STUDY UNIT 8

RIFLE FREE-BORE: ADVANTAGES AND DISADVANTAGES

BORED TO BE FREE?

Few terms in the ballistics lexicon are less understood than "free-bore." A close second in the dubious-meaning derby is "over-bore." Since the two subjects are related, we're going to discuss them both — "freely" and, we trust, without being "overly boring." As a matter of fact, these topics are probably the most fascinating (and controversial) in the realm of interior ballistics.

Let's first talk about "free-bore." Free-bore has its advocates and its detractors. Some swear that free-bore ruins accuracy and is not to be countenanced. Others vociferously deny the charge and wave half-inch MOA groups in rebuttal. Some harrumph that free-bore always *reduces* velocity. Their opponents triumphantly point to the free-bored, ultra-velocity Weatherby and Apollo rifles. Many shooters claim they wouldn't *own* a free-bored rifle. Unknown to them, their favorite tack-drivers *are* free-bored. And so it goes.

Regardless of the viewpoint expressed, they are all right. Or all wrong. This seeming paradox stems from the fact that the *amount* of free-bore used, in connection with the powder charge and the bullet weight, has everything to do with pressure, velocity, and accuracy. One combination of factors may produce superlative results, another a ballistics can of worms.

Before getting into the pros and cons and the whys and wherefores, let's pin down the meaning or definition of free-bore.

JUST WHAT <u>IS</u> FREE-BORE?

Free-bore is that section of the bore measured from the ogive (pronounced O-jive) or shoulder of the bullet to that point in the bore where the leade commences (see Figure 2). This smooth, sometimes slightly tapered cylindrical area is free of rifling, thus constituting "free-bore." It is also called a long throat or long chamber; cynics sometimes re-

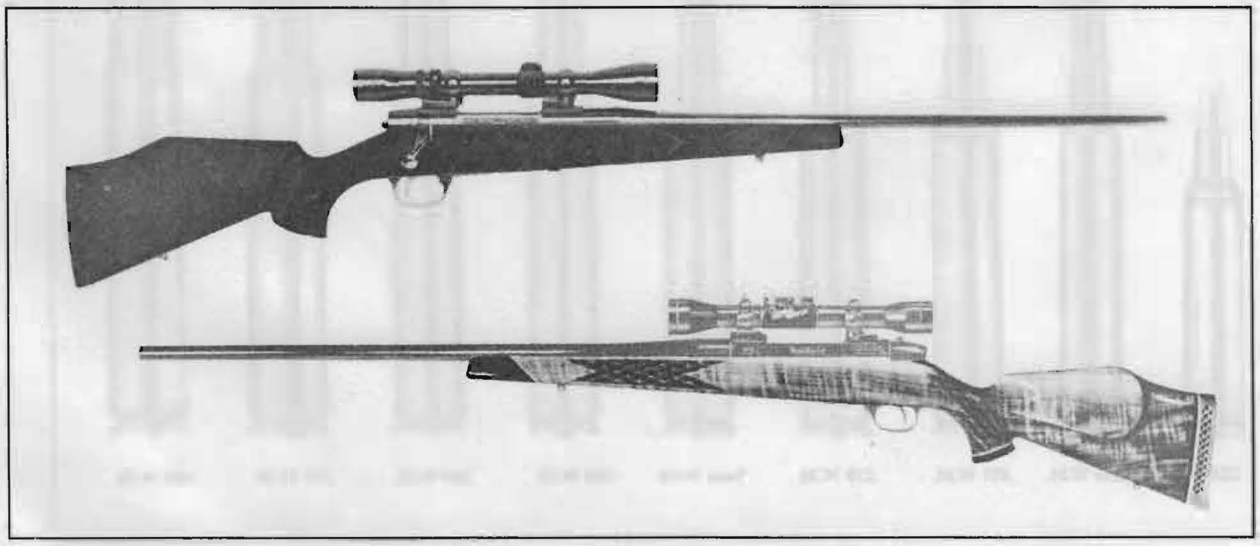

FIGURE 1 — Two prime examples of free-bored production rifles are the recently introduced Apollo (top) and the long-established Weatherby.

fer to free-bore as "pre-erosion." At least one well-known powder pundit claims that a throat of less than one inch in length has no business being called free-bore. (This would exclude most of today's free-bored rifles.) On the other hand, most ballisticians conclude that free-bore has no business being longer than three diameters. (In a .30-caliber rifle, this would amount to .924" [3 x .308], well under an inch.)

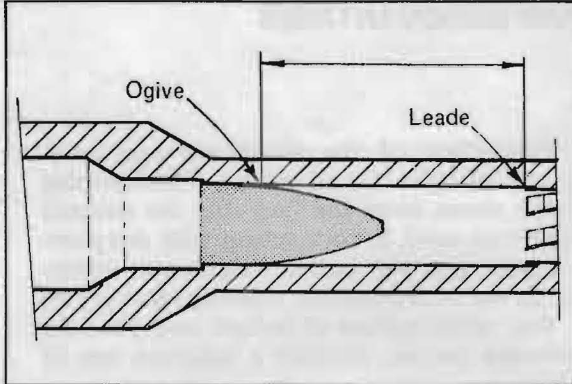

FIGURE 2 — Cutaway of a free-bored chamber. Free-bore is measured from the ogive of the bullet to the leade, and may vary from perhaps a quarter of an inch to two inches.

Call it what you will — free-bore, long chamber, or long throat — they all add up to the same thing. Free-bore is most often described in terms of "calibers" or "bore diameters." A two-caliber free-bore in a .30-caliber rifle would be .62" (2 x .308). A three-caliber or three-diameter free-bore in a 7mm rifle would amount to .85" (3 x .284"). At other times free-bore is simply measured on the basis of a half, three-quarters, or a full inch of free-bore. Up to the point where accuracy starts falling off (and it may be at the half-inch of free-bore point with one rifle, the inch point with another), the precise amount of free-bore incorporated isn't important. Unless using factory-developed cartridges, you develop loads related to the amount of free-bore; you don't cut the free-bore to conform to existing loads.

FREE-BORE LENGTH IS RELATIVE TO OTHER FACTORS

Once free-bore has been cut into a rifle, the true length of that free-bore is always relative to the *seating depth* of the bullet and to the *shape* of that bullet. When short and long bullets of the same caliber are seated to the same depth, the shorter bullet provides more free-bore area in a given free-bore chamber.

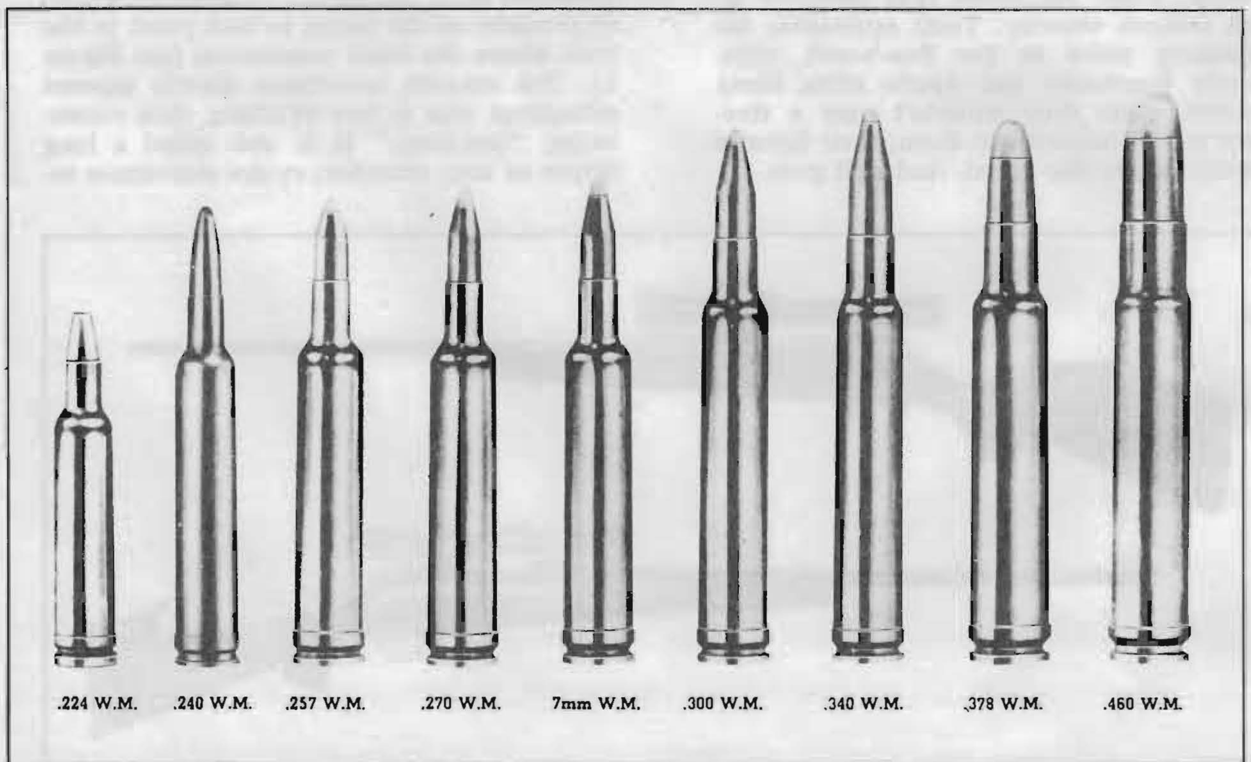

FIGURE 3 — The Weatherby cartridges in the most popular loadings, those establishing the optimum amount of free-bore within a given caliber.

