STUDY UNIT 7 – PART 1

INTERIOR BALLISTICS – RIFLES AND PISTOLS

WHEN THE BLOOM IS ON THE SAGE

Interior ballistics has to do with what happens *inside* a gun from the moment the trigger is pulled until the bullet leaves the muzzle.

The attitude of many shooters toward ballistics is like teenagers and the opposite sex. Those with a little experience think they know it all. Those with no experience are sure interested and want to "adventure into the unknown," but are a bit fearful of the whole thing being just too complicated.

The woods and gun counters are full of "know-it-alls" who, with no encouragement at all, smugly announce that they've "got ballistics down pat." They've read a loading manual or two, and they are aware of the dangers of excess chamber pressure. You know the type. There's at least one in every crowd of shooters. But ask such sages of smokeless savvy just *why* one powder is better than another, *why* it produces better velocity and accuracy at a lower pressure level, and the silence is deafening. The know-how in question is usually of the "tip of the iceberg" variety.

And from the "blooming sage" variety of ballisticians, we go to the other extreme, who take the *hands-off* approach. Other shooters, usually novices who are still using factory ammo, are inclined to regard ballistics as only slightly less complicated than plotting the paths of space probes. That isn't quite so.

BALLISTICS IS KNOWING WHAT WILL HAPPEN – BEFORE FIRING A GUN

The truth, of course, lies between the two extremes. Interior ballistics isn't simple; yet it isn't all that complex. Understanding why one powder/bullet combination is better than another for a given gun, and learning how to calculate chamber pressures and velocity accurately, at your desk, *don't* require an intricate knowledge of math formulas and equations. Mathematical wizards have already done your homework for you. You work with principles and theories they have recognized and developed. In other words, you don't have to be an inventor or designer of automobile engines to understand how they *work*.

There are so many variables represented by the various calibers, barrel lengths, and powder/bullet/primer/brass components that you might well wonder how it's possible to sort out any sense from such a conglomeration, much less learn how to select the best combinations and predict their performance. It's precisely because of these variables and the need for understanding their interactions that the science of internal ballistics came into existence.

Regardless of the type of gun and cartridge involved, there are certain functions that affect the internal ballistics of that arm at firing. Let's discuss them . . .

FIGURE 1 – Interior ballistics can be fun! With a bit of practice and two slide rules, your desk or kitchen table can become a "ballistics laboratory." You'll accurately predict cartridge performance without filling a case or firing a shot.

LOCK TIME

When a trigger is squeezed, the sear is depressed and the striker moves forward, indenting and exploding the primer. The time taken to complete these functions, no matter how infinitesimal, is known as lock time. It varies from about .0057 second for the slowest to around .0022 second for the fastest, depending on the type of action; even individual actions of the same make differ to a slight degree. Lock time is governed by (1) the distance the firing pin must travel, (2) the weight of the firing pin or striker, and (3) the amount of pressure or tension exerted by the mainspring.

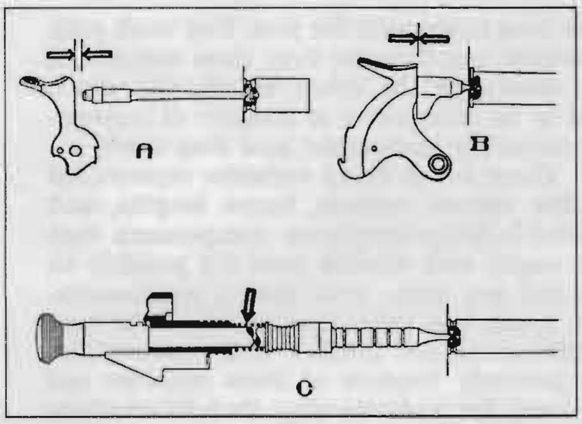


FIGURE 2 — The three types of firing pin fall: A illustrates the inertia system wherein the pin is unsupported (as in the M1911 Colt semi-auto); B is typical of instances where the hammer supports the pin at ignition (as in many lever and single-shot actions); C shows a typical bolt-action design wherein the pin is supported by the mainspring (as in the Springfield 1903).

