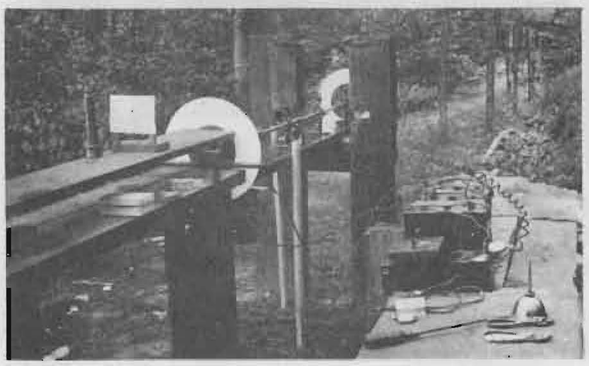


FIGURE 4 — The rotary chronograph consisted of two cardboard discs which were rotated at the same speed by an electric motor. The distance between the bullet holes in the two screens, relative to the index lines, "told" the bullet's velocity.

THE ABERDEEN CHRONOGRAPH

The Aberdeen chronograph, now over a half century old, was developed by U.S. Army ordnance personnel at the Aberdeen Proving Ground, Maryland. Like the Boulenge instrument, it records velocity by means of two electrical circuits placed a known distance apart. Unlike the Boulenge device, the Aberdeen chronograph depends on electrical circuits which are *closed*, not broken, by the bullet's passage. Each circuit or screen consists of two sheets of metallic foil separated by insulating paper. When the bullet bridges or connects the foil sheets, the circuit is closed (or completed) and current flows to a spark plug positioned immediately adjacent to a rapidly rotating drum of paper. The plug, when activated by the bullet passing through and "connecting" the screens, sparks twice and burns two small holes in the paper. The distance between the two burned holes provides the data by which bullet flight time and velocity are computed.

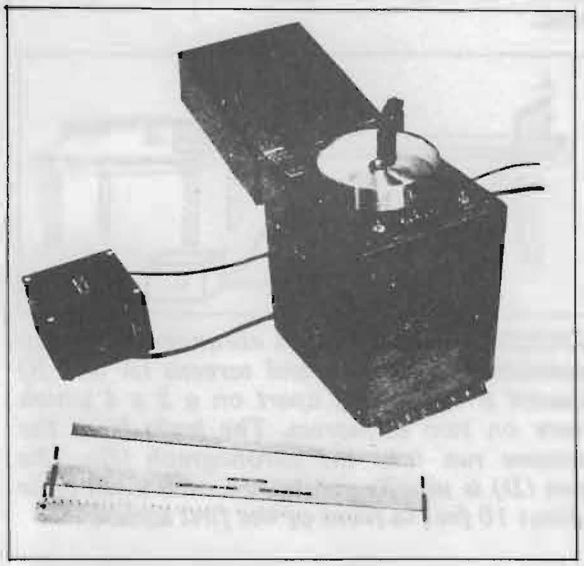


FIGURE 5 — The Aberdeen chronograph utilized a narrow strip of paper (shown next to the ruler) which was held by centrifugal force against a rotating drum within the box. The spark plug at the top "fired" when the bullet passed through the first and second screens, burning two tiny holes in the paper strip. The distance between the two burn holes was the velocity index.

MODERN CHRONOGRAPHS

Today's compact, transistorized chronographs, unlike their predecessors which were often expensive and/or cumbersome laboratory instruments, are, through modern technological and manufacturing techniques, within the reach of the serious shooter's pocketbook.

While most chronographs are used outdoors on rifle ranges, the units are so compact, and the distance required for computing muzzle velocities so short (a range of 20 to 25 feet is usually sufficient), that many shooters do their chronographing in a basement set-up — where local laws permit. The basic element of this set-up consists of a small table or rifle support, a couple of sawhorses over which a 5-foot 2 x 4 (to hold screen clips) is placed, and an old 30 to 50-gallon hot water heater which is filled with sand and placed directly behind and in line with the screens, which serves as a bullet trap. Oh, yes, one must not forget a good set of ear protectors. One shot from a bellowing magnum in the close confines of a basement and you'll never worry again about hearing loud sounds — if your ears aren't adequately protected.

We are not recommending that you establish such a set-up, as the hazards are considerable. We are only pointing out that modern chronographs make such an arrangement quite feasible, as many shooters have discovered.

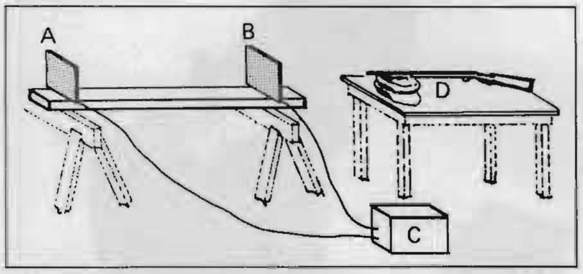


FIGURE 6 — A typical chronograph set-up consists of two clips and screens (A and B) spaced 5 to 10 feet apart on a 2 x 4 which rests on two sawhorses. The leads from the screens run into the chronograph (C). The gun (D) is usually positioned on a small table about 10 feet in front of the first screen.

DIFFERENT TYPES OF SCREENS USED

All currently produced chronographs rely upon two screens (or circuits) being placed a known distance apart and from the muzzle, with the circuits being either opened or closed by the passage of a bullet. The first screen is usually placed 10 feet from the muzzle to avoid muzzle blast (or most of it); the second screen, depending on the manufacturer, is placed 5, 10, or 20 feet from the first. In some usually very expensive instruments, photo-eye screens are used which allow the shooter to fire for velocity and accuracy at the same time (see Figure 7). Most chronographs, however, employ one-time use screens which contain a fine metallic ink or enmeshed-wire circuit. When the circuits are broken by bullet passage, the time interval between breaking of the first and second circuits, as registered by the instrument, provides the time and velocity index.

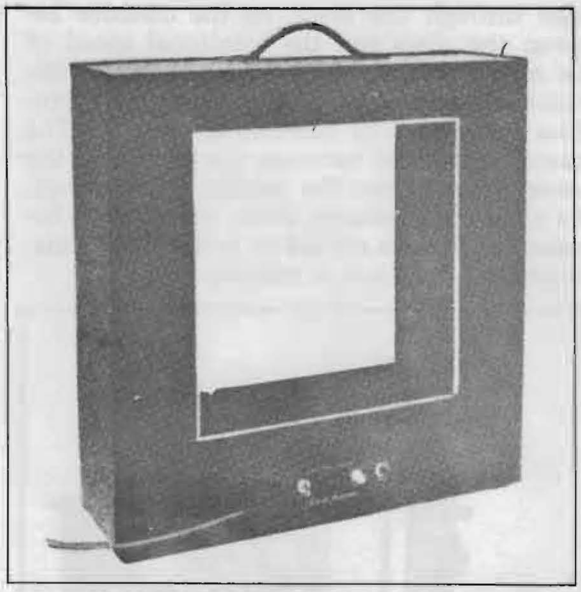


FIGURE 7 — Photoelectric screens, such as the Oehler shown, have large apertures and permit the shooter to check the accuracy of the load he is chronographing, even at fairly long range.

Other chronographs utilize reusable "poly screens" which can be fired through from 10 to 30 times, depending on the bullet caliber and screen size. Here, the time interval between closing or shorting of the first circuit and the second provides the time/velocity data.

FIGURE 8 — Digital chronographs like the Oehler Model 21 are relatively expensive, but provide a direct read-out of velocity.

Chronograph screens vary from about business card size, for close-range recording of muzzle velocities, on up to about 20" x 20" size, for chronographing velocities at 200 or even 300 yards. The less expensive chronographs, in the $125 to $150 range, provide a flight time index by means of a sequence of numbers which light up following each shot.

These numbers, when totaled, are then related to read-out figures (usually listed in a booklet) which translate the "time" numbers into velocity fps numbers. The more expensive chronographs, in the $350 to $600 bracket, are hooked up to digital computers which do the time/velocity translation, providing an instant read-out of the fps velocity after each firing.

FIGURE 9 — The Techsonics Model 65 chronograph shown costs less than $75, and uses ordinary kitchen foil as screens. "Yes" and "No" readings provide time pulse figures which, when related to handbook listings, provide feet-per-second velocity data.

Modern chronographs measure velocities as low as 250 fps on up to as high as 6,000 fps, and are used to time projectiles from air guns, pistols, shotguns, and, of course, rifles. Because of slight variations between cartridges, chronographed velocities are customarily taken on the basis of five or ten-shot averages. Tables have been worked out (see Table 1) whereby a given figure is added to the chronograph reading because of the velocity loss before the bullet strikes the first screen. In this way, *actual* muzzle velocities are determined.

Velocity Loss over 20 feet							
Instrumental Velocity, f/s.	Ingalls' Ballistic Cofficient						
	.10	.15	.20	.25	.30	.40	.50
700	6	5	4	3	2	—	—
800	8	6	4	4	3	—	—
900	10	7	5	4	4	—	—
1000	12	8	6	5	4	—	—
1100	17	12	8	7	6	—	—
1200	24	16	12	10	8	—	—
1300	30	20	15	13	10	—	—
1400	35	24	18	15	12	—	—
1500	38	25	20	16	13	—	—
1600	40	27	20	17	14	—	—
1700	42	29	21	18	14	—	—
1800	—	33	24	19	16	12	9
1900	—	34	25	20	17	13	10
2000	—	35	26	20	18	13	10
2200	—	36	27	21	18	13	10
2400	—	38	28	22	19	14	11
2600	—	39	29	23	19	15	11
2800	—	41	31	24	20	15	12
3000	—	43	32	25	21	16	12
3200	—	44	33	26	22	16	13
3400	—	46	34	27	23	17	13
3600	—	48	36	28	24	18	14
3800	—	50	37	29	25	18	15
4000	—	52	38	30	25	19	15

TABLE 1

There are other and less expensive means of calculating bullet velocity, as you will see shortly, yet an inexpensive chronograph — or access to one — is very nearly a *must* for any serious and dedicated rifleman/reloader.

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.

PROGRAMMED EXERCISE

1

1. When measuring bullet velocity by chronograph, why is the "timing of the bullet" started after the bullet has traveled a few feet from the gun, instead of right at the muzzle?

2. Why is it necessary to make a "velocity correction" when measuring bullet velocities whereby the time between a bullet passing through two screens is measured?

Answers on Page 6

THE "POOR MAN'S" CHRONOGRAPH

We are *not* suggesting that you are not rolling in dough, but the Powley High-Velocity Trajectories Chart, which you already have, is known as the "poor man's chronograph." Without expensive and complicated electronic equipment, your Powley chart enables you to calculate muzzle velocity for any modern high-powered rifle cartridge with great accuracy. You will, however, need to know the ballistics coefficient (B.C.) of your bullet, and have access to a reasonably flat firing range of at least 300 yards to employ this method.

The idea is to determine the bullet drop for a bullet of known B.C. at a known range. Once the drop is known, and related to the Powley chart, muzzle velocity can be quickly calculated.

The first thing to do is zero your rifle at an exact 100-yard distance. Adjust your sights so that you're dead-on at this range. Fire two or three shots to prove that your group center is on or close to the aiming point (it doesn't have to be exact). Next, move your target, on as horizontal a plane as possible, back to 300 yards. Leave your sights on the 100-yard setting and get the same sight picture. Fire a three or preferably five-shot group from as solid a rest as possible. Then find the approximate center of that group (see Figure 11) and measure the distance from the center of the aiming point to the center of the bullet group. Write this down as this is the drop figure you will work with.