Conversely, the heavier bullet protrudes farther into the free-bore, reducing the volume of the free-bore chamber (see Figure 4).

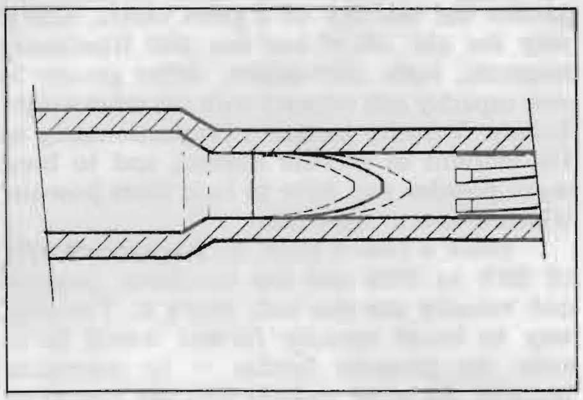

FIGURE 4 — Free-bore length is always relative to bullet length. The heavy line indicates the "free-bore standard" bullet; the dotted lines indicate lighter and heavier bullets, which increase or decrease respectively the amount of free-bore.

When two bullets of the same weight and caliber are seated to the same depth, but one is round-nosed and the other spitzer-shaped, the blunt bullet occupies more of the free-bore space than the spitzer because the former's ogive is farther forward (see Figure 5).

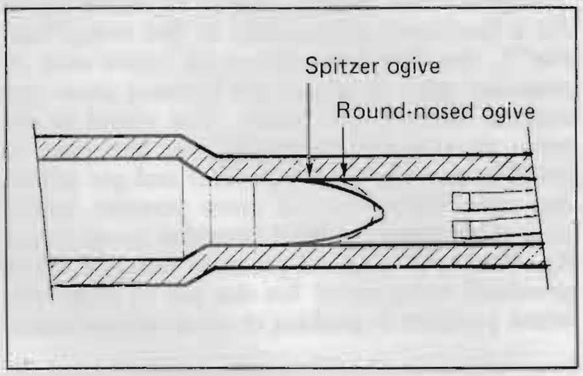

FIGURE 5 — Bullets of the same weight, but of different shape influence the amount of free-bore. The spitzer type (solid line) permits more free-bore area than the round-nose type.

It is because of this variance in the distance from the ogive to the leade with different sizes and shapes of bullets that factory rifles are, in effect, "free-bored" when light bullets are used. In factory ammunition, the heavier bullets, regardless of weight or nose shape, are seated to a depth (and overall length) that assures proper functioning through the magazine. The position of the leade is in turn geared to this maximum overall cartridge length. When the cartridge is chambered, the bullet is positioned just short of engaging the lead (see Figure 6).

With a short bullet it's a different story. There is no point in deep-seating such a bullet. To seat it out to conform to the same overall length of the cartridge with a heavy bullet would provide very little gripping surface between the case neck and the bullet (see Figure 7). Short bullets are therefore seated with the base of the bullet flush with the base of the case neck. The distance between the ogive of that bullet and the leade is substantial. For all practical purposes, this space is free-bore. Find a shooter who doesn't want or like free-bore, but who does very well, thank you, with light bullets out of his factory rifle, and you've found a rifleman with a free-bored rifle — whether he admits it or not!

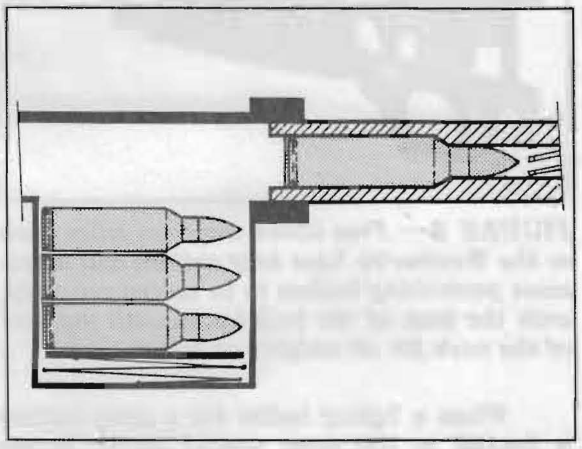

FIGURE 6 — The heavier bullets for a given cartridge are all seated to the same overall length to fit in the magazine; the leade is positioned relative to this one overall length.

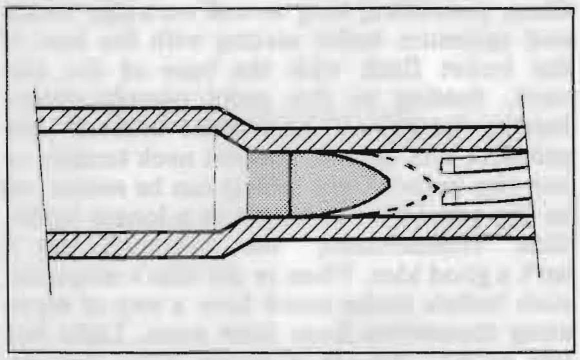

FIGURE 7 — The leade in a .30/06 is customarily positioned just ahead of the bullet tip, relative to medium and heavier bullets (dotted line). When a light 100-grain bullet is loaded flush with its base even with the base of the case neck, that rifle is free-bored!

NOW YOU SEE IT, NOW YOU DON'T!

In a given free-bored rifle, the free-bore can either increase or disappear altogether, depending on the bullet used. When a rifle is purposely free-bored, as are the Weatherbys, Apollos, and many custom-made sporters, the amount of free-bore specified is always relative to the weight and shape of *one* bullet — the spitzer-type that will most often be used in that particular rifle. The "standard" to free-bore bullets are usually the 180-grain in .308-caliber, the 139 to 140-grain in 7mm, and the 100 or 117-grain in .257 bore size.

FIGURE 8 — Free-bored magnum rifles such as the Weatherby have long actions and magazines permitting bullets to be seated properly, with the base of the bullet even with the base of the neck for all weights of bullets.

When a lighter bullet for a given caliber is loaded to the same seating depth as the "standard" bullet, the free-bore increases; when a heavier bullet is used and seated to the same depth, the free-bore either diminishes or disappears.

Most free-bored magnums have long actions, permitting long overall cartridge length and optimum bullet seating with the base of the bullet flush with the base of the case neck. Seating to this point permits proper loading density of the powder without compression, and assures the best neck tension on any size bullet. Light bullets can be seated out to the same overall length as a longer bullet, thus "standardizing" the free-bore, but it isn't a good idea. When in the rifle's magazine, such bullets under recoil have a way of separating themselves from their cases. Light bullets set well out are, however, often used for target or varmint work and are loaded singly. Accuracy is usually a bit better because the short bullet hasn't as long a gap to "jump" before engaging the leade.

Now that you know what free-bore *is* and *isn't*, let's talk about what free-bore *does.*

HOW FREE-BORE AFFECTS PRESSURE AND VELOCITY

Consider a basic axiom of ballistics: The more powder burned in a given caliber, the greater the velocity of a given bullet. This is why the old .30/30 and the .300 Winchester magnum, both .308-caliber, differ greatly in case capacity and velocity with the same weight bullets. Velocity increases proportionately to the amount of powder burned, and to burn more powder you have to *hold* more powder, which means a larger case.