The obvious advantage of a fast lock time is that, when the sights are on target and the trigger is pulled, the cartridge is ignited and the bullet is on its way *before* the sights can waver off. This is a matter of practical marksmanship. It has nothing to do with interior ballistics.

A second factor, the speed — or more properly, the energy — of the striker as it hits the primer, has much to do with ballistics. If the primer isn't struck hard enough, it doesn't explode properly and either a hang-fire (delayed ignition) or erratic accuracy results.

Slow lock time isn't particularly objectionable if the striker delivers sufficient energy to explode the primer properly. (A heavy striker moving slowly, and a light striker moving rapidly, can produce the same *energy.)* When, however, slow lock time is caused by a weak mainspring, dirt, or other factors, it can have a very adverse effect on interior ballistics, as we shall see.

PRIMER IGNITION

The primer is the heart or "spark plug" of the cartridge, and far more important than most shooters realize. Primers *explode* upon impact; gunpowders *burn* upon ignition. The primer is an energy output entity in its own right, contributing from 4% to about 6% of the total pressure generated by a given cartridge. When a primer explodes properly, it spews a flame of white hot gas through the air spaces between the powder granules, igniting them almost simultaneously. Average ignition time is almost .0002 second. Contrary to widespread belief, the purpose of the primer is *not* that of "kindling" and "starting" a few powder granules at the bottom of the case which then burn upward. A properly constructed and properly struck primer floods the entire case with hot gas, causing near-instant ignition of all powder particles (see Figure 3).

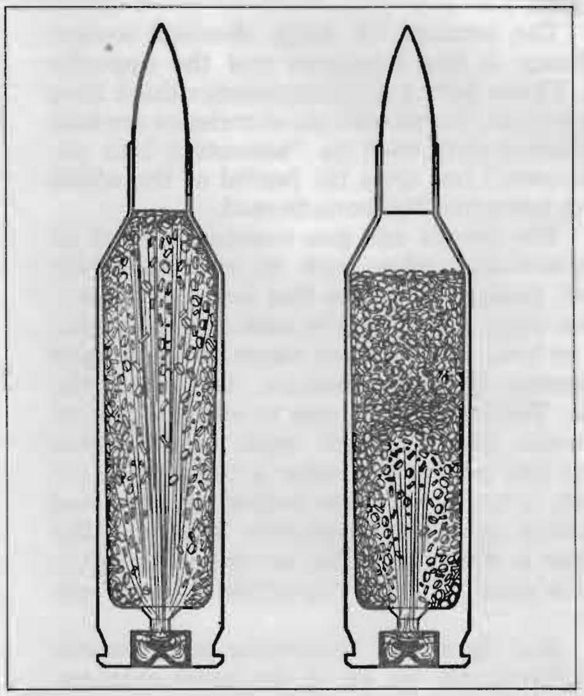


FIGURE 3 — Perfect and incomplete primer ignition. The drawing at the left shows instantaneous ignition due to the right size primer and proper firing pin fall. At the right, you see what happens when firing pin fall is too light or when a standard primer is used in a magnum case.

When a primer is struck weakly, the amount and temperature of the primer flame are reduced proportionately. The primer then *does* act as "kindling" and because of slow and inefficient powder burning, anywhere from 100 to 200 fps velocity is lost.

This is why slow lock time resulting from malfunction greatly influences interior ballistics.

Fine-grain powders, usually used in smaller cases, are more easily ignited than the large-grain powders used in large and magnum size cases. It is for this reason that we now have magnum primers — to provide better and faster burning of large powder granules in the ever growing family of magnum cartridges.

MANY DIFFERENT TYPES OF PRIMERS

As shown by the Primer Interchangeability Chart (see Table 1), there are eight different types of primers in wide use today. All are of the standard Boxer type (see Figure 4), and all are of one of two diameters. Small rifle and small pistol primers, standard and magnum, are of .175" diameter. Large rifle and large pistol primers, standard and magnum, measure .210" in diameter. Within these diameter similarities, there are many substantial differences.