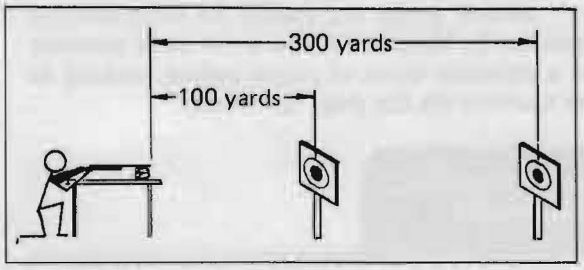


FIGURE 10 — To determine bullet drop and velocity, first fire a three to five-shot group at 100 yards. Next, move the target back to 300 yards and fire another group. With the same sight picture at both ranges, the distance between the center of the first group and the center of the second is your bullet drop at 300 yards.

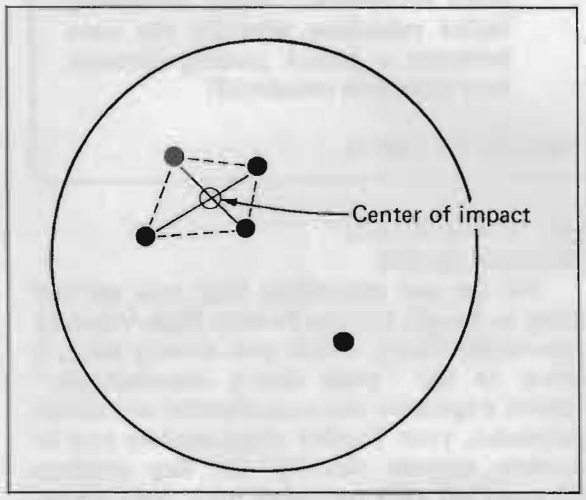


FIGURE 11 — To determine the center of bullet impact, connect the holes farthest apart vertically and horizontally with straight lines. Where the lines intersect is your "center." Disregard any "flyers" such as the bullet hole at the lower right.

You're now ready to consult your Powley chart and figure the muzzle velocity of those bullets you fired at 100 and 300 yards. If you used a scope mounted a normal 1½ inches above bore, the top horizontal line of the chart is your reference line. If you used a high-mounted scope (about 2 inches above bore), you would stretch a string from the "2.00" point at the top left of the chart straight across to the right and parallel with the top printed line. If you used iron sights, you'd stretch that string from the lower "1.00" point to the right.

ANSWERS

1

1. You can't start timing at the muzzle because muzzle blast would interfere with the timing if the first net attempted to record bullet passage too near the muzzle. It would not be a true measure of bullet flight time.

2. Some small bullet velocity is lost when the bullet *breaks through* the first screen. This loss of velocity must be calculated back into the final result.

Next, find the 300-yard vertical line on the chart and measure down from the top printed line (or string) exactly half the distance of your bullet drop figure, and pencil a dot on the chart. *You use a half measurement because the chart is to half-scale.* The location of the pencilled dot will be on or near the curved trajectory line that corresponds to your bullet. Follow this line down and to the right until it ends at the righthand vertical line. Make a pencilled dot here. Read across to the left, to the first column that shows the appropriate B.C. number of your particular bullet *opposite* the trajectory starting point. Above this figure, in the column heading, is your muzzle velocity.

Let's run through an actual example of how muzzle velocity can be determined by firing at two distances, then relating the drop data to the Powley chart. You have a scoped .270 rifle and have worked up some exceedingly accurate 130-grain loads using bullets with a B.C. of .406, but you don't know the muzzle velocity. Here is what you'd do:

1. Zero your rifle to print on at 100 yards, firing three to five shots for group center verification.

2. Move the same target back to a measured 300 yards. With the same sight setting and sight picture, fire a five-shot group from a firm support (a benchrest if possible). Allow your barrel to cool between shots.

3. Find the center of that five-shot group, then measure from the center of the target to the center of the group. Let's say this distance is 12½ inches.

4. Back at home, use the top horizontal line on your Powley chart as your reference line because your scope is mounted a conventional 1½ inches above bore. Measure 6¼ inches (half of the 12½ inches) down from the top horizontal line, on the 300-yard vertical line, and make a pencilled dot at this point which intersects trajectory curve number 34 (see Figure 12).

5. Find the starting point of trajectory curve number 34 at the lower right-hand portion of the chart. Directly to the left of the number 34 starting point, and in the third column, locate ".40," which closely corresponds to the .406 B.C. of your bullet. Directly above this figure, in the column heading, is the muzzle velocity — 2,900 fps (see Figure 13).

THE SPEER BALLISTICS CALCULATOR

The Speer ballistics slide rule, which you also have, is most useful in determining remaining or residual velocities at various distances from the muzzle. And when velocity at a given range is known, bullet energy at that point can quickly be determined — either mathematically by the formula explained in Part 1 of this study unit or by use of the "quick-conversion" bullet energy table you've previously worked with.

The Speer calculator also enables you to compute bullet drop for bullets of known B.C. at all ranges. However, these drop figures are based on the axis of the bore being parallel to the ground and to the force of gravity. They do *not* take the various zero points into consideration. This feature of the computer is most useful in *comparing* the drop of one bullet to another. It is *not* practical from a hunting or shooting standpoint, where drop is always compensated for by tilting the barrel upward. In other words, any drop figure shown by the computer is a straight-line drop, which is quite different from the drop you'd experience at 300 to 400 yards with the rifle zeroed in at 200 or 250 yards.

Calculating Bullet Drop

To calculate straight-line drop at a given range, you have to know the velocity of the bullet and its ballistics coefficient. As an example, let's figure the drop of a 150-grain bullet (caliber doesn't matter) moving at a muzzle velocity of 3,000 fps, and with a B.C. of .387 at 300 yards.

The first step (see Figure 15) is to line up the B.C. (.387) with the range in yards (300). Adjacent to the second computer opening, below, you find your muzzle velocity, and opposite this figure an angled line bearing an ".01" designation. This line, the Value of Ingalls "A," represents the trajectory curve or value for a bullet with a B.C. of .387 and a muzzle velocity of 3,000 fps at 300 yards (see Figure 15). Now turn the computer over.

Again line up the B.C. (.387) with the range in yards (300). Find the Value of Ingalls "A" (.01) in the scale at the bottom of the opening. Above this figure is the mark corresponding to a drop of 20.8 inches for your 150-grain bullet at 300 yards (see Figure 16). As you see, computing the drop for any bullet at any reasonable range can be done in moments once the B.C. of that bullet and its velocity are known.

Calculating Remaining Velocities

Determining the residual energy or killing power of a bullet at various distances from the muzzle can be quickly and easily done with the Speer ballistics calculator, once the muzzle energy and bullet B.C. are known. As we have pointed out, the higher the B.C., the greater the velocity retention and, of course, the remaining energy or knock-down power.

To illustrate how remaining velocities are determined, let's say we are working with a 7mm Remington magnum bullet weighing 139 grains. It has a B.C. of .390 and the muzzle velocity is 3,300 fps. By using our quick-conversion bullet energy table, we have calculated the muzzle energy at 3,355 foot pounds. We want to know the remaining velocity (and energy) at 400 yards. Our procedure is as follows:

1. Set the range in yards, 400, opposite the top black arrow (middle window). Above the ballistics coefficient number of .390, you see that the "Factor Z" value is about 3050 (see Figure 17). Factor Z represents the "resistance" or "delay" value of a bullet of a given B.C. over a given distance. Jot down "Factor Z, 3050."

2. Reset the computer so that the mark corresponding to a muzzle velocity of 3,300 is opposite the black arrow in the bottom window. Find the Z factor of 3050 on the scale at the bottom. Above this line is the line indicating that your remaining velocity is 2,300 fps (see Figure 18).

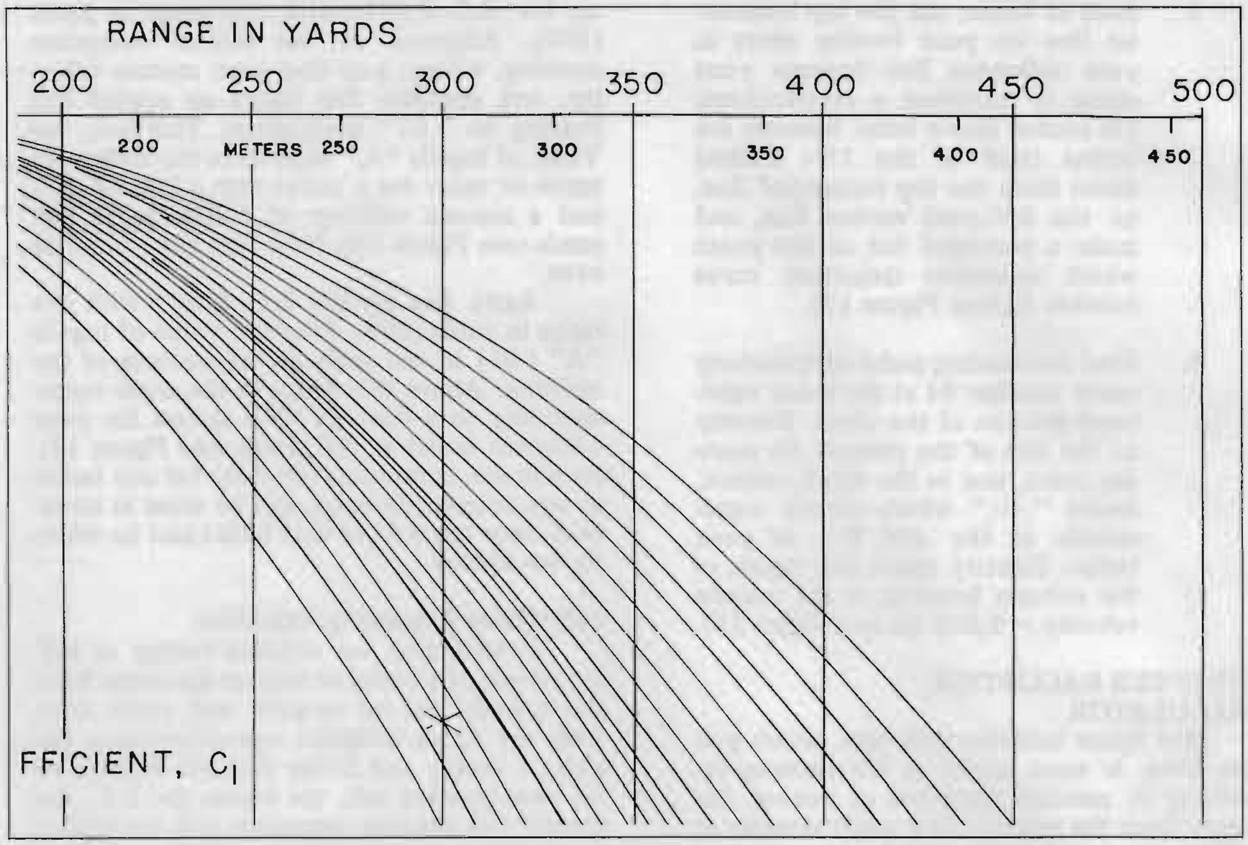


FIGURE 12 — On the vertical 300-yard line, measure down half the distance of your 12.5" bullet drop, or 6.25". Make a light pencil mark here (see above). Then trace the trajectory curve back to its starting point near the lower right corner of the chart.