Once a case is filled to a loading density of 85% to 95% and the maximum pressure and velocity are reached, that's it. The only way to boost velocity further would be to raise the pressure further — by cramming more of the same powder into the case or by filling the case with a faster-burning powder. Right? Wrong. Through the use of free-bore, we can increase the "capacity" of that same case — permitting us to burn more powder and gain more velocity — *without* raising pressure.

We go *outside* the case for that extra capacity. The area of the free-bore space, which may equal, say, 5% to 10% of the case's actual volume (depending on free-bore length and diameter), lets us add about the same amount of powder that a case 5% to 10% larger would justify. How does this figure? Because once the bullet has moved forward and "plugged" the rifling (where it slows down for a fractional millisecond at the twist "barrier"), the free-bore serves as extra case or chamber area in which the burning gases can expand behind the bullet. The effect is the same as actually stretching out the case to provide more room for powder and gas *within* the case. We've burned more powder, which at a given pressure level provides more velocity. We haven't *raised* pressure because we've provided *extra room* for the gas to flow into when pressure is peaking or close to maximum.

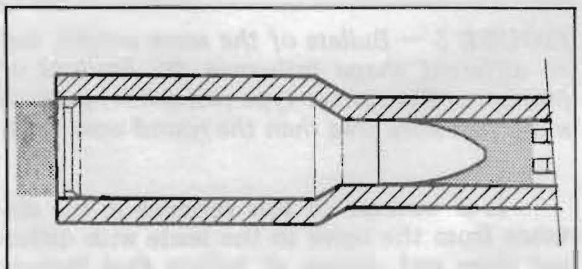

FIGURE 9 — If the free-bore area (shaded area at the right) is equal to, say, 7% of the case capacity, then as much powder may be added as if the case were actually *that much larger (shaded area to the left).*

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

Free-bore is shrouded in facts and myths. Separate them by checking only those that are true.

____ 1. Free-bore ruins accuracy.

____ 2. Free-bore always reduces velocity.

✓ 3. Free-bore is affected by charge and bullet weight.

____ 4. Free-bore causes increased erosion.

____ 5. A rifle is not considered free-bore unless the distance from the ogive to the leade is one inch or more.

✓ 6. Free-bore increases when a light bullet is used.

✓ 7. Free-bore increases efficiency.

____ 8. Free-bore raises pressures.

Answers on Page 7

FREE-BORE IS A DOUBLE-EDGED SWORD

At a given pressure level, say 50,000 psi for a "standard" rifle and 53,000 psi for a magnum, a free-bored rifle will always produce a higher velocity for a given bullet than a non-free-bored rifle with the same bullet. The reason is that more (or faster-burning) powder is needed to reach a specific pressure level in a free-bored rifle. And the more powder burned, the greater the velocity.

On the other hand, when two identical cartridges are fired — one in a standard rifle, the other in an identical but free-bored rifle — the cartridge in the free-bored rifle will produce less pressure and, as a result, less velocity. In effect, with free-bore we have a "larger" case with the same amount of powder. Because the case isn't "full," pressure falls. And when pressure drops, so does velocity!

As an example of this free-bore phenomenon, let's take a .308 rifle with a 24" barrel firing a 180-grain bullet. The chamber is *not* free-bored. A maximum velocity of 2,743 fps is achieved with 47 grains of IMR 4064. Pressure is also at maximum for this gun, right at 51,000 psi.

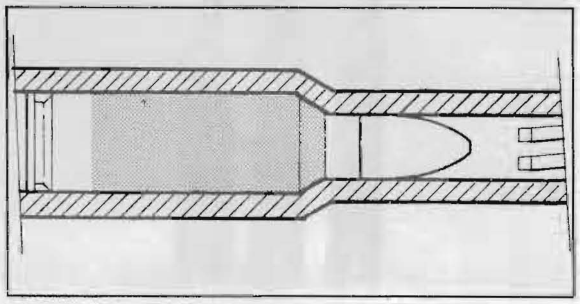

FIGURE 10 — When the powder charge isn't increased *in proportion to the free-bore, the powder charge is in effect "reduced" relative to the free-bore-increased case capacity, and pressure and velocity drop.*

Now we cut half an inch of free-bore into this same rifle, thus increasing the gas expansion area. The identical load now generates only 47,000 psi and velocity drops to 2,672 fps. Next we add a full inch of free-bore. Now the same load produces but 45,100 psi and the muzzle velocity is down to 2,644 fps. Yes, free-bore can *reduce* velocity when sufficient powder isn't added to keep pace with the increased free-bore-provided case capacity. It is for this reason that a small amount of free-bore, maybe only a quarter inch, is often cut into a rifle that, because of a "tight" barrel, handles standard factory ammo at too high a pressure.

Back to our .308 test rifle. We've shown that in the *non-free-bored* rifle, our maximum velocity with a 180-grain bullet and at 51,000 psi was 2,743 fps. With an inch of free-bore and using 48 grains of the faster-burning IMR 3031, necessary to reach that same 51,000 pounds of pressure, our velocity is 2,830 fps — nearly 100 fps faster than the maximum load in the non-free-bored rifle! The performance increase is even more dramatic in the larger magnum calibers.

APOLLOS PROVE FREE-BORE PERFORMANCE

The Apollo Rifle Company, to demonstrate the advantages of free-bore, recently ran extensive chrono-pressure tests on a rifle with a 26" barrel chambered for the *standard* .300 Winchester magnum cartridge. The 180-grain W-W factory cartridge averaged a muzzle velocity of 2,985 fps, about 85 fps less than the factory-published figure (3,070) at a pressure of about 53,000 psi.

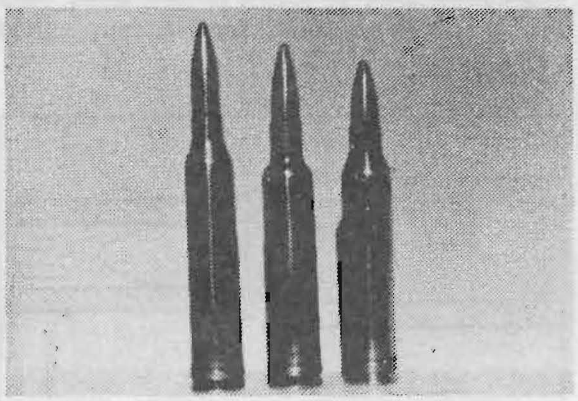

FIGURE 11 — Cartridges used in the test were the long-throated version of the .300 Winchester magnum at left and the adjacent .300 Winchester magnum standard factory cartridge. The .30/06 is shown at the right for comparison.

The same rifle was then free-bored two diameters relative to the 180-grain bullet to permit this long bullet to be seated properly with its base even with the base of the case neck. (The Apollo rifle permits this cartridge to be hand-loaded to 3.60" overall; the factory round is 3.25" to accommodate standard actions.) The same W-W factory cartridge, in the now free-bored Apollo chamber, generated less pressure — and clocked off 2,930 fps at the muzzle for a 55 fps velocity loss.

RIFLE WITH STANDARD CHAMBER (NO FREE-BORE) 26" BARREL

Cartridge	Bullet Wt.	MV (fps)
.300 W-W fact. load	180 grains	2985

SAME RIFLE AFTER FREE-BORING TO APOLLO SPECIFICATIONS

Cartridge	Bullet Wt.	MV (fps)
.300 W-W fact. load	180 grains	2930
.300 Apollo handload	180 grains	3270

TABLE 1 — Comparison of the non-free-bored Apollo with the free-bored Apollo, using the same and different loads.

However, the .300 Apollo load — with the bullet seated properly and using sufficient powder to achieve the same 53,000 psi factory pressure — averaged a muzzle velocity of 3,270 fps, or nearly 300 fps faster than the factory cartridge in a factory-standard chamber!

Bear in mind that this substantial velocity increase was accomplished with only two diameters (about .60") of free-bore. Most Apollos consistently achieve accuracy of 1" MOA or better, which certainly indicates that a minimum amount of free-bore is not detrimental to gilt-edged accuracy.

FREE-BORE OFTEN REQUIRES POWDER SUBSTITUTION

Some rifles have as much as one to two inches of free-bore. In such instances, *so much* of a given type of powder is called for (because of the larger case "capacity") that there is no way the huge powder charge could fit into the physical limitations of the *actual* case — without hiring a very small elf to jump up and down on the granules.

When this situation arises, the solution, to achieve the right loading density and pressure level, is usually a smaller charge of the next faster-burning powder (see Figure 12). For example, 75 grains of large-stick 4831 may not fit into a given case; 71.3 grains of the smaller-granule 4350 (5% less) *would* fit, and generate about the same pressure as the larger but slower-burning charge of 4831.