BOXER PRIMER INTERCHANGEABILITY CHART

PRIMER TYPE	ALCAN	CIL	FEDERAL	HODGDON	NORMA	OMARK CCI	REMINGTON	WIN-CHESTER WESTERN	RWS
SMALL PISTOL	SP	1	100	SP	SP	500	1½	1½-108	4031
SMALL PISTOL MAGNUM	–	–	–	–	–	550	5½	1½M-108	–
LARGE PISTOL	LP	2½	150	LP	LP	300	2½	7-111	5337
LARGE PISTOL MAGNUM	–	–	–	–	–	350	–	7M-111F	–
SMALL RIFLE	SR	1½	200	SR	SR	400 BR-4	6½	6½-116	4033
SMALL RIFLE MAGNUM	–	–	–	–	–	450	7½	–	–
LARGE RIFLE	LR	8½	210	LR	LR	200 BR-2	9½	8½-120	5341
LARGE RIFLE MAGNUM	–	–	215	–	–	250	9½M	–	5342

TABLE 1

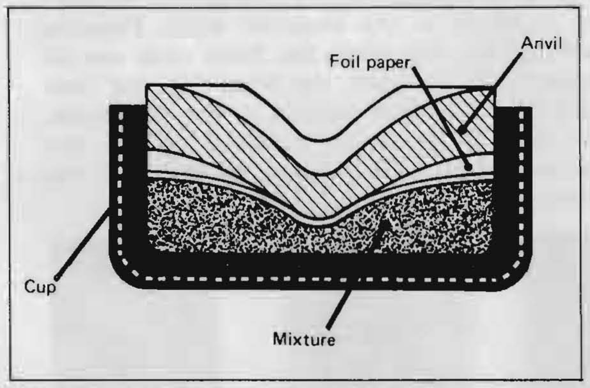


FIGURE 4 — Boxer primers all embody the same construction principle, but vary in cup thickness and in the explosive intensity of the mixture. The dotted line approximates the relative thickness of a pistol primer compared to a rifle primer.

Rifle primers of all types are of greater overall height, contain a more potent explosive pellet, and have thicker cups because of the heavier firing pin blow and the fact that rifle cartridges generate much higher pressures than do pistol cartridges. Non-magnum centerfire cartridges operate at pressure levels as low as 12,000 psi for handguns and as high as 50,000 psi for rifles.

Magnum primers, while of the same dimensions as their standard counterparts, contain a larger or more intense explosive charge. They are used with some of the slower burning ball powders, with the coarse extruded powders in large cases, and in comparatively small cases when the ammo will be used in sub-zero temperatures. Primers are extremely sensitive to cold. When exploded at a normal 70^{o}F., the primer initially generates as much as 10,000 pounds of pressure per square inch. However, the flame is rapidly cooled by the "cold" powder and case, resulting in a psi level of about 2,000 (more for magnums).

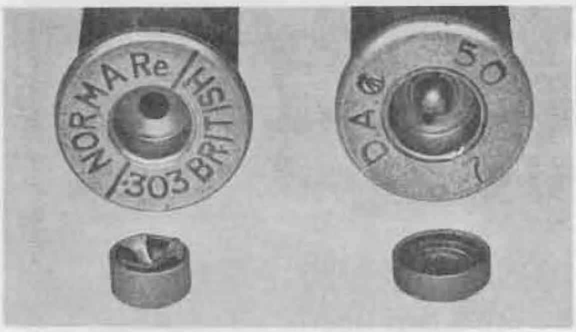


FIGURE 5 — Primers are tiny, yet they generate (initially) as much as 10,000 psi! The case at the right is the Berdan type (note the protruding anvil).

The use of magnum primers where standard primers *should* be used doesn't increase the speed of combustion (except in cold weather, as noted). It's like shooting a deer with a .460 Weatherby. The more powerful primer succeeds only in raising overall chamber pressure and usually in widening bullet groups.

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.

PRIMERS ARE NOT INTERCHANGEABLE

Cartridge cases are recessed to fit a specific diameter primer, but this doesn't preclude the possibility of using the wrong *type* of primer. For example, you *could* insert a small rifle primer in a pistol case. Because of the thicker cup, it's likely that the light firing pin blow wouldn't detonate the primer. If it did explode, the hotter pellet would vastly boost pressure within the small case, creating a possible hazard to the shooter and certainly spoiling accuracy.