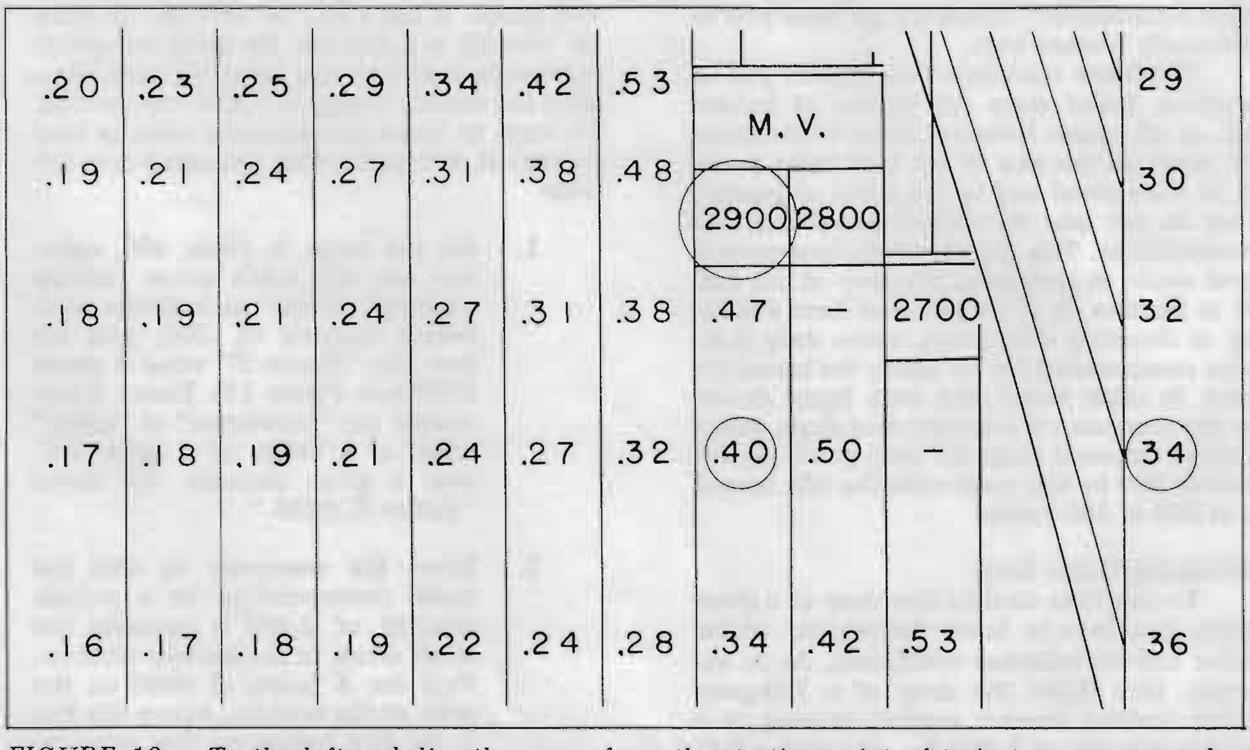


FIGURE 13 — To the left and directly across from the starting point of trajectory curve number 34, find the approximate B.C. number of your bullet (.40). Directly above this number and in the column heading is your velocity (2,900 fps).

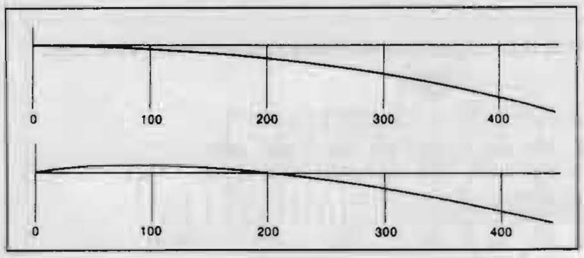


FIGURE 14 — Drop figures obtained with the Speer ballistics calculator are relative to a straight-line drop with the bullet's line of departure parallel to the ground and to the force of gravity (top drawing). A rifle is normally zeroed at 200 (bottom drawing) or 250 yards, so the drop is much less at 400 yards than the calculator indicates.

3. To compute the *energy* relative to this 2,300 fps figure, turn to your bullet energy table and find the value for 2,300, which is 11.74 per grain of bullet weight. By multiplying this 11.74 value by the weight of your bullet (11.74 x 139), you discover that your bullet energy at 400 yards is 1,632 foot pounds.

Remaining velocities and energies can be as quickly determined for all other bullets at all other ranges.

Complicated? Yes. But it will *become* simpler for you if you *stick with it and work with it.* And it really doesn't take that long to become familiar with your Speer calculator.

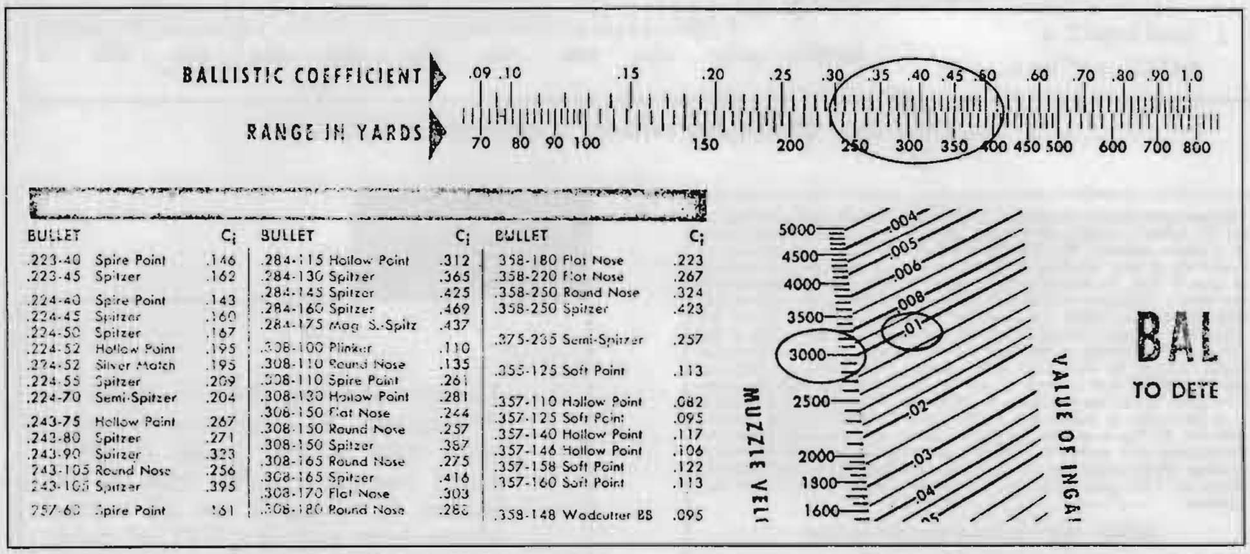


FIGURE 15 — Line up the B.C. (.387) with the range in yards (300) to get a muzzle velocity of 3,000 fps.

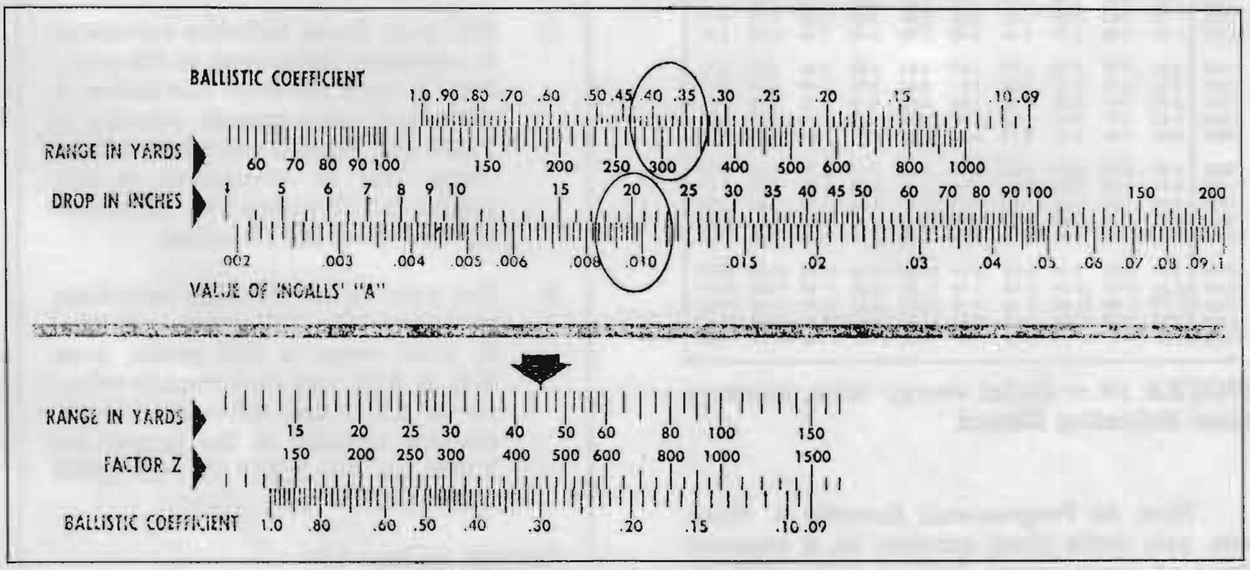


FIGURE 16 — Drop is 20.8 inches.

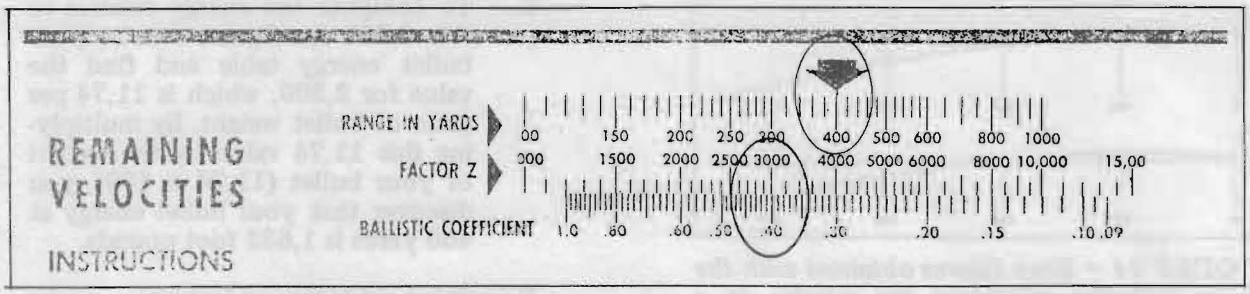


FIGURE 17 — With a range of 400 yards, you will get a "Factor Z" of 3050.

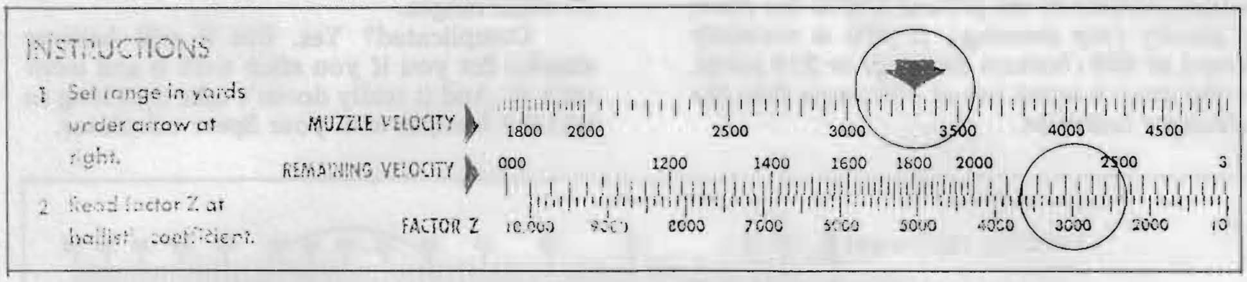


FIGURE 18 — Remaining velocity is indicated as 2,300 fps.

Following are factors developed by computer which, when multiplied by the bullet's weight, determine the amount of energy produced at a given velocity. The left-hand column of figures is velocity in hundreds of feet; the figures across the top of the tables is velocity in tens of feet. To illustrate the use of the tables let's imagine that we have a 150-grain bullet with a velocity of 2500 fps. You would then locate the 2500 figure in the left-hand column. Since the velocity is in exact hundreds of fps the factor will be found in the column immediately to the right numbered 00. By multiplying this factor, 13.88, by the weight of the bullet, 150 grains, we find that we have 2082 foot pounds of energy. Now suppose that the same 150-grain bullet has a velocity of 2540 fps. To determine this factor it is necessary to locate the 2500 figure in the left-hand column and the 40 figure at the top of the tables. By scanning down the 40 column and across the 2500 row of figures we find the factor number which intersects the two columns, 14.32. Multiplying this factor by 150 grains we find the bullet energy to be 2148 foot pounds.