This powder "switching" is common not only to free-bored rifles. Sometimes a larger charge of a slow-burning powder will provide better accuracy than a smaller charge of fast-burning powder — and vice versa. The pressure levels are the same, but rifles are like people — they often function better on one diet than on another.

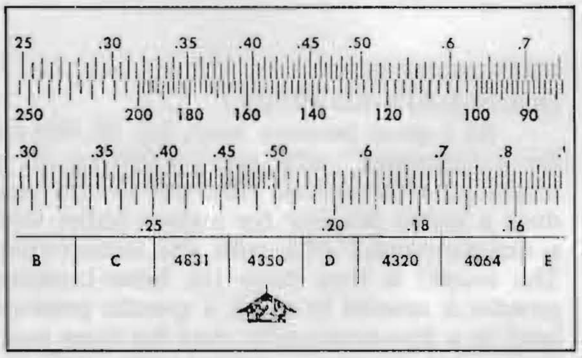

FIGURE 12 — When the recommended powder charge of 4831 is too large to fit into the case, select the next fastest-burning powder, 4350, and reduce the "recommended" charge by 5%.

FREE-BORE AND ACCURACY

Free-bore, like anything else, can be carried to extremes. Opponents of free-bore (and there are many) undoubtedly base their sentiments on experience or hearsay connected with rifles having excessive amounts of free-bore.

Just what constitutes the "proper" amount of free-bore is the problem (and it's like trying to gauge how much "reaming" a youngster should receive to straighten up and fly right). There are an awful lot of variables — barrel "tightness," type of brass and bullets used, etc. — that enter the picture, and no two guns are exactly alike in their performance characteristics, even when made by the same manufacturer. The point is, some rifles shoot well with a large amount of free-bore; others can tolerate only a small amount before accuracy falls off.

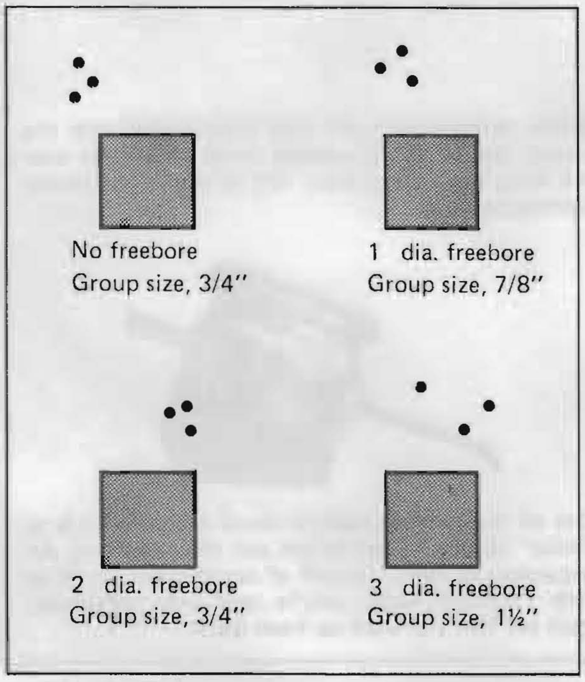

FIGURE 13 — The above groups, fired at 100 yards with the same .257-caliber rifle free-bored in progressive stages, showed that accuracy started going to pot with three diameters.

When free-bore is cut into a rifle, a gap is created between the bullet's starting point and the leade, which the bullet must "jump." If the gap is too long for a given bullet, if the free-bore is too "loose" or not perfectly concentric, then the bullet *could* skid into the rifling slightly off-center. And when this happens accuracy not only suffers — it howls in outright anguish!

There are rifles that shoot well indeed with as much as one and a half or even two inches of free-bore, but they should be considered exceptions (except with *very* long bullets). Generally speaking, accuracy isn't impaired when two and sometimes three diameters of free-bore are used. Beyond this point, you're asking for it — and there's nothing more disgusting than to get excellent results with three diameters, then to try for four diameters — and see your tight groups spread all over the target. And there's no way you can replace that reamed-out metal!

If a man isn't satisfied with the extra velocity three diameters provide, he had better think about moving up to a gun with a lower expansion ratio. You can only get so much velocity out of any rifle, free-bored or not, and overdoing free-bore can ruin the accuracy of the gun. Permanently.

ANSWERS

1

Statements 3, 6, and 7 are true.

HOW MUCH CAN FREE-BORE INCREASE VELOCITY?

There are no tables, as such, for equating specific amounts of free-bore for a given cartridge with specific pressures and velocities. There are just too many variables — type and weight of bullet, barrel length, bullet seating depth, thickness of brass used, whether the bore is slightly over or undersize — you name it.

As a rule of thumb, two to three diameters of free-bore will often increase velocity from 100 to 200 fps. Increases in magnums, as pointed out, can be even more pronounced.

All wildcat cartridges (and a cartridge in a free-bored chamber is a "wildcat" in that it is no longer standard because the effect is that the case capacity has been "changed") should be worked up carefully, from a known safe starting point. The powder charge is increased, a grain at a time, until the pressure signs are obvious (see Figure 14). When this happens, you back off a grain or two for your safe operating maximum, and you'll be awfully close to the recommended "maximum" for your rifle and your brass. (The brass and primers are designed to "tell" when pressure reaches near maximum.)

A bright mark made by the ejector shows that your charge is at or close to maximum pressure. Back off at least one grain. (Sometimes a burred ejector or a bit of grease or dirt under the ejector can cause this bright mark without attendant high pressure. Check the extractor and polish it if necessary before firing.)

A flattened or "cratered" primer means you're surely at maximum, and perhaps a bit over. Back off at least two grains. (This condition can also be due to an overly long or hung-up firing pin. Check for debris in the bolt.)

A dark ring around the primer, caused by leaking gases, means you're at least 5,000 psi over maximum. Back off at least two or three grains.

A pierced or popped primer means you're living dangerously and well into the 60,000 psi range. Check for a defective firing pin. However, the chances are you have to tap the bolt with a plastic hammer to release the action. Back off 10% or change to a slower powder.

Blown primers with the case head swaged into the ejector and extractor recesses mean you're way over the limit. Back off at least 10% or switch to a slower burning powder.

One of the best methods to check for pressure is to "mike" the case head before and after shooting. An expansion of even one-half of one-thousandth of an inch (.0005") means you're well over maximum. Back off 10% and work up from there.

FIGURE 14 — The above illustrations are symptomatic of high pressure caused by excessive powder charges, and assume that case lengths are correct and that the rifle does not have excess headspace. The latter two situations can also cause the symptoms shown.

Before getting into the loading of cartridges for free-bored chambers, we want to emphasize that increased velocity, while desirable, is still secondary to accuracy. The idea is to *improve* a rifle by free-boring. So what if it shoots like a flashlight, if the groups are the size of your head? As you will soon learn, free-boring is a very simple task to perform, requiring only precise measurements plus skilled use of a throating reamer and a depth gauge. Therefore, you should approach a job of free-boring in stages. First, remove only enough metal to gain a one-diameter free-bore. Work up some loads and test-fire for accuracy. Some rifles show a remarkable velocity increase and excellent accuracy with only one diameter of free-bore (especially the .224's, 6mm's, and some .257's). If, as will probably happen, the velocity increase is minimal and the accuracy remains as good as it ever was, you will want to remove enough metal for two diameters of free-bore. Make up some loads and shoot them. If accuracy is still good, then you might want to cut three diameters of free-bore.

We don't recommend going beyond this point unless you're a gambler at heart and/or plan to rebarrel the gun anyway. Accuracy can go to pot beyond three diameters of free-bore, and once you've cut away the metal you can't put it back. (You can set the barrel back, deepening the chamber to its original dimensions — which leaves you with less free-bore, but what a hassle!)

COMPUTING STARTER LOADS

Let's get back to that starting powder charge for your free-bored rifle. First calculate the *maximum* charge for your case/bullet combination with your Powley computer and PSI calculator, but based on a *non-free-bored* chamber. Check your results against a good loading manual like Speer's or Hornady's to make sure you figured correctly.