PROGRAMMED EXERCISE

1

From Table 1, indicate which primer should be used in each of the following:

Manufacturer & Primer Type	Designated Primer
1. Alcan, small pistol	SP
2. Omark CCI, small pistol magnum	550
3. Federal, large pistol	150
4. Winchester, large pistol magnum	WM-111F
5. Hodgdon, small rifle	SR
6. Remington, small rifle magnum	7½
7. Norma, large rifle	LR
8. RWS, large rifle magnum	5342

9. F True or false? Because of the relatively short barrel length in handguns, more explosive pellets are used in handgun primers than in rifles to assure more complete powder burning before exiting the barrel.

Answers on Page 6

Conversely, a pistol primer used in a rifle case can also cause problems. The heavier firing pin impact on the thin cup may puncture the cup, causing blowback of hot gases. If the cup isn't punctured, it may still rupture and lead to gas blowback because of the rifle's comparatively high chamber pressure.

Don't take chances. Primers may look alike, but there's a big difference. Store them in their original boxes, and after loading return them to those boxes for positive identification and *safety*. A mixup can result in poor accuracy at the very least, in possible injury to yourself or bystanders at the worst.

POWDER BURNING

There are many different types of smokeless powder, varying widely in appearance, density, and burning rate. And the latter, more than any other factor in internal ballistics, governs the bullet velocity, accuracy, and chamber pressure of any cartridge. We will discuss the various powders and their characteristics a bit further on. For now, let's talk about what happens following the primer explosion (assuming the powder used is reasonably suitable).

As the primer flame jets into the cartridge case, the exposed surfaces of the powder granules are ignited. Gas is formed, the interior of the case begins to heat, and heat pressure "bounce-back" from the case walls makes the powder burn faster and faster. More gas is formed, which thrusts violently against the sides of the case, causing the case to expand and conform to the chamber walls. Pressure rises rapidly, and when the brass walls can no longer move outward, the brass "ripples" forward in a wave-like motion to the case neck. The neck then swells outward against the chamber slope and releases its hold on the bullet.

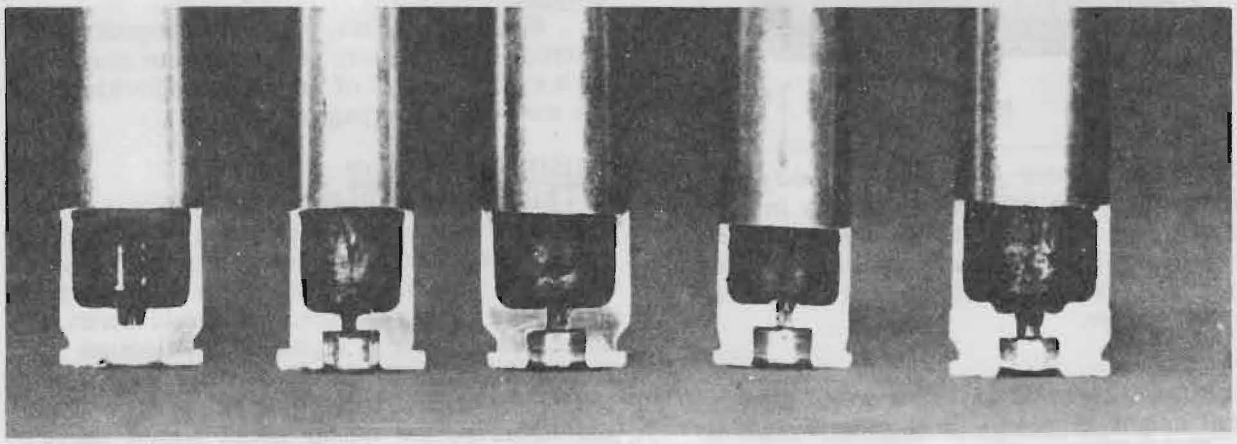


FIGURE 6 — These different types of rifle cases all handle the same large rifle size primer. However, magnum primers are indicated for the belted magnum case at the right, and are sometimes used in the rebated case shown in the center. (Illustration courtesy Speer, Inc.)