ENERGY PER GRAIN OF BULLET WEIGHT

Vel fps	00	10	20	30	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
500	55	58	60	62	65	67	70	72	75	77
600	80	82	85	88	91	94	96	99	1.02	1.05
700	1.08	1.11	1.15	1.18	1.21	1.24	1.28	1.31	1.34	1.38
800	1.42	1.45	1.49	1.53	1.56	1.60	1.64	1.68	1.72	1.76
900	1.79	1.83	1.87	1.92	1.96	2.00	2.04	2.08	2.13	2.17
1000	2.22	2.26	2.31	2.35	2.40	2.45	2.49	2.54	2.59	2.63
1100	2.68	2.73	2.78	2.83	2.88	2.93	2.99	3.04	3.09	3.14
1200	3.19	3.25	3.30	3.36	3.41	3.47	3.52	3.58	3.63	3.69
1300	3.75	3.81	3.86	3.92	3.98	4.04	4.10	4.16	4.22	4.29
1400	4.35	4.41	4.47	4.54	4.60	4.66	4.73	4.79	4.86	4.93
1500	5.00	5.06	5.13	5.19	5.26	5.33	5.40	5.47	5.54	5.61
1600	5.68	5.75	5.82	5.90	5.97	6.04	6.12	6.19	6.26	6.34
1700	6.41	6.49	6.57	6.64	6.72	6.80	6.88	6.95	7.03	7.11
1800	7.19	7.27	7.35	7.43	7.51	7.60	7.68	7.76	7.84	7.93
1900	8.01	8.10	8.18	8.27	8.35	8.44	8.53	8.61	8.70	8.79
2000	8.88	8.97	9.06	9.15	9.25	9.33	9.42	9.50	9.60	9.70
2100	9.80	9.90	9.98	10.07	10.17	10.26	10.36	10.45	10.55	10.65
2200	10.74	10.84	10.94	11.04	11.14	11.24	11.34	11.44	11.54	11.64
2300	11.74	11.83	11.95	12.05	12.16	12.26	12.37	12.47	12.58	12.68
2400	12.78	12.90	13.00	13.11	13.22	13.33	13.44	13.55	13.66	13.77
2500	13.88	13.99	14.10	14.20	14.32	14.44	14.55	14.67	14.78	14.89

FIGURE 19 — Bullet energy table, courtesy Speer Reloading Manual.

Now 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. Use your Powley chart to calculate this answer. At benchrest, you zero your rifle at 100 yards. At 300 yards you get a bullet drop of 14 inches. Your sights are 1½ inches above bore and the B.C. of your bullet is .340. What is your muzzle velocity? (a) 2,900 fps. (b) 3,000 fps. (c) 3,100 fps. (d) 3,200 fps.

2. Use your Speer ballistics calculator to complete the answer in this problem. If your ballistics coefficient is .390 and your muzzle velocity is 3,000 fps, what is your bullet drop (from line of departure) at 250 yards? (a) 12 inches. (b) 14 inches. (c) 16 inches. (d) 18 inches.

3. Use your Speer ballistics calculator to answer the following question. If your range is 300 yards, your B.C. is .410, and your muzzle velocity is 2,900 fps, what is your remaining velocity at the target? (a) 2,000 fps. (b) 2,225 fps. (c) 2,500 fps. (d) 2,750 fps.

Answers on Page 12

ANSWERS

2

1. Measure 7 inches down from the top line of the chart at the 300-yard line. Follow the curve intersected to the point where it ends at the lower right part of the chart. Draw a horizontal line to the left until you intersect the ballistics coefficient of .340. You are in the 2,900 fps muzzle velocity column. Therefore, (a) is the correct answer to this problem.

2. Line up B.C. .390 with 250 yards on Side 1 to get Ingalls Value "A" of .008. On the other side, line up 250 yards with a B.C. of .390 and read drop in inches at Ingalls Value "A" of .008. You get 14 inches, therefore (b) is the correct answer.

3. Set the arrow at the 300 range in the middle window. Read the Z factor at a ballistics coefficient of .410. You get a Z factor of 2200. Set a muzzle velocity of 2,900 fps at the black arrow in the bottom window. Read the remaining velocity at "Factor Z" of 2,200. You get 2,225 fps, therefore the correct answer is (b).

STUDY UNIT 9 – PART 3

RIFLE BARRELS – DESIGN AND MANUFACTURE

IS LEAD-FEATHERED LEAD BETTER?

The concept of a rifled bore, one that would spin a projectile for point-on concentricity and better accuracy than could be provided by the smooth-bore musket, undoubtedly stemmed from the arrow. The first arrows didn't have feathers and more or less wandered toward their targets. Then somebody dreamed up the idea of adding feathers and setting them at a slight angle to the axis of the arrow. The feathers constituted the "rifling," and with the angled plumes the arrows flew straight and true.

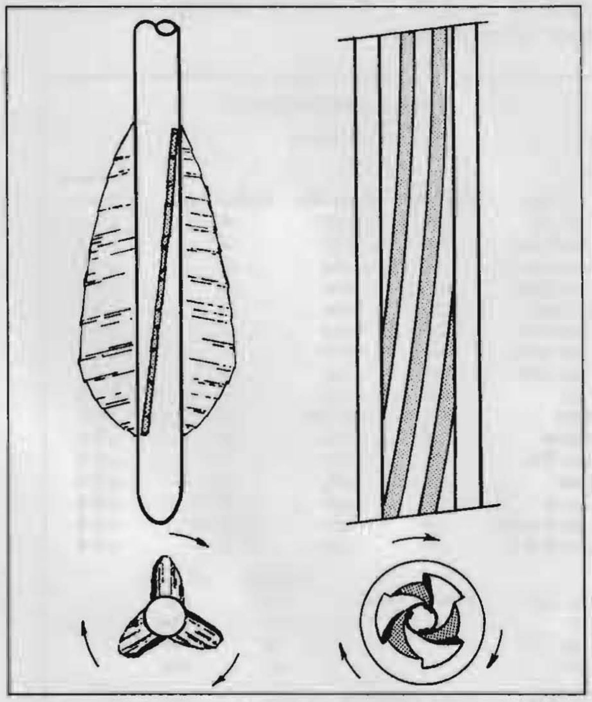


FIGURE 1 — The feathers of an arrow, which are slightly canted to the shaft's axis, constitute exterior "rifling." Many of the first rifles, with the rifling constituting interior "feathers," had three and sometimes only two grooves.

The first "ballisticians," in their attempts to impart rotation to projectiles, tried vaned bullets. They didn't work because gas escaped up the sides, between the vanes. The obvious solution was "reverse" vanes, or rifling, and the first rifled bores were developed in Europe in the 16th century. In the U.S., the first example of the true rifle was the Kentucky or Pennsylvania long arm which evolved in the early 1700's.

The first rifle barrels, like Damascus shotgun barrels, were manufactured by winding and forging a series of thin metal strips, called skelbs, around a mandrel which gave the tube its bore diameter. After the barrel was formed, the mandrel was pulled out and the barrel was ready for rifling.

The relatively crude rifling machines of the time consisted of a small, sharp knife or bit attached to a wood bar with an indexing guide, which permitted the bit to cut a curved groove of a specified barrel length. After one cut or pass was completed, with the muscle-powered rotating bit pushed forward through the bore from the breech, the wood bar was shifted to the next index point and the second cut was made. Barrels of the time incorporated anywhere from two to six grooves, depending on the patience and ability of the gunsmith (gun-making blacksmith), and took from two to three days of painstaking labor.

Then, as now, the bore diameter corresponded to the caliber designation, and the groove diameter (the distance from the bottom of one groove to the bottom of its opposing groove) to the bullet diameter. Today, for example, a .30-caliber barrel has a bore diameter of .300". The groove diameter is .308", meaning that each groove and its opposing groove is .004" deep, the rifling lands .004" high. The bullet is .308" in diameter, which causes the rifling or lands to "engrave" themselves into the bullet. The result is a tight gas seal between the bullet and the bore (see Figure 3).

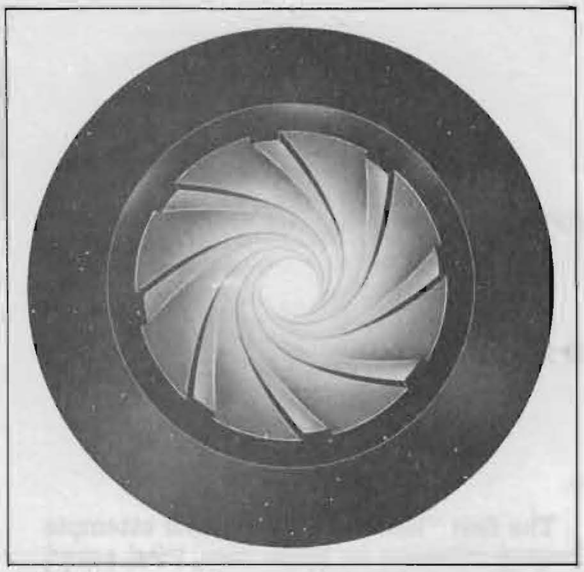


FIGURE 2 — Rifling is formed in several different ways within a bore, and the number of grooves may vary. Most rifles have four-groove bores; others, like Marlin products, may have as many as the eight grooves illustrated.

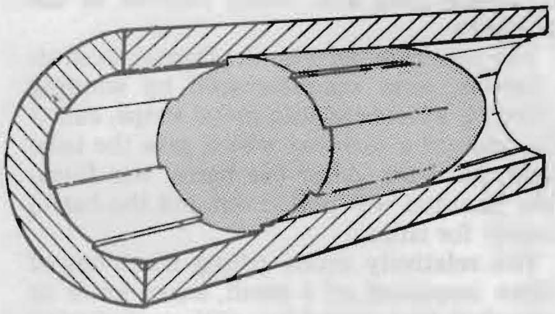


FIGURE 3 — Bullet diameter is almost always nearly the same as a barrel's "groove-to-groove" diameter. The raised lands or "rifling" cut into the bullet, thus creating a tight gas seal.

BARRELS START OUT AS BILLETS

All rifle barrels start life as *billets* — long, rectangular blocks of steel which are rolled and cut to the desired length by the steel mill and usually sold by the pound. Sometimes, for economy, billets are ordered slightly smaller than will be the largest or chamber portion of the finished barrel. To bring the chamber section up to size, the steel is heated and softened at the appropriate end, then "bumped" with heavy machinery until sufficient metal has been displaced or forced outward to accommodate the desired chamber dimensions. In other instances, billets large enough to contain the chamber area are purchased. This eliminates the "bumping," but does result in considerable waste by weight of the steel.

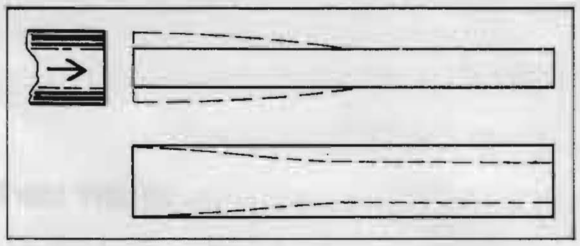


FIGURE 4 — Barrel billets are sometimes "bumped" to increase diameter to proper chamber diameter; at other times billets are ordered to chamber diameter, then machined down — resulting in considerable steel waste.