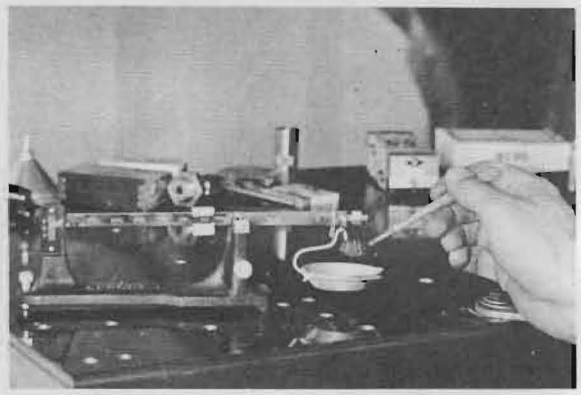

FIGURE 15 — When working up test loads, it's always best to weigh each charge individually and know you're right. Even the best powder measures vary a bit in "throws," especially with large-stick propellants. (Photo courtesy RCBS)

Back off two grains from this maximum (better safe than sorry). You now have a good starting load for a rifle with a *one-diameter* free-bore. Pressure and velocity will be *less* than with a non-free-bored chamber, so start working up your load — a grain at a time — until the pressure signs show you're at maximum. Then back off one to two grains. You now have the optimum load for your rifle with one diameter of free-bore.

If and when you decide to increase the free-bore to two diameters, use the one-diameter maximum load (or perhaps that load increased by not more than one grain) as your starting point. Proceed as before until pressure signs show you're at maximum, then back off one grain. This load, plus no more than one extra grain, is your starting load if you decide to incorporate three diameters of free-bore.

THE .30/06 AS AN EXAMPLE

Let's say that you have a .30/06 rifle you wish to free-bore. It has a 24" barrel and you want to make the free-bore relative to the 150-grain spitzer bullet. You first calculate the proper maximum or near-maximum load for this rifle, but with a *non-free-bored* chamber. The Powley computer and PSI calculator show a velocity of 2,850 fps at a pressure of 49,000 psi. The charge is 55 grains of IMR 4320 (55/4320).

FIGURE 16 — Never start with maximum loads for any rifle, whether the chamber is standard or free-bored.

You back off two grains, to 53/4320, and you have your starter load for that .30/06 rifle with a one-diameter free-bore. You'll probably get up to 55 or 56 grains of 4320 before the pressure signs show up. When your pressure gets up there, let's say you back off one grain and settle for 56/4320 as your maximum load with a one-diameter free-bore.

You decide to free-bore the rifle to two diameters. Okay, you start at 56/4320 (maybe 57/4320) and get up to 58 or 59 grains before the pressure signs are visible. But you've got problems. The case is so full of powder that you have to trickle it in, and you're getting into the area of powder compression, which isn't good (see Figure 17).

SWITCHING POWDERS FOR BETTER LOADING DENSITY

At this point you'd change over to IMR 4064, the next faster-burning powder on the Powley computer scale. Because it is quicker-burning, we reduce our optimum charge of, say, 58/4320 to 5% less of 4064. This figures out to 55.1 grains of 4064 (.05 x 58 = 2.9, 58 - 2.9 = 55.1), which will produce close to

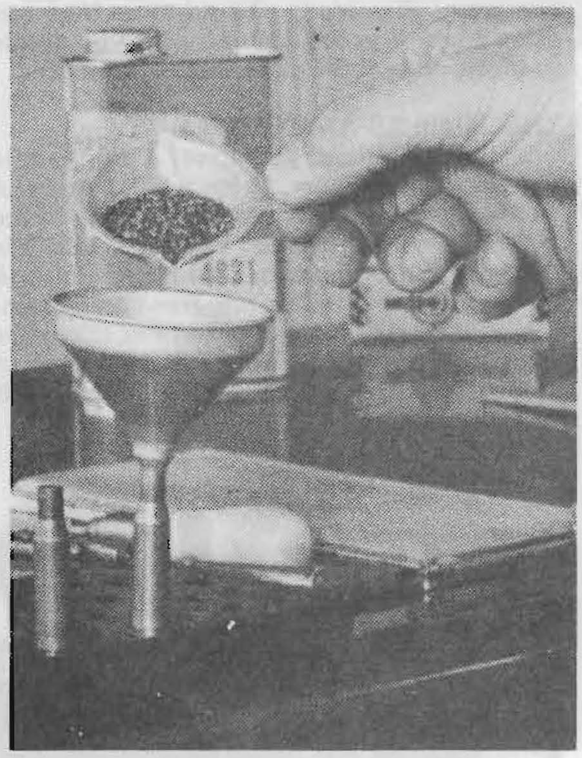

FIGURE 17 — When your case gets so full you have to use a funnel and "tamping" to fit the charge into the case, it's time to change to a smaller quantity of a faster-burning powder.

the same pressure and velocity of the 58/4320 charge. Because we have changed powder, and to play it safe, we would start with 54/4064 and work up from there.

Should you wish to go on to three diameters of free-bore, you would use the maximum load for two diameters as your starting point. Should your case again get too full as you approach maximum, you would switch over to the next fastest-burning powder, 3031, on the Powley computer. Here, because "E" intervenes, you'd deduct 5% for E and 5% for 3031, for a total reduction in powder volume of 10%. In other words, if you got up to 58 grains of 4064 before encountering pressure signs, you'd reduce the charge by 10% (.10 x 58 = 5.8, 58 - 5.8 = 52.2) to 52.2/3031. To play it safe, you'd start working up from 51/3031. These are merely examples of powder reduction. In some cases (both ways) you could use the specified charges without powder substitution.

FIGURE 18 — Always verify accuracy with the existing free-bore before extending that free-bore. If there is any deterioration, stop there!

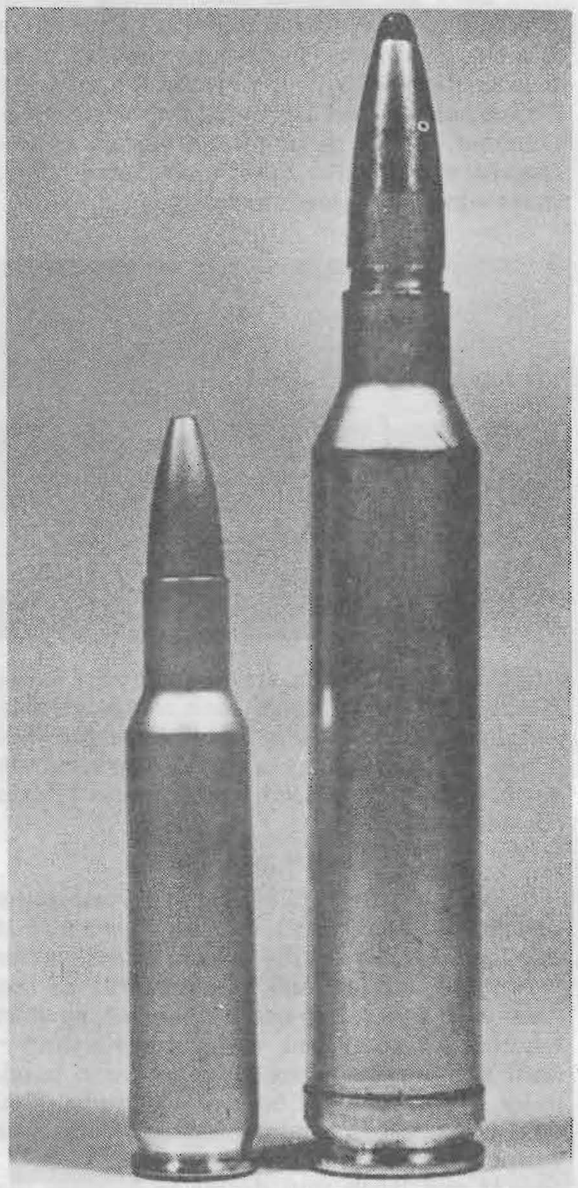

FIGURE 19 — In standard or free-bored rifles, small cases like the .222 Remington often deliver the best accuracy with light loads; large cases like the 7mm Remington magnum with maximum loads.

It takes a good deal of time to tailor loads for any rifle, especially one that has been free-bored, but the experience can be fascinating and the results worthwhile. Two or three diameters of free-bore can give a standard-size cartridge such as the .30/06 or .270 near-magnum performance — and with no appreciable decrease in accuracy or increase in barrel erosion.

As a matter of fact, some authorities believe free-boring helps retard erosion, for the reason that the rifling has already been "removed" from the area where the greatest "wear" normally takes place. Interesting, but hardly conclusive.