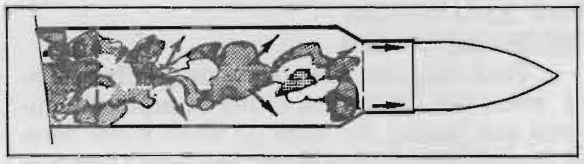


FIGURE 7 — When the case walls are pressed firmly against the chamber, gas pressure causes the brass to "ripple forward," thus relaxing the tension of the neck around the bullet.

HOW PRESSURE BUILDS UP

When the case has expanded to its limit, the rapidly expanding gas has nowhere to go but forward, as the bullet is the only movable object (other than the gas itself). Acting against the base and inertia of the bullet (the tendency of a body at rest to remain at rest), the now furiously burning powder builds up the gas volume and pressure until the bullet moves forward and engages the rifling. There, the ever increasing pressure forces the bullet jacket to indent to accommodate the rifling grooves, thus achieving a tight gas seal (see Figure 8).

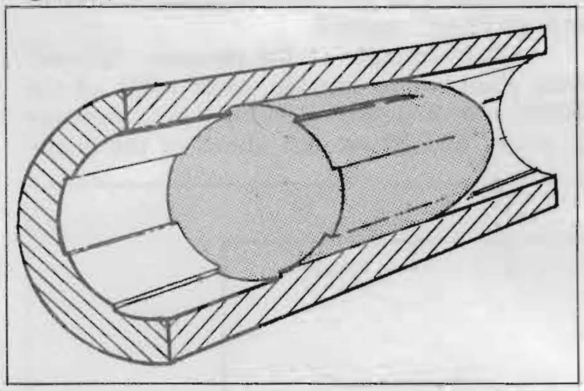


FIGURE 8 — The bullet diameter is the same as the bore diameter. For a bullet to fit, the grooves are "engraved" on the bullet by gas pressure, thus creating a snug seal.

If the chamber is free-bored or has a long throat (non-rifled area) between the bullet and the rifling, a small amount of gas may escape around the sides of the bullet before it reaches the rifling and the case neck will often be powder-smudged on the *outside.*

As the bullet enters the rifling and seals off the bore, the chamber pressure is at or approaching maximum. *Where* peak pressure occurs is most dependent upon the type of powder used; other factors, however, enter the picture. A "tight" barrel or one that is badly fouled or leaded can boost pressure; a rifle with a fast, say 1-9, twist will raise the pressure higher than one with a slower 1-14 twist — all else being equal. The length of the throat or "freebore" has a big influence on pressure.

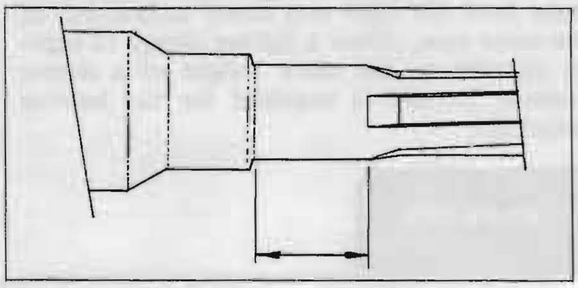


FIGURE 9 — The chamber cast shows the leade or "throat" in a slightly free-bored rifle. This is the area where gas can slip around the sides of the bullet, causing smudging of the case neck, before the bullet enters the rifling.

The temperature of the cartridge itself bears on pressure. Identical cartridges, one fired in sub-zero temperature, the other after sitting in the blazing sun for a few minutes, can show a pressure differential of 6,000 psi and more (see Table 2)!