When the billet is of the correct dimensions to permit working to the desired barrel size, the squared piece of steel is then "hogged off" or roughly rounded for the next step — deep-drilling of the blank to the appropriate bore diameter. Here, the barrel rotates against and then around a long drill with a V-shaped groove running down its axis. One side of the V is slightly raised and serves as the cutting edge. A small hole through the length of the drill permits lubricating oil to spray under pressure into the cutting area as the drill moves through the bore. This oil also drives metal fragments and chips into the V groove where they do not interfere with the further cutting of the drill. With the specialized machinery used for this operation, the average time required to drill a barrel of average length is about 30 minutes.

BARREL SPECIFICATIONS

P. O. ACKLEY

Caliber	*Bore Dia.*	*Groove Dia.*	*Rifling Twist*	*Number of Grooves*
.22 L.R.	.217	.223	16"	4 & 6
.22 Hornet	.219	.224	14"	4 & 6
22/3000	.219	.224	14"	4 & 6
219 Zipper	.219	.224	14"	4 & 6
.22/250	.219	.224	14"	4 & 6
.220 Swift	.219	.224	14"	4 & 6
.228 Ackley	.220	.226	10"	4 & 6
.250/3000	.250	.257	14"	4 & 6
.257	.250	.257	10"	4 & 6
6mm	.236	.242–.243	10"	4 & 6
6.5mm	.256	.263	10"	4 & 6
.270 Win.	.270	.277	10"	4 & 6
7mm	.276	.284	10"	4 & 6
.30-06	.300	.308	10" & 12"	4 & 6
.300 H & H	.300	.308	10" & 12"	4 & 6
.375 H & H	.368	.375	10" & 12"	4 & 6
		6 Groove	4 Groove	
.22 Cal.	Width of Lands	.028	.043	
.25		.032	.049	
.270		.035	.053	
.30		.039	.059	
.22 Cal.	Width of Grooves	.084	.129	
.25		.096	.147	
.270		.105	.159	
.30		.117	.177	

TABLE 1 — Barrel specifications, courtesy P. O. Ackley.

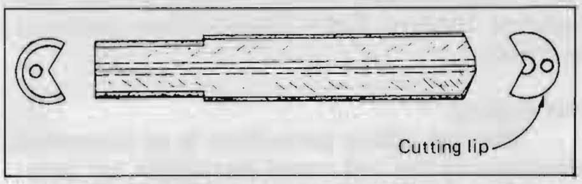


FIGURE 5 — Typical bore drill bit. The V-shaped cutting head cuts on one circular edge only. The oil forced through the hole in the axis of the bit and out the cutting head flushes metal particles down the V groove and out of the bore.

STRAIGHTENING THE BARREL

Following the drilling operation, and irrespective of the quality of the tools and workmanship, most barrels require a bit of straightening. The barrel is placed in a special clamp or jack, slowly rotated, then sighted through by a craftsman whose ability and finely tuned sensitivity to even minor variations can be compared to that of a master violin maker (see Figure 6). Slight deviations in straightness create slight shadows within the lighted bore. As the barrel rotates and a shadow edges into view, the workman applies pressure at that point with the jack until the shadow disappears. Some barrels require a good deal of time in this operation, which is the reason the most accurate barrels cost more money. The quality of the steel has little to do with the final cost.

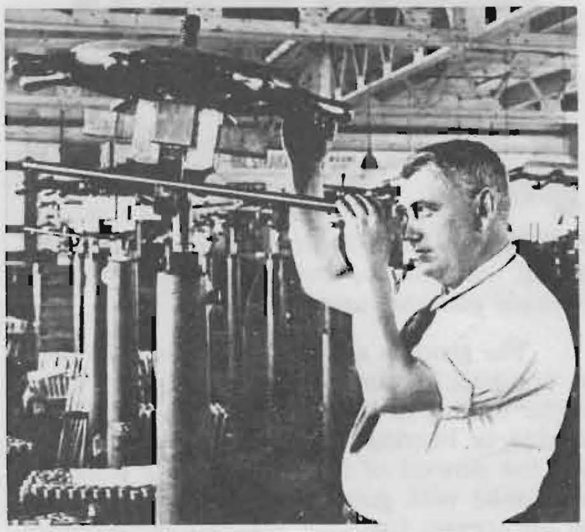


FIGURE 6 — Barrels are checked for straightness, and straightened where necessary by means of this jack-pressure machine.

After straightening, the outside of the barrel is machined to assure that the exterior taper is perfectly concentric with the bore. If the thickness of the metal around the bore isn't of equal thickness at all points, then that barrel will produce poor accuracy.

FIGURE 7 — In the days of yore, crooked barrels were straightened by pounding the barrel against lead blocks with a lead hammer.

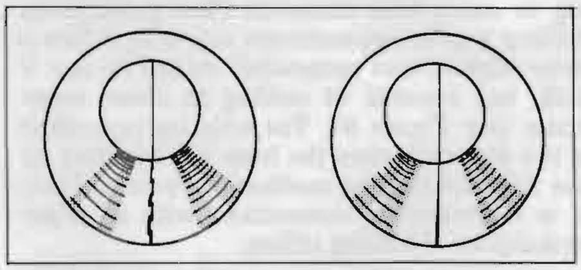
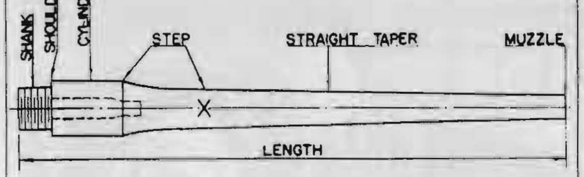


FIGURE 8 — By viewing a thin, perpendicular rod through the bore, the shadow cast by the rod reveals the condition of the bore. In the drawing at the left, the jagged shadow line "tells" that the barrel is out of alignment; the right drawing, showing a straight shadow line, illustrates a perfect barrel.

The machining of the bore exterior is always done on a lathe. The amount of metal removed determines the taper and the ultimate weight of the barrel (see Table 2). Large-bore barrels usually incorporate a very slight taper, as do barrels made exclusively for target work. (Some "bull gun" barrels have no taper at all.) Sporter barrels usually have pronounced tapers, in the interest of saving weight. The chamber area, regardless of barrel weight or taper, always incorporates plenty of steel as a safety hedge. Modern cartridges generate high pressures, and the greatest stress is exerted against the steel cocoon surrounding the cartridge.

SPORTER BARRELS



Weight Type	Caliber	Cylinder Diameter	Length to Step	Diameter at Step	Muzzle Diameter	Length
Minimum	.22	1.03"	2.5"	.625"	.40"	22"-24"
Light	.22	1.0625	2.5	.687	.50	24 -26
Standard	.22	1.125	3.0	.750	.55	24 -26
Minimum	.25	1.0625	2.5	.650	.45	21-23-24
Light	.25	1.0625	3.0	.750	.50	21-23-24
Standard	.25	1.125	3.0	.800	.60	24 -26
Minimum	.270	1.100	2.5	.750	.50	23 -24
Light	.270	1.100	3.0	.775	.55	24
Standard	.270	1.125	3.0	.800	.60	24
Minimum	.30	1.100	2.5	.775	.50	22 -24
Light	.30	1.100	3.0	.800	.57	22 -24
Standard	.30	1.125	3.0	.850	.625	24 -26
Heavy	.30	1.250	3.0	1.000	.650	26 -28
Standard	.35-375	1.250	3.0	1.000	.650	24 -26

TABLE 2 — courtesy Roy F. Dunlop's "Gunsmithing."

BARREL REAMING AND RIFLING

Once a barrel has been drilled, straightened out, and contoured, it is ready for reaming to exact bore diameter. (The preliminary drilling was to approximate size only.) This is done with a tool somewhat similar to the V drill, but capable of cutting to closer tolerances (see Figure 9). The reaming procedure is not required when the bore will be rifled by the hammer-forging method, as you will see; it is necessary in connection with all other techniques of cutting rifling.

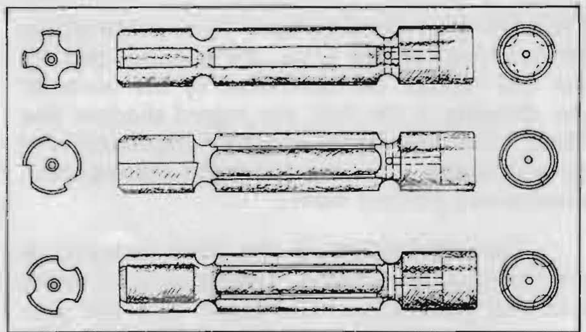


FIGURE 9 — Barrel bore reamers. From top: four-flute roughing reamer; six-flute finishing reamer; six-flute burnishing reamer. All the reamers illustrated have front pilots, a hole through the axis for the delivery of cutting oil, and clearance flutes on the rear pilot for chip passage.

Today there are four basic methods of forming the rifling with a barrel. They are cut rifling, button rifling, broach rifling, and hammer forging. Let's discuss these methods in detail.

Cut Rifling

The cut rifling procedure is an improved variation of the old wood bar/single bit technique. Modern cut rifling machines, like their colonial counterparts, hold the barrel in a fixed position. The old wood bar is now called a sine bar which, depending on its angle of adjustment, determines the pitch or ratio of the twist. A single cutting head, rotating at a predetermined speed, is introduced into the bore. After one shallow groove (usually .002") is cut, the barrel is rotated or indexed 90° (in the case of four-groove rifling) and the cutter is placed in position for another cut. The procedure is repeated until four shallow grooves have been completed. The cutter is then readjusted for a deeper cut to achieve the desired total groove depth (usually .004"), and four more passes are made.

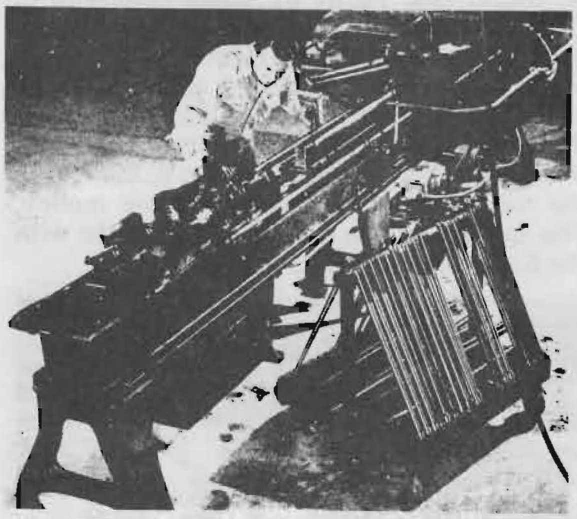


FIGURE 10 — A Pratt & Whitney universal rifling machine, of the type used by many firearms manufacturers.

The grooves are not cut to the full depth in one pass because of the probability of the cutter dulling or breaking and the barrel steel tearing or burring. The cut rifling process is still the slowest of all. When proper tools are combined with good workmanship and steel of the correct hardness, superlative barrels result. Rejections are high, and a *fine* cut-rifled barrel usually produces better accuracy than barrels rifled by any other method.

Button Rifling

Button rifling is probably the fastest, and therefore the least expensive, method of forming rifling. As a result, the button process is the most widely used today by the rifle manufacturers and by most custom barrel makers.

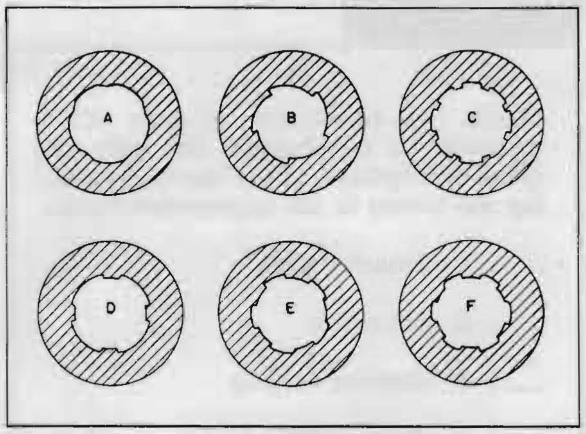


FIGURE 11 — Types of rifling used currently and in the past: A, segmental rifling of the type used by Charles Newton; B, experimental elliptical rifling (not used on any production arms); C, multi-band rifling once used in match rifles firing lead bullets; D, modern four-groove rifling; E, British five-groove rifling as found in the Enfield service rifle; F, modern six-groove rifling.