Free-boring does incorporate a built-in "safety valve" as far as pressure is concerned. But free-bored or not, never start with the maximum loads listed in loading manuals or figured by yourself on your computers. Rifles vary, components vary, and mistakes are possible. When actually test-firing, always back off at least one grain from the maximum listed or computed load for a *non-free-bored* chamber. Then take it from there — working up your loads carefully and watching continually for the pressure signs previously discussed.

The old adage of "rather safe than sorry" was never more meaningful than when applied to internal ballistics.

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

Using your Powley calculator, determine the following powder charges:

1. You're up to 58 grains of 4320. How many grains of the next powder would you now use?

2. You're up to 59 grains of 4064. How many grains of the next powder would you now use?

Answers on Page 13

DETERMINING VELOCITY

Velocity is, of course, the name of the game with free-bore (providing the accuracy level remains constant). Unfortunately, the Powley computer and PSI calculator were not designed to take case capacity *outside the case* (which is what free-bore is all about) into consideration. Therefore, these instruments cannot be used in calculating velocity or pressure in connection with free-bored rifles.

When working up from your starter load (which *can* be computed with your Powley slide rules), pressure signs will indicate when you've reached maximum — about 50,000 psi for standard cartridges, about 55,000 for magnums. The easiest way to determine the velocity of your free-bored loads is with a chronograph. However, in your next study unit, which deals with exterior ballistics, you'll learn how to use the Powley High-Velocity Trajectories Chart (which you've already received) to compute accurate velocities for any high-powered rifle for which the muzzle velocity isn't known.

"OVERBORE" CARTRIDGES — LARGELY A MYTH

Sooner or later you'll be talking with a group of shooters when the subject of Remingchester's new zinger, or somebody's hot wildcat, arises. "Man, does that cartridge produce the velocity!" one will exclaim. "Yeah, that's about the flattest shooting cartridge around, in its caliber," another will second. About this time someone else — usually the group "expert" — delivers the ultimate squelch. "That cartridge," he intones with the air of a hanging judge asking a defendant to rise, "is overbore." Oh. No one is exactly sure what "overbore" (or "overbore capacity") is, but it can't be good. Says who??

The term "overbore," invented by a leading gun writer of the 1940's, has been a pain in the posterior to cartridge developers for years. It has to do with a *gun's case capacity relative to its bore capacity*. A large case combined with a small bore diameter, which is typical of today's low-expansion-ratio magnums, is labeled "overbore" because case capacity is "over" the bore's capacity to completely burn the powder charge. If nobody cared about barrel length, there wouldn't be, within reason, such a thing as an "overbore" cartridge. Barrels would simply sprout in length like Pinocchio's nose, until they were sufficiently long to burn *all* the powder involved. Present magnums would then resemble their ancestral cousins, the Kentucky rifles (which had long barrels for the same reason)!

Well, 26 inches is about the maximum tolerable length for a hunting barrel. This

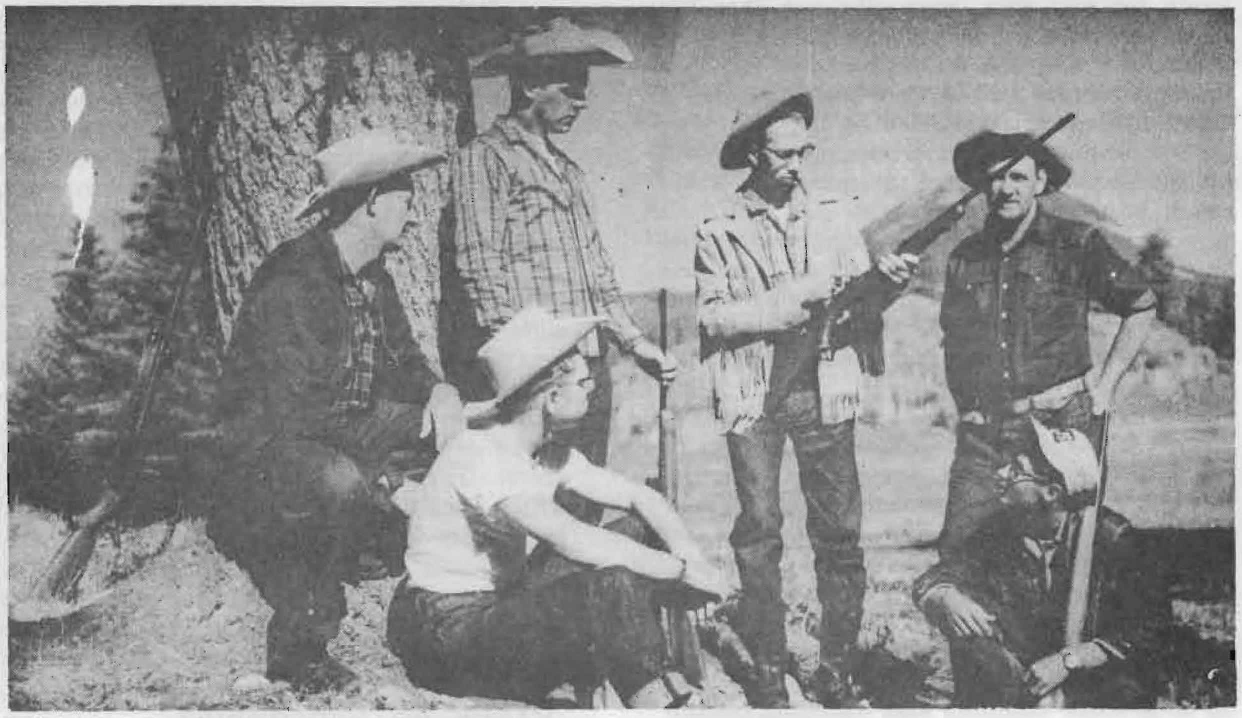

FIGURE 20 — In any group of knowledgeable (or pseudo-knowledgeable) shooters, the subject of "overbore capacity" is apt to arise. You'll soon be in a position to dispel the myths and mysteries.

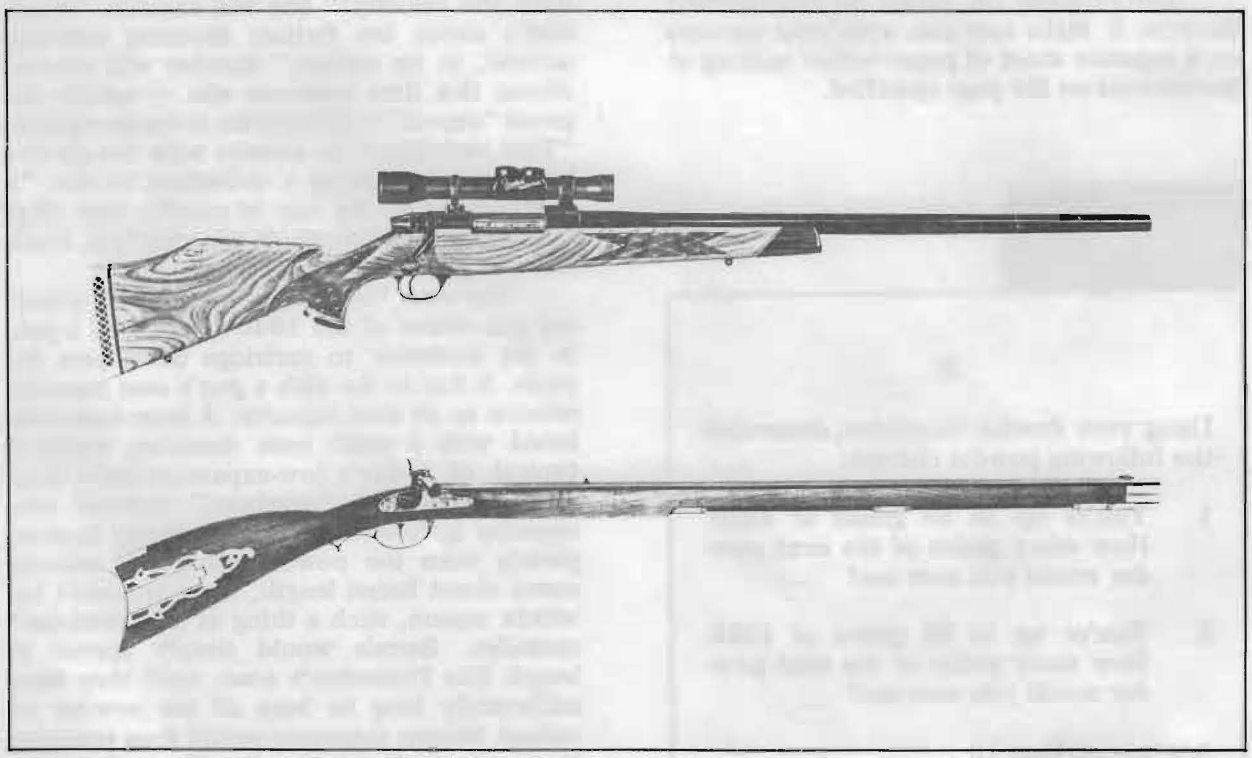

FIGURE 21 — Most modern magnums, like the Weatherby shown with a 26" barrel, are considered "overbore" by some experts. The Kentucky rifle, with its long, long barrel, wasn't *"overbore" because the long barrel length permitted complete burning of the powder charge.*

means that a percentage of the powder in the case is *not* going to get burned. And the shorter the barrel (or the larger the chamber in relation to the bore volume), the less powder that will be burned in a given charge. The problem is compounded by the fact that large cases usually require slow-burning powders that release their energy slowly, to avoid the "bomb-like" effect of a fast-burning powder "plugged" in a large case by a small-bore "outlet."