VARIATION OF MUZZLE VELOCITY WITH POWDER TEMPERATURE

Temperature Degrees Fahrenheit

0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
2631	2641	2648	2657	2668	2682	2700	2722	2750	2784	2827
2733	2738	2746	2755	2767	2782	2800	2823	2851	2887	2931
2830	2836	2846	2854	2866	2881	2900	2924	2953	2990	3036
2928	2934	2942	2952	2965	2981	3000	3025	3055	3093	3141
3025	3032	3040	3051	3064	3080	3100	3125	3157	3196	3246
3127	3130	3138	3149	3163	3179	3200	3226	3258	3299	3350
3221	3228	3236	3248	3261	3279	3300	3327	3360	3402	3453
3318	3325	3334	3346	3360	3378	3400	3428	3462	3505	3560
3416	3423	3433	3444	3459	3477	3500	3529	3564	3608	3664
3514	3521	3531	3543	3558	3577	3600	3629	3666	3711	3769
3611	3619	3629	3641	3657	3676	3700	3730	3768	3814	3874
3709	3717	3727	3740	3756	3775	3800	3831	3870	3918	3978
3806	3814	3825	3838	3854	3875	3900	3932	3971	4021	4083
3904	3912	3923	3936	3953	3974	4000	4033	4073	4124	4188
4001	4010	4021	4035	4052	4073	4100	4133	4173	4227	4292
4099	4108	4119	4133	4151	4173	4200	4234	4277	4330	4398

These data were not obtained from High Velocity firings of rifle cartridges, but, rather, indicate what may be expected from progressive burning smokeless powder with normal density. They are, however, in approximate agreement with scattered and meager data available for rifle cartridges. Cartridges with very high loading density and high chamber pressures may vary quite considerably, with respect to temperature changes, from the above values. It should be remembered that even carefully loaded cartridges fired at constant temperature will show variations in muzzle velocities of from 10 to 80 f/s from one shot to the next. This table will serve, however, to indicate the direction and approximate magnitude of the effect of temperature changes.

TABLE 2

The weight of the powder charge and the type of powder must always be balanced to bullet weight. The right charge for a 150-grain bullet would generate sky-high pressure behind a 180-grain bullet because of the added resistance (weight) against a given gas volume. Heavier bullets not only require a slower energy release than light bullets, but they also have a longer bearing surface (within a given caliber) which creates additional friction and pressure. To keep chamber pressure at the same level for light and heavy bullets out of the same case, either a lighter charge of a given powder or the same weight of a slower burning powder is required for the heavier projectile.

ANSWERS

1	
1.	SP
2.	550
3.	150
4.	7M-111F
5.	SR
6.	7½
7.	LR
8.	5342
9.	False

WHY AND WHERE PRESSURE DROPS

Peak chamber pressure is normally reached when the bullet has either completely entered and sealed the bore or when it has passed two to four inches down the bore (depending on the variables previously mentioned). At this point the powder is burning faster and hotter than ever, yet from then on, until the bullet clears the muzzle, the pressure drops. The reason is that the farther the bullet moves up the bore, the larger the area in which the gases can expand. The powder is still burning, still generating gas, and because the initial inertia of the bullet has been overcome, it constantly accelerates and continues to accelerate until the bullet leaves the muzzle.

Most medium to large-case cartridges, such as the .30/06 on up, require barrels of 30 to 32 inches to completely burn the powder which, of course, aren't practical. Even longer barrels would *reduce* velocity because of bullet/bore friction after the powder stopped burning. Shorter barrels reduce velocity proportionate to the amount of barrel removed (and "fuel" wasted).

As an example of the pressure "spread" from chamber to muzzle, most rifles of the .30/06 and .270 genre develop a peak pressure of about 50,000 psi just ahead of the cham-