The highly polished carbide "button" resembles a bullet with vanes; the vanes are forcing, not cutting, edges. The button is simply forced through the bore; the vanes, being harder than the barrel steel, form corresponding grooves or rifling by compressing the barrel steel. If the bore-diameter hole is of a uniform dimension from one end to the other, and the steel is of uniform hardness throughout, the result is a rifled bore unsurpassed for smoothness and lack of friction between bullet and bore. Good-grade button-rifled barrels therefore never require lapping for final smoothness. When there are slight variations in bore diameter and steel hardness, the button tends to displace metal unevenly, resulting in a rough bore at these points and subsequent accuracy and fouling problems.

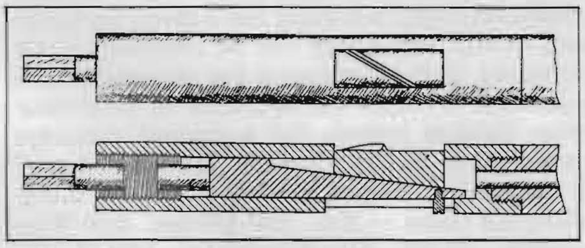


FIGURE 12 — Old scrape-type cutter, of the type used in the past to cut relatively soft steel. Top view cross-section shows how the cutter "threads into" the bore, cutting a single groove at a time. Bottom view shows how cutter is adjusted by screw-actuated wedges.

Broach Rifling

Like the button rifling method, broaching completes the job of forming the rifling with one pass of the tool. Also, like the button, the broach is forced through a stationary barrel..However, unlike the button, the broach is a tapered, multi-edged cutting tool. When "screwed" or rotated into the bore, the comparatively low cutting edges at the front of the broach make a shallow cut. As the broach progresses forward, the height of the tapered cutting edge increases, cutting a correspondingly deeper groove. Thus, when the broach has passed completely through the bore, the barrel is rifled.

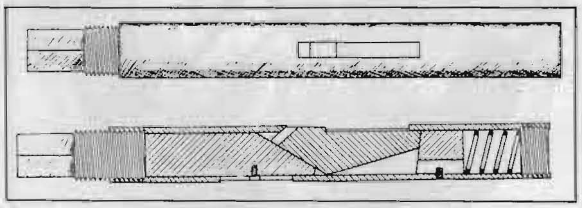


FIGURE 13 — Top and sectional view of modern hook-cutter rifling head. This type of cutter is also adjusted by means of wedges which raise or lower the cutting head to the desired degree.

The quality of a broach rifling job depends largely on the sharpness of the cutting edges and on the quality of the barrel steel. Here, soft-softs can really cause problems, and "tearing" of the bore interior to the point where the barrel has to either be discarded or rebored to a larger caliber.

Hammer Forging

The newest method of imparting rifling to a bore is the hammer forging or cold swaging process, developed in Europe during World War II. No American rifle manufacturer employs this system, although many rifles made in other countries for export to the U.S. utilize hammer-forged barrels. Included, among others, are the German-made Apollo and Weatherby rifles.

In the hammer forging method, a roughed-out barrel drilled to the approximate bore diameter is slipped over a mandrel which incorporates the rifling in reverse. A rotary hammer arrangement, traversing the length of the barrel, then pounds against the barrel with tremendous force, impressing the rifling grooves into the bore and actually hardening the steel. The hammer marks on the exterior of the barrel produce a distinctive "wavy" pattern (see Figure 15) which is machined and polished away.

The hammer forging method is extremely fast and produces quality barrels. Here, as in other processes, if the barrel steel isn't of perfectly uniform hardness, rough spots occur which, if not too serious, may be removed by lapping or polishing the barrel's interior.

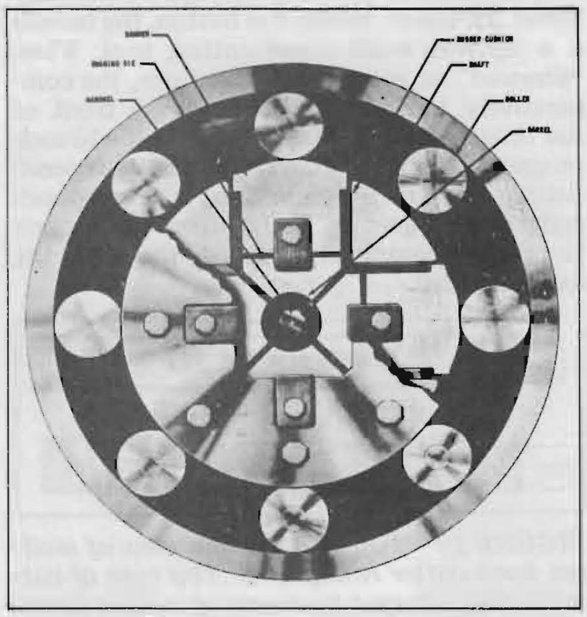


FIGURE 14 — Schematic drawing of hammer-forging machine. When the cammed surfaces of the hammers rotate under the rollers, nearly half a million pounds of squeezing action is exerted against the barrel. This pressure also "stretches" a 20" blank to over 24 inches.

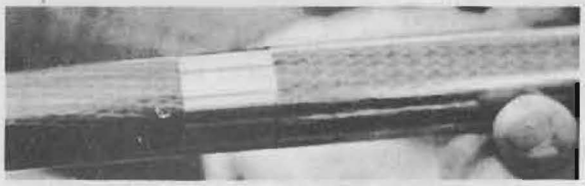


FIGURE 15 — The impact of the swaging hammers creates a distinctive "wavy" pattern on the barrel exterior, which is then smoothed on a lathe. The center section of the above barrel has been machined for a "before and after" comparison.

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.

After a barrel has been drilled, reamed, and rifled, it is usually "normalized," as it's called, through heat-treating. By placing the barrel in a special oven and heating it to a predetermined degree (dependent upon the type of barrel steel used), the possibility of that barrel warping after heating up from firing is virtually eliminated. In other words, the stresses induced into the steel at the time of the rolling process of the mill, and in the various machining operations, are neutralized by the "normalizing."

PROGRAMMED EXERCISE

1

Match the description of bore rifling methods in the bottom list with the name descriptions in the top list by placing the letters in the appropriate blanks.

_____ 1. Broach rifling

_____ 2. Cut rifling

_____ 3. Hammer forging

_____ 4. Button rifling

A. With this slow process, superlative barrels result. Rejections are high, but these barrels produce better accuracy than any other barrel.

B. A tapered, multi-edged cutting tool is *screw-forced* through a stationary barrel.

C. The fastest and least expensive method of rifling, and most widely used today.

D. This is the newest method of rifling, a cold-swaging process developed in Europe during World War II. Not used in America.

5. Briefly describe the two methods by which billets are first processed in the barrel-making operation.

Answers on Page 8

The barrel is then carefully checked for flaws. If none are found, that barrel is then chambered and threaded for a given cartridge and action. Or it may not be chambered and threaded if it is intended for shipment to a gunsmith or small manufacturer or fabricator who finishes barrels for a desired cartridge and action. If, for example, the blank barrel is .30-caliber, it may be chambered for many different cases — the .300 Savage, .308 Winchester, .30/06, .300 Winchester, .300 Weatherby, etc. — plus an infinite number of wildcats.

CHAMBERING AND THREADING

Two steps are involved in chambering, both of which are done on a lathe. A rough reamer or drill of the approximate chamber size is used to remove most of the metal from the chamber area. After this "roughing out" has been completed, a sharp finishing reamer is introduced into the rough chamber. This precision tool then cuts the chamber to the precise specifications of the cartridge case, including the shoulder angle and the throat. If the rifle is to be free-bored to specifications previously determined, the finishing reamer also cuts away the free-bored area, thus removing the required amount of rifling to provide a throat or free-bore of the desired length.

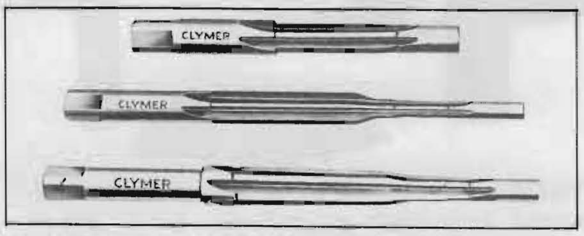


FIGURE 16 — Chamber reamers, like the Clymer tools illustrated, come in two types: roughers with four or six flutes for preliminary cutting, and six-flute finishers for final cutting. They also have detachable throaters so the chamber and throat can be cut at the same time.

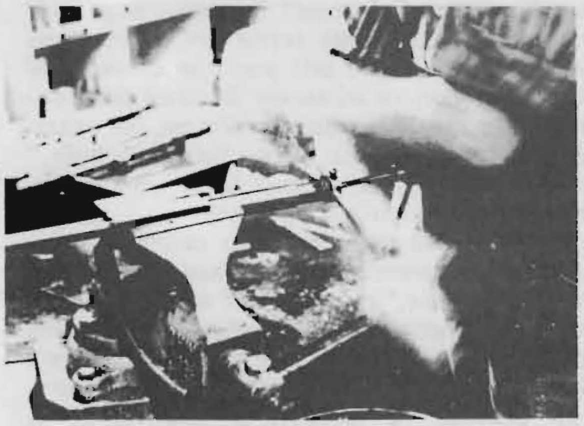


FIGURE 17 — Military rifles with hammer-forged barrels often have the chamber formed on a mandrel. Sporting rifle chambers are always cut by hand, as shown above.

Various types of threads, to match up with various types of receivers, are sometimes incorporated. Manufacturers, of course, thread their barrels for their particular actions. Barrel-makers producing barrels for the trade may or may not incorporate threads. One batch of barrels may be threaded for the popular Mauser action; another batch may be left blank as the gunsmiths for whom these blanks are intended may use the barrels with a variety of different actions — each of which has its own thread specifications.

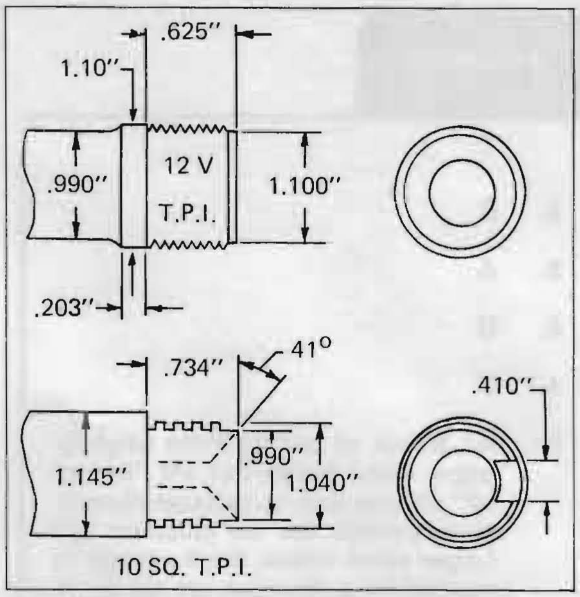


FIGURE 18 — Barrel shank specifications differ among the various and popular rifles. For this reason, barrel blanks are not normally threaded. The gun pro usually does his own threading, and for a particular action. Examples are: top, U.S. Springfield M1903, 1903A3-A4; bottom, Winchester 54 and 70.