Thus, "overbore capacity" relates to powder waste. Or, to put it another way, to cartridge efficiency or lack of efficiency in burning its powder charge.

ANSWERS

2

1. 54.1 grains of 4064
   (5% of 58 = 2.9
   58 - 2.9 = 55.1
   less 1 for safety)

2. 52 or 53.1 grains of 3031
   (10% of 59 = 5.9
   59 - 5.9 = 53.1
   Best to back off to 52)

THE PROBLEM IS, WHAT IS "EFFICIENCY"?

As far as rifles are concerned, everyone has his own idea or definition of efficiency. One shooter will claim, with justification, that his "overbore" .257 Weatherby is "efficient" because it kills game efficiently at long range and produces venison where a lesser rifle couldn't, and wouldn't, justify the cost of his hunting trip.

Another shooter would scoff at the Weatherby and swear by the "efficient" .250 Savage or the .257 Roberts. If he hunts in country where a long shot is 250 yards, then he's right. His gun is "efficient" for his purpose.

Rifle or cartridge "efficiency" therefore boils down to the purpose for which a given shooter will use a given gun — and these purposes vary widely indeed. To condemn a magnum for being overbore is the same as recommending a 50-year-old cartridge because it *isn't* overbore. Condemned and recommended for *what*??

FIGURE 22 — The two extremes of "efficiency." The splendid .257 Weatherby is one of the most "overbore" and "inefficient" cartridges in existence. The .22 rim-fire short is about the most "efficient." Obviously, "efficiency" isn't the only yardstick for cartridge choice.

For an expert to state flatly that one rifle is efficient and another inefficient smacks more of personal prejudice than scientific evaluation. The fact is, most writers who delight in grumping about "overbore capacity" are getting on in years, and their feelings have a lot to do with "the rifle that was good enough for me years ago is good enough for today's shooters" syndrome.

NEW CARS HAVE "OVERBORE" PISTONS

Such reasoning is best described as antediluvian (wow — what a fancy word for *antiquated*) for at least two reasons. For one thing, there isn't nearly as much game to be had today as there was 30 or 40 years ago, and long-range rifles often make the difference between meat in the locker and failure to connect. Secondly, to deny the merits of the new magnums is to thumb one's nose at progress which, while acceptable in other fields, is somehow objectionable with rifles. If one wishes to live in the past, so be it. Our beef is with those (and there are still plenty around) who want to inflict their dated concepts on today's generation of shooters and gun pros.

FIGURE 23 — The Winchester .30/30 rifle and various types of .30/06 rifles have undoubtedly killed more game than all other calibers of rifles combined. Yet the former is now 85 years old, the latter nearly 70. Progress has been made in ballistics, as in all other fields.

In line with the "old guard" reasoning, only a dunce would drive anything but an efficient 1937 Ford with an 85-mph top speed. Why buy an "inefficient" new car with 250 more horses when top speed is increased only an illegal 30 to 40 miles per hour? For performance, of course! And the same thing holds true of rifles.

LET'S GET DOWN TO SOME SPECIFICS

We've made the point that the reasons for dubbing one rifle "overbore" and another "efficient" are largely emotional. Lest we be accused of the same malady, let's look at some cold, hard facts.

All rifles, including those favored by the old-school conservatives, are woefully inefficient. It's the nature of the beast. Even the old 7 x 57 (7mm Mauser) cartridge, considered one of the most "efficient" center-fires around, has an efficiency rating of only about 30%, based on powder utilization, which is what "overbore capacity" is all about. Here, to refresh your memory, is how we arrive at this figure: We're talking about a 160-grain bullet driven at a velocity of almost 2,800 fps by 53 grains of powder. Muzzle energy is therefore 2,785 foot pounds. The potential energy of the 53 grains of powder, because each grain produces 178 foot pounds of energy, is 9,434 foot pounds. By dividing the *potential* foot pounds into the *actual* foot pounds, we can calculate the efficiency:

$$9434 \,\overline{)\,2785.00}^{\;.30} = 30\%$$

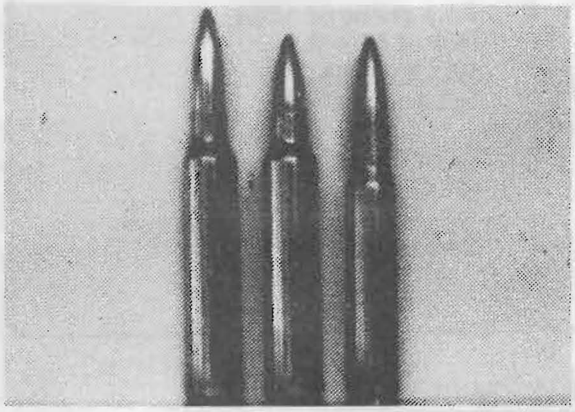

FIGURE 24 — Modern 7mm magnum cartridges are, from left, the Apollo, Weatherby, and Remington. All are "overbore" and "inefficient," yet are enormously powerful, long-range cartridges.

By way of contrast, let's take the new 7mm Apollo, using 72 grains of powder to drive the same 160-grain bullet at 3,200 fps. Muzzle energy is 3,637 foot pounds, for an efficiency rating of 27.5%. Yet this rifle, only 2.5% less efficient than the 7 x 57, is considered "overbore."

Rather than belabor the relative *efficiency* of these two rifles, let's look at the other side of the coin and discuss "inefficiency." The old 7 x 57 wastes 70% of its powder, the new Apollo 72.5%. The "efficient" 7 x 57 is, at best, a 300-yard rifle; the "overbore" Apollo, because of its much flatter trajectory and greater down-range energy, is lethal, in the hands of a good marksman, to 450 yards.

Granted, the Apollo, because of its larger powder charge and higher operating pressure (53,000 psi as opposed to the Mauser's 50,000) might "shoot out" its barrel faster. However, if both rifles were used only for hunting and occasional target shooting, it's doubtful that the owner of either rifle would live long enough to "wear out" his barrel. On the other hand, both rifles, using maximum loads and shot rapid-fire, would wind up with shot-out bores in less than 1,000 rounds. The Mauser might last 200 to 300 shots "longer," but because of softer barrel steel it might not.

EXTRA POWDER ALWAYS MEANS EXTRA VELOCITY

Some of the old-time experts would have you believe that, at some magic point, extra powder (case capacity) fails to produce any additional velocity (so who needs a magnum?). One gets the feeling, in reading some of their writings, that if you add too much powder, the bullet is going to slow down or even go backwards. This is rubbish! It's true that the larger the case and the powder charge, the less *efficiency* one gains from the powder because of unburned granules, yet there is always *some* velocity increase.