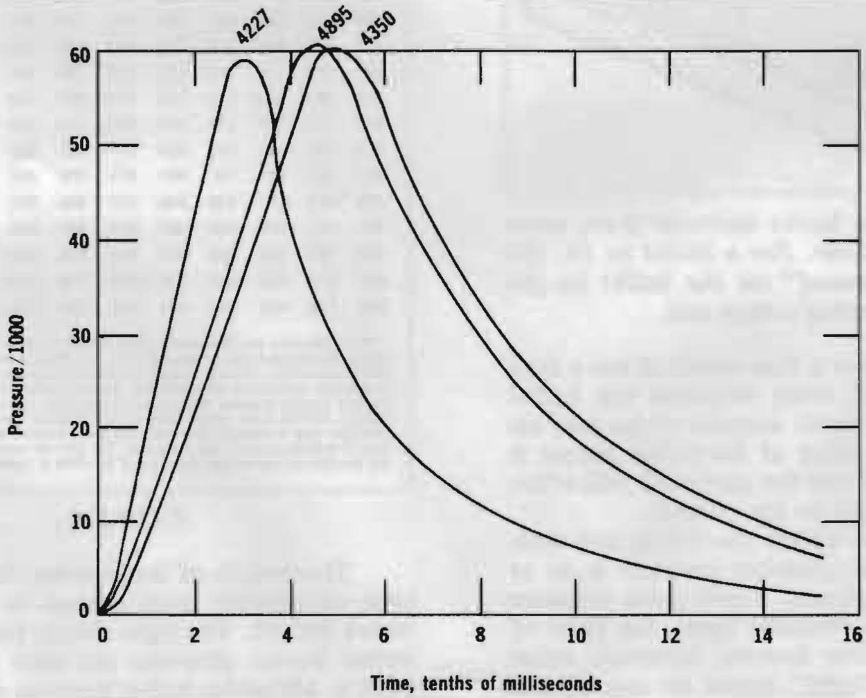


FIGURE 10 — Pressure curves for three different powders behind a 180-grain .30/06 bullet. The fastest burning powder, 4227, reaches a pressure of about 58,000 pounds with a light 28.5-grain charge; the next fastest, 4895, hits around 60,000 pounds with a 47.5-grain charge. The slowest burning, 4350, requires 57 grains to reach the same pressure level. The faster burning the powder, the less powder required behind a given bullet to achieve a given pressure range.

ber. At the muzzle, pressure drops to anywhere from 8,000 to 12,000 psi, depending on the expansion ratio (which we'll discuss a bit later). Magnum rifles have much higher muzzle pressures, often in the 30,000 psi range. Figure 11 includes a typical pressure curve from chamber to muzzle for the .30/06 service cartridge.

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.

BARREL TIME

The amount of time it takes for a bullet to travel through a barrel is so short as to appear insignificant; yet it *is* part of interior ballistics.

Let's take a .30-caliber 150-grain bullet moving at 3,000 fps out of a 24" barrel. This 3,000 fps figure, translated, means that the bullet travels one foot in 1/3,000th of a second. It follows that when the bullet moves two feet (the length of our barrel), the time involved is 1/1,500th of a second, or twice as long. Expressed in decimals, this is .00067 second.

Sounds logical, *doesn't it?* However, the conclusion is wrong. Slightly. The error lies in the fact that a bullet *gains speed* in the bore. It starts out relatively slowly when the pressure is the highest, but is moving fastest at the muzzle where the pressure is the lowest. When plotted on a chart (see Figure 11), it can be seen that the velocity curve of the constantly accelerating bullet results in an *average speed* during its travel through the barrel equal to about two-thirds of the muzzle velocity.

Our *average speed* is thus 2,000 fps, meaning that the bullet moves one foot in 1/2,000th of a second. It therefore moves two feet (the length of the barrel) in 1/1,000th of a second. Barrel time, expressed decimally, is actually .0010 second.

For practical purposes, the barrel time of any rifle may be calculated on the basis of the average bullet velocity while in the barrel, which is *two-thirds* the muzzle velocity.

The time intervals relating to interior ballistics, which include lock time, ignition time, and barrel time, average out as follows:

Lock time	from .00220 to .0057 seconds
Ignition time	from .00020 to .0002 seconds
Barrel time	from .00075 to .0015 seconds
Total time	from .00315 to .0074 seconds

The above figures represent the "spread" in time, from squeezing of the trigger to the instant the bullet leaves the bore, in most modern sporting rifles.