POLISHING AND BLUEING

The last step in barrel manufacture, by gun-making firms, is polishing and blueing. As you will soon learn, the quality of any blueing (or blackening) job depends on how well the barrel is polished prior to its baths in the degreasing and blueing tanks. Minor scratches and machine marks are, of course, an abomination under any type of blueing. A quick, once-over-lightly polishing job results in a dull or near-matte finish; a highly polished barrel makes possible a glossy finish in which you can see your face reflected. The depth or darkness of the blueing depends on how long the barrel remains in the blueing tank.

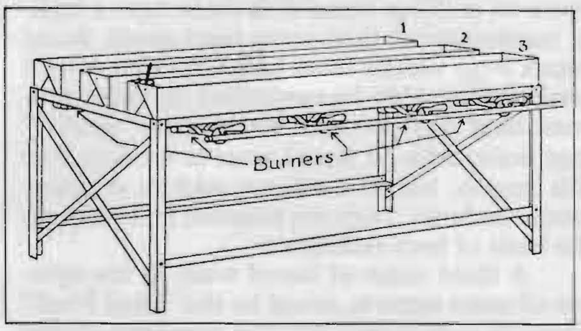


FIGURE 19 — A three-tank blueing set-up, as shown, is advantageous when doing a fair volume of blueing. The first tank is for degreasing, the second for rinsing, and the third for blueing. Burners are mounted under the first and third tanks.

ANSWERS

1

1. B

2. A

3. D

4. C

5. (a) Billets of approximate (slightly larger than) barrel size are "bumped" on one end to increase diameter to provide for the chamber. (b) Larger sized billets, large enough to provide for a chamber, are cut down to size, which results in excess metal waste.

For a perfect blueing match of action and barrel, the blueing, in nearly all instances, takes place after the barrel has been joined to the action and headspaced.

Barrels shipped to gunsmiths and small manufacturers are always shipped in the white, unless chambered and threaded. Even in these instances, the barrels are sent out in the white unless the customer orders otherwise.

TYPES OF BARREL STEELS

The type of steel used in rifle barrels always represents a compromise between resistance to erosion and ease of machining. Surprisingly, harder steel barrels don't necessarily "wear out" more slowly than softer steel barrels. The hardness of a steel depends on its composition and alloy ratio, while erosion or "wear" primarily depends on the steel's resistance to melting. Some soft steels have a higher melting point than some hard steels. Scant barrel wear results from bullet friction, which could presumably be controlled by bore hardness. Heat and pressure are the twin "debills" that contribute to barrel wear or erosion. For this reason, barrel steels are seldom of maximum hardness. They are selected primarily on the basis of heat resistance.

A third cause of barrel wear, in the opinion of some experts, *could* be the "sand blast" effect of unburned large-stick powder particles when driven into the chamber's throat under tremendous pressure. As incomplete powder burning most often occurs in high-velocity, large-case, small-bore magnums of low expansion ratio, and such rifles are notorious for rapid barrel burn-out, the "sand blast" theory may be valid — to some extent anyway. It follows that the use of slow-burning spherical powders, when possible, and harder than normal barrel steel, would reduce the "sand blast" erosion factor. In any event, no conclusive tests have been made. The theory has been neither proved nor disproved.

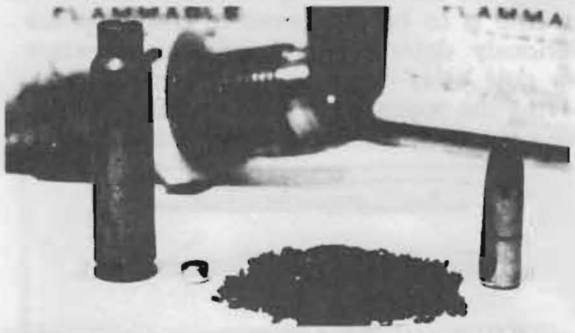


FIGURE 20 — Some experts believe that unburned large-stick propellants, when driven into the chamber throat under tremendous pressure, cause erosion through a "sand blast" effect.

Various manufacturers have come up with high-sounding trade names, or simple generic terms such as "chrome moly," "tungsten," or "nickel steel" in describing their barrel material. These terms are meaningless because they don't tell you the *amount* of chrome, nickel, or whatever the steel mix contains. The smallest trace of chrome, for example, can justify the term "chrome-moly," which sounds great, even if there isn't sufficient chrome to harden a pretzel.

All barrel manufacturers order steel by specification numbers which assure the same quality or "mix," regardless of which mill processes the order. The specification numbers are always prefaced by the letters SAE (Society of Automotive Engineers), ASME (American Society of Mechanical Engineers), or AISI (American Iron and Steel Institute), which mean that the numbers which follow, designating a given type of steel, meet the requirements for that type of steel as laid down by these societies.

Thus, any steel identification number always starts out with the appropriate letters, followed by four digits. The first digit refers to the family of steel, the second to the percentage of the alloy, and the third and fourth to the amount of carbon contained — which is the primary hardening agent. See Table 3.

As Table 3 indicates, there are six general families of steel, ranging from (1), carbon steel, to (6) chromium vanadium steel. Within these families are subdivisions or steels of varying alloy content.

Family	Type of Steel	Numerals and Digits
1	Carbon Steels	1xxx
1	Plain Carbon	10xx
1	Free Cutting, (Screw Stock)	11xx
1	Manganese Steels	13xx
2	Nickel Steels	2xxx
2	3.50% Nickel	23xx
2	5.00% Nickel	25xx
3	Nickel-Chromium Steels	3xxx
3	1.25% Nickel, 0.60% Chromium	31xx
3	1.75% Nickel, 1.00% Chromium	32xx
3	3.50% Nickel, 1.50% Chromium	33xx
4	Corrosion-and Heat-Resisting Steels	30xxx
4	Molybdenum Steels	4xxx
4	Carbon-Molybdenum	40xx
4	Chromium-Molybdenum	41xx
4	Chromium-Nickel-Molybdenum	43xx
4	Nickel-Molybdenum	46xx and 48xx
5	Chromium Steels	5xxx
5	Low Chromium	51xx
5	Medium Chromium	52xxx
5	Corrosion-and Heat-Resisting	51xxx
6	Chromium-Vanadium Steels	6xxx
6	1% Chromium	61xx

TABLE 3 — Barrel steel table, originated by P. O. Ackley.

During World War II, most Springfield barrels were made of SAE 4140, meaning that the steel was in the molybdenum family (4), had a chromium content of 1%, and had 40 points of carbon — meaning that the carbon content was four-tenths of 1%.

A barrel using steel of an SAE 2340 designation shows that the steel is in the nickel (2) family, contains a nickel percentage of 3%, and has a carbon content of 40 points.

Today, however, nickel or nickel/chromium steels (Families 2 and 3 respectively) are seldom used for rifle barrels because of the difficulty in machining. The majority of barrels are made from SAE or AISI 4130 to 4150, meaning that the carbon content varies from 30 to 50 points.

Stainless Steel Barrels

Some manufacturers and shooters swear by stainless steel barrels, particularly for use with such highly erosive cartridges as the .220 Swift and the various large-capacity, small-bore magnums. The belief is that stainless steel greatly increases barrel life. However, in the opinion of P.O. Ackley, one of America's leading gunsmiths and a North American Schools faculty member, this isn't so. Mr. Ackley has had long and extensive experience in reboring "shot-out" barrels, and he claims that stainless and alloy barrels wear out after approximately the same number of shots. Of course, the intensity of the cartridges involved, and whether the shots were fired rapidly or at intervals, have as much or more to do with the wear factor of any barrel than the type of steel involved.

In any event, it appears that any slight advantage of stainless steel is more than offset by the high initial cost and the problems involved in reblueing or touch-up work. Stainless steel barrels cannot be reblued in the normal, relatively inexpensive manner. They must be stripped of the old blueing, replated with an iron oxide, then reblued. Also, it is extremely difficult to rechamber or otherwise rework such barrels.

The merits of stainless steel for rifle barrels, in the opinion of most knowledgeable experts, exist largely in the imagination of firearms advertising writers.

.22-Caliber Barrels

Rifles of .22-caliber rim-fire design require barrel steel of much milder or softer characteristics than do center-fire rifles. Pressures and velocities are so low that .22 rifles, even though used in shooting galleries, seldom shoot out their barrels. (Some retain accuracy even after half a million rounds have been fired!) The softer steel utilized is not only cheaper, but it is easy to machine — which is a major reason for the relatively low price of most .22 rim-fire rifles.

BARREL VIBRATION AND ACCURACY

Barrel vibration and its effect on accuracy is something that has intrigued and challenged shooters for decades. As you know, a barrel vibrates like a tuning fork when the bullet races through the bore. Uneven dampening of that vibration, such as is caused by a pressure point at only one side of the barrel, can seriously impair accuracy. One can't really stop a barrel from vibrating; the vibration can only be controlled by barrel weight and/or pressure.

A leading ballistician, the late F. W. Mann, calculated that to eliminate all vibrations in a barrel chambered for the .22 Short, the barrel would have to weigh 300 pounds. Such a rifle, while unquestionably impressive with its wheels, springs, and shooter's seat, would be somewhat impractical.

Yes, weight can help control vibration, which is the reason most long-range target rifles incorporate massive or "bull" barrels and weigh upward of 30 pounds. Paul Mauser, the famous gun designer, attempted to control barrel vibration by means of step-tapering which, if nothing else, resulted in untold hours of work by generations of customizers intent upon "smoothing out" those ugly steps. How well Mauser's principle worked is open to conjecture. It would appear that the problems involved in correctly bedding a stepped barrel more than offset any advantages.

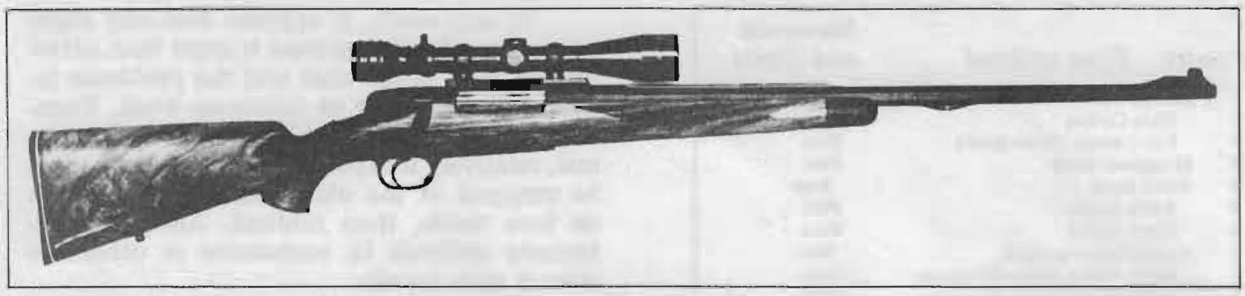


FIGURE 21 — Fine custom rifles, like the Champlin illustrated, are often offered with optional stainless steel barrels. Whether such steel actually prolongs barrel life is a matter of opinion.

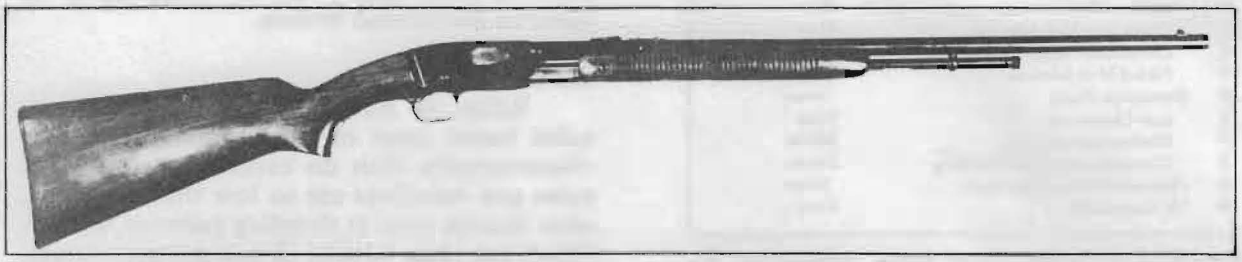


FIGURE 22 — Old .22's, like old soldiers, seldom "die." Erratic accuracy usually results from lead fouling, not "wear." Some shooting gallery .22's, like the Remington 121A shown, shoot well after more than half a million rounds.