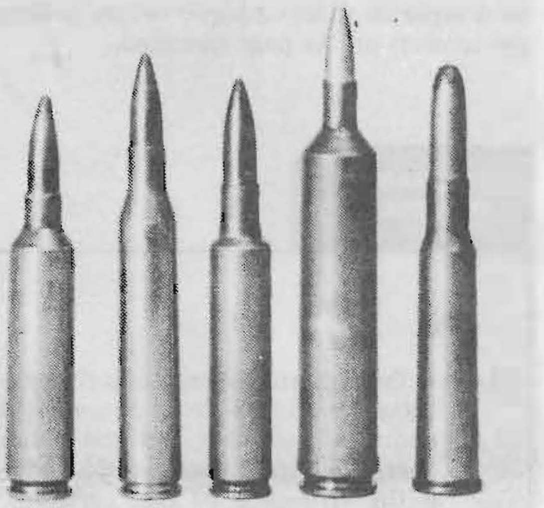

FIGURE 25 — All the above cartridges can be considered "overbore" except the old 7 x 57 Mauser at the far right. From left, 6mm-.284 wildcat, .25/06, .25-.284 wildcat, and Hutton's .22-.378 "Loudenboomer." The latter deserves *the description!*

Proof of this phenomenon exists in the "Eargensphlitten Loudenboomer" developed by Robert Hutton, technical editor of *Guns & Ammo* magazine. He necked the .378 Weatherby case down to .22-caliber, loaded a 15-grain bullet ahead of 108 grains of powder, and let loose. The chronographed velocity was 7,200 fps! The barrel burned out after just a few shots, but the monster proved Hutton's contention — the more powder burned, the higher the velocity.

IS THE TERM "OVERBORE" EVER JUSTIFIED?

Yes. Some cartridges, like Hutton's .22-.378, are so overbore that they're ridiculous. However, "overbore" cartridges, in the sense that they have no practical purpose, or that their disadvantages outweigh their advantages, can't be found in the pages of any ammo manufacturer's catalog. They are almost exclusively within the province of the ballistics experimenter or researcher.

According to a leading contemporary ballistician, overbore capacity is defined as follows: "any rifle with an expansion ratio (ER) lower than 4, or when a powder slow enough to permit a minimum 80% loading density isn't available."

Let's examine this definition. Expansion ratio, as has been previously pointed out, is the room provided within the gun for the gases to expand and the powder to burn. Rifles with a low ER waste a greater percentage of their powder because of lack of "burning space" than guns with a higher ER. (Hutton's "Loudenboomer" had an ER of 3.) You can figure the ER of any gun in a few seconds by relating case capacity to barrel length on your Powley computer (see Figure 26).

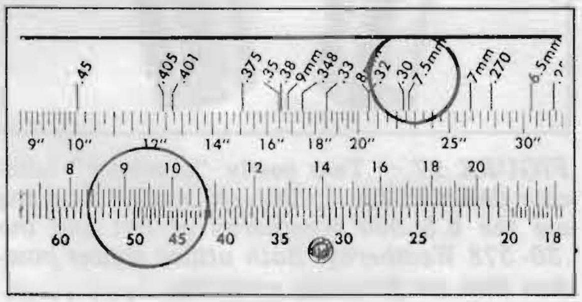

FIGURE 26 — The Powley computer provides the ER (expansion ratio) of any rifle in a few seconds. For example, a .308 Winchester with a 24" barrel and a case capacity of 51.5 grains has an ER of 9.

Concerning the 80% loading density figure, remember that the larger a case gets compared to a given bore diameter and bullet weight, the slower the powder has to burn to maintain a safe pressure level. For example, if you were to decide to neck down that huge .378 Weatherby case to, say, 6mm, you'd have a problem locating the right powder. If you started out with 4831, you'd discover that it was too fast and that you'd reach the maximum pressure permissible with your case about half full. You'd move on to a still slower-burning powder and finally have to settle for the slowest obtainable — H570. Unfortunately, this powder, too, is still too fast-burning, meaning that at the correct pressure the case is only about 70% full, or too large for the powder charge. Such a cartridge *would* be overbore, in the true sense of the word, because about 20% of the case isn't used.

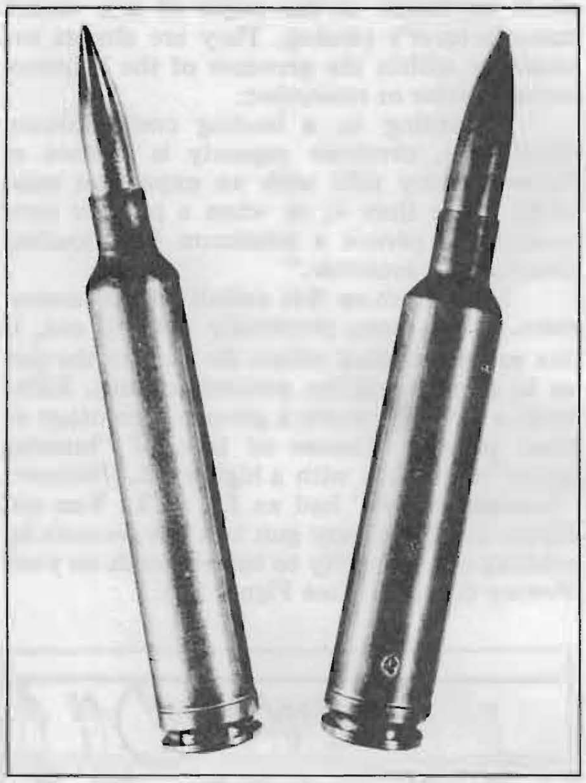

FIGURE 27 — Two vastly "overbore" wildcats designed for 1,000-yard match shooting are the 6.5-.300 Weatherby at left and the .30-.378 Weatherby. Both utilize slower powders than are generally available.

RATIO OF CHARGE AS THE CRITERION

Another yardstick used by the "old school" for determining "overbore capacity" is ratio of charge to bullet weight, a factor used by modern ballisticians in connection with other factors in arriving at efficiency. However, the oldtimers rely heavily on this ratio alone in defining overbore cartridges. Here's how their theory works: If the powder charge for a specific cartridge weighs more than one-third of the bullet's weight, then the gun is "overbore" because it wastes powder. Acceptable guns, by this reasoning, are the 7 x 57, .30/06, .300 Savage, etc., all of which use a powder charge equal to around 33-1/3% of the weight of the most popular size of bullet.

For example, the .30/06, using a charge of 51 grains of powder behind a 150-grain bullet has a ratio of charge of 34% (51.00 ÷ 150 = 34), meaning that the weight of the powder is 34% of the weight of the bullet.

All these "acceptable" rifles have an ER of 6 to 8, which, like the RC (ratio of charge), points up the fact that they are "efficient." There is no squabble here. The point of departure concerning "efficiency" arises with the big magnums.

The 7mm Apollo, for example, with 72 grains of powder behind a 160-grain bullet, has an RC of .45; with 75 grains of powder driving a 120-grain bullet, an RC of .62. These ratios of charge are, to the conservatives, much too high and clearly indicative of an "overbore" situation. Again, we say rubbish! If a reloader wants to spend 3¢ more per round, which is the only practical "penalty" he's paying for high performance, that's his business.

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

PROGRAMMED EXERCISE

3

1. If the *potential* energy of a rifle cartridge is 8,900 foot pounds (49 grains of powder) and the *actual* energy is 2,600 foot pounds, what is the *efficiency* of that cartridge?

2. Briefly describe "overbore capacity."

Answers on Page 18

"OVERBORE" RIFLES ARE NEEDED!

The point is, no one cartridge will ever satisfy all shooters. There are, basically, at least three different types of shooters/reload-

FIGURE 28 — These rifles reflect the three categories into which most shooters/reloaders fit: .300 Savage, M99; .270 Winchester, M70; and the .300 Weatherby magnum.

ers, each with his own requirements. The first is represented by the man who is happy with modest velocity and the attendant mild recoil and long barrel life. He hunts with a .30/30, .300 Savage, or .308 Winchester.

Another type of shooter is a "compromiser" by nature. He wants higher velocity, but not at the expense of heavy recoil and muzzle blast, and a barrel whose life expectancy will be a cause of worry. He probably shoots a .30/06, .270 or .280 Remington.

The third type suffers from "magnumitis." He isn't concerned about the high cost of his ammo or handloads. If he shoots a lot, he'll probably use reduced loads on targets to lengthen barrel life, or he'll use maximum loads and *plan* on rebarreling when the time comes. His fun is worth the cost.

"Overbore," like beauty, exists largely in the eyes of the beholder. What is "overbore" and negative to one shooter is precisely what another shooter needs.

The new magnums and their high-performance cartridges are products of *your* generation. When somebody knocks them on the basis of yesteryear's yardstick, set them straight. "Overbore," to the informed, is an "overly boring" subject!

And now, when you get refreshed and ready to go again, it's time to complete Exam 8 and send it to School Headquarters for grading.

ANSWERS

3

1. ~~.342 or 34%~~
2600) ~~8900.00~~
.292 or 29.2%
8900) 2600.00

2. A rifle with an expansion ratio (ER) lower than 4, *or* when a powder slow enough to permit a minimum 80% loading density isn't available.

NOTES

NOTES