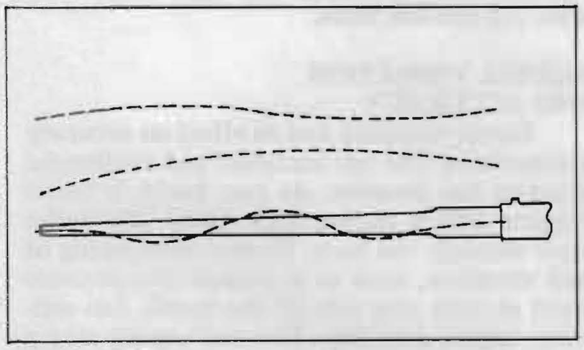


FIGURE 23 — Barrel vibration in ultra-high-velocity rifles is normally in the S-shaped curve shown at the top (exaggerated for emphasis); the higher the velocity and the longer the barrel, the "sharper" the curve. This shock wave results in barrel whip, horizontal and vertical, as shown by the lower dotted lines.

Today the accepted means of controlling or dampening barrel vibration is through pressure or lack of pressure. Free-floating barrels often shoot fine with no pressure at all; at other times, a free-floating barrel provides better groups when a pressure point at the forearm tip bears against the barrel.

On the other hand, P. O. Ackley has stated that by the time a barrel starts vibrating, the bullet is long gone, and that accuracy depends primarily on the straightness and quality of the barrel itself. Another factor which bears on accuracy, and that has nothing to do with bedding, pressure, or barrel weight, is the appetite of a given rifle for given loads.

Very often a rifle that scatters bullets all over the target (spewing them out like a mouthful of too-hot chili beans) will settle down and group its bullets close as quail when the diet is to that gun's liking. In other words, you might discover that a maximum or near-maximum load in a temperamental magnum delivers fist-size groups at 100 paces. Before fussing around with the bedding, make up a few test loads with the powder charge two to four grains under what produced the eye-blinking "accuracy." Very often that same rifle, delighted with its new load, will deliver minute of angle groups. In short, a lot of time is spent trying to adjust bedding and pressure to a given "hot" load, when the solution for accuracy is simply to adapt the powder charge to the rifle.

REVOLVER BARRELS

Modern revolver barrels are usually bored from a solid-forged billet of steel. Such forgings, as in the case of the Smith & Wesson, not only provide material for the barrel itself, but also for the barrel lug on the bottom, and sometimes for the sights. After reaming and rifling, the same as for rifle barrels, the exterior of the forging is machined to shape.

Other barrels, usually those found in inexpensive revolvers, are not forged at all. The small barrel billet is hogged down, reamed and rifled, then turned on a lathe to true up the exterior dimensions. Dovetails are then cut

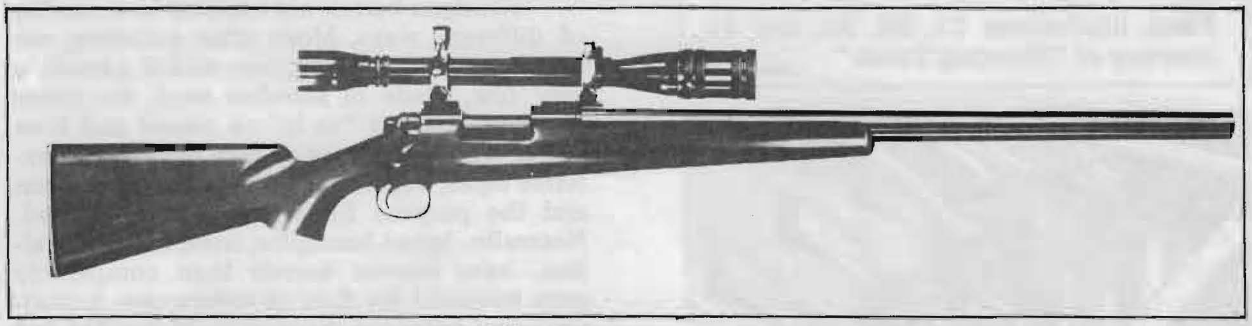


FIGURE 24 — Target rifles such as the Remington 40-XB invariably have heavy barrels to help dampen vibration and reduce barrel whip.

FIGURE 25 — "I don't believe it!" Often a miserable bullet grouping is due more to the rifle's dislike for a particular load than to problems in bedding. Check several different loads before fussing with the barrel channel and pressure points.

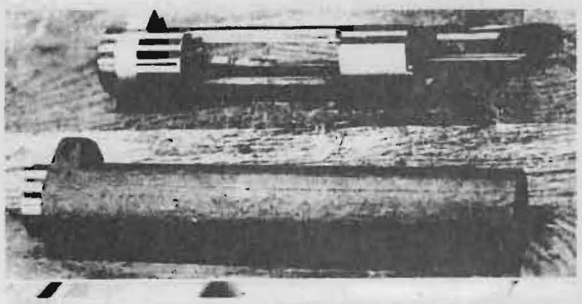


FIGURE 26 — Revolver barrels, like the rifle receiver shown above, are usually bored from a solid billet of steel. External appurtenances (like the recoil lug at left) are formed during the forging process.

crosswise to accommodate the sights, or the sights are simply silver-soldered into place.

The barrels of good-quality revolvers are attached to the receiver or frame by matching threads, the same method used in most rifles. They do not, of course, incorporate chambers; however, the rear portion of such barrels is belled or bored slightly oversize to permit easy entry of the bullet from the cylinder into the rear of the barrel.

The revolver barrel usually has a shoulder which butts against the front edge of the frame, and the barrel is screwed into the receiver up to its shoulder. Quite often, to position the front sight perpendicular to the barrel, a small amount of metal must be removed from the barrel shoulder.

Also, after the barrel is installed, the gap between the front edge of the cylinder and the back edge of the barrel must be gauged; if necessary, to bring this gap within acceptable tolerances (usually .005"), a varying amount of metal must be removed from the rear of the barrel.

FIGURE 27 — Threaded and in-the-white barrels are first rough-fitted, as shown in this S&W factory photograph. They will later be checked for headspace and polished prior to blueing.

SEMI-AUTO HANDGUN BARRELS

Barrels for autoloading handguns are a bit more complicated in that they incorporate the chamber in the rear portion of the barrel. The barrel for the Colt .45 M1911, for example, is turned to diameter on a lathe after the interior has been reamed, rifled, and chambered. Locking slots are then machined into the barrel, and any exterior appurtenances (such as the barrel shrouds) are built up by welding and shaping. Other external parts are brazed into place.

Pistol, illustrations 27, 28, 29, and 30 courtesy of "Shooting Times."

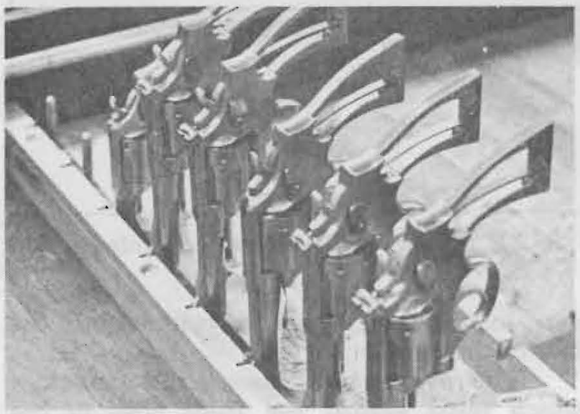


FIGURE 28 — The last stage in revolver manufacture is usually the fitting of hardwood grips. Here, a group of S&W M29's await this final fitting operation.

MANUFACTURING METHODS SIMILAR

While the basic operations of boring, reaming, rifling, and chambering are the same for pistol and rifle barrels, the former are much easier and much less expensive to make. Also, handgun barrels can utilize less expensive steel because the pressure and erosion factors in pistols are considerably less potent than those resulting from center-fire rifle cartridges. Even magnum handguns, such as the .41 and .44 magnums, do not require barrels of high tensile strength and great resistance to heat. Most of the pressure involved in revolvers is confined to the cylinder chamber or charge hole. In automatic pistols, the chamber lies within the barrel. Here again, however, the low pressures sparked by low-intensity loads don't require steel of the strength and composition necessary for center-fire rifles.

FIGURE 29 — On special order, better grade revolvers like the S&W .44 magnum are available with the owner's initials engraved and filled with gold.

Handgun barrels are finished in a number of different ways. Most, after polishing, are blued; a small number are nickel plated; a very few, made of stainless steel, are either polished and left "as is" or plated and then blued. The barrel may or may not have an exterior taper, depending on the style of the gun and the purpose for which it will be used. Normally, target handguns, irrespective of caliber, have heavier barrels than comparable guns intended for field or service use. A heavier barrel helps the shooter "hold steady" and improves scores considerably, all else being equal.

FIGURE 30 — The vast majority of handguns are blued. Some enthusiasts prefer a nickeled finish and custom grips, which are usually available on special order.

BARREL LENGTHS DIFFER

The length of a pistol's barrel depends almost exclusively on the purpose of that particular gun. Normally, when the arm will be concealed under street clothing, as is the case with detectives, a two-inch barrel length is desirable. Uniformed officers, who holster a gun "in the open" and most handgunners prefer a four-inch barrel. Target shooters lean toward barrel lengths of six inches and even longer. Some .22-caliber revolvers made today boast ungainly, super-long "Buntline" barrels. They don't do a thing for accuracy, but they do hike velocity a bit. As a gimmick, they undoubtedly also hike sales for the manufacturer.

FIGURE 31 — S&W's new .44 magnum revolver is designed primarily for hunting. Note the long 8-3/8" barrels on this rack of guns that just passed final inspection.

The rifling in a pistol barrel may be of either righthand or lefthand twist; it most assuredly will be slow. Pistol bullets are ordinarily of large caliber and rather short, functioning well only at a slow rotational speed.

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. Why are barrels heat-treated?

2. Barrels made of which of the following are from the chromium steel family? (a) SAE 2345. (b) SAE 5234. (c) SAE 4523. (d) SAE 3452.

3. Refer to Table 3. Barrels made of which of the following have two-tenths of 1% carbon? (a) SAE 3204. (b) SAE 2034. (c) SAE 0234. (d) SAE 4320.

4. What is the amount of *carbon* content in the majority of barrels made today?

5. What is the major disadvantage of a stainless steel barrel?

6. True or false? Most of the pressure involved in revolvers is confined to the cylinder chamber or charge hole.

Answers on Page 14

PRACTICALLY PERFECT —

When you consider the process — that of taking a solid steel billet and gauging, reaming, cutting, and polishing it into a perfectly rifled bore — it's quite an amazing process. Perfect? Well, maybe not perfect, but practically perfect. Perfect enough to achieve desired accuracy for almost any shooter.

And that's what you will be involved in as a gun pro. Being more practical than perfect perhaps, but perfect enough in advising on guns and diagnosing gun problems so that your customers will be able to get the desired performance out of their firearms.

Now we're going to see how perfectly you've soaked up the concepts presented in this study unit (and how perfect we've been in getting them across). Complete and mail Examination 9 before going on to your Gun Shop unit and Study Unit 10.

Many of the illustrations in this lesson were provided by Stackpole Publications' *Gunsmithing* by Roy E. Dunlop.

ANSWERS

2

1. Heat-treating "normalizes" stresses in the steel and prevents warping of barrels that could occur in the *heat* of firing.
2. B
3. D
4. Between three-tenths and five-tenths of 1%.
5. Difficulty in reblueing and rechambering; to be reblued, a stainless steel barrel must first be stripped of old blueing, replated with iron oxide, then reblued.
6. True.

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