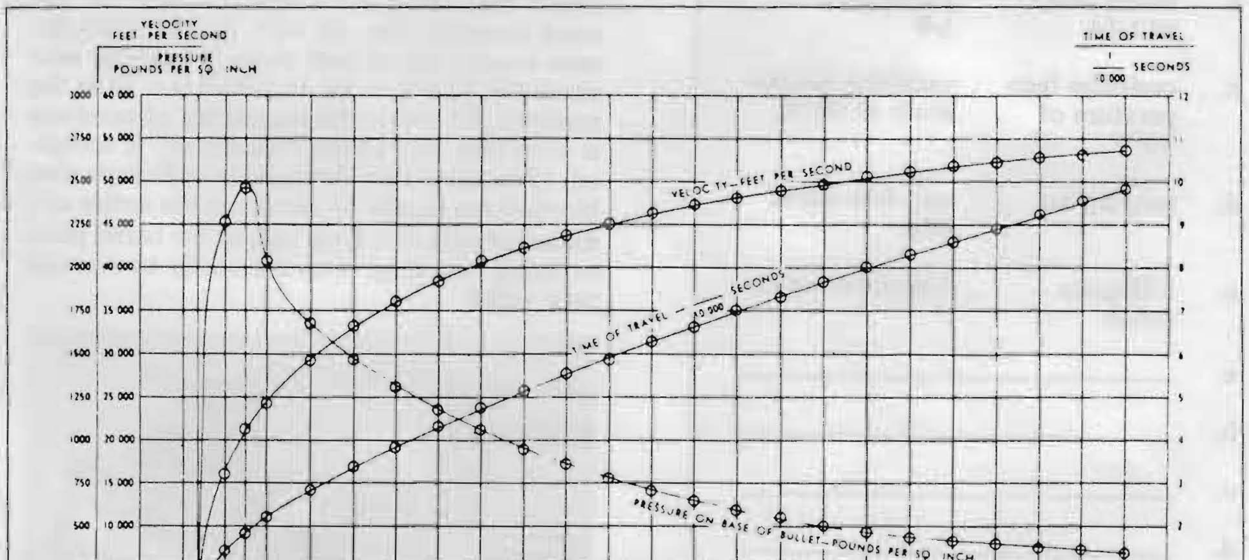


FIGURE 11 — Interior ballistics curves for U.S. Rifle Cal. .30, M1903, using 150-grain M1906 flat-base bullet with approximately 50 grains Pyro D. G. powder, giving 2,700 fps muzzle velocity. (From Hatcher's Notebook, The Stackpole Co., Harrisburg, Pa., by permission)

PROGRAMMED EXERCISE

2

1. What would happen if a pistol primer was used in a rifle case?

2. True or false? Primers are extremely sensitive to cold temperatures.

3. True or false? To achieve maximum velocity with a .30/06 cartridge, you would have to fire it from a 30" to 32" barrel since a shorter barrel would not permit complete burning of the powder.

4. What effect does a *long throat* (space between bullet and rifling) have on the gas seal in a rifle?

5. State whether the conditions in Column A would contribute to *higher* or *lower* chamber pressures than the conditions in Column B.

	Column A	Column B
a.	tight barrel	normal barrel
b.	rifling twist of 1-14	rifling twist of 1-9
c.	cartridge temperature of 70°F.	cartridge temperature of 20°F.
d.	long throat	non-free-bored rifle
e.	150-grain bullet	180-grain bullet

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

6. What would probably happen if you could insert a small rifle primer in a pistol case?

Answers on Page 10

INTERIOR BALLISTICS — PISTOLS

Much that has already been said applies to handguns as well as to rifles. There are differences, of course, but they stem primarily from a pistol's relatively small case, short barrel, and short, blunt bullet. The principles of primer ignition, combustion, pressure, and velocity are the same as those governing a rifle's internal ballistics.

Factors affecting the internal ballistics of handguns include the design of the gun itself, and to a much greater degree than "design" influences the ballistics of a rifle. Handguns with integral (one-piece) barrels and chambers, such as the various semi-autos and single-shots, have different ballistics for a given cartridge than guns with separate chambers (that is, revolvers). Also, revolvers fired single-action have different ballistics than those fired double-action, when the cartridge is identical.

Other than barrel length, which has a great deal to do with velocity in any rifle or pistol, let's see what gun design has to do with handgun ballistics. Semi-autos and single-shots have no gas leakage design-wise because the chamber is part of the barrel. Revolvers, on the other hand, have a gap of approximately .005" between the front of the cylinder (chamber) and the bullet entry point of the barrel (see Figure 12). As the bullet passes this gap, gas escapes out the sides. In the few instances where semi-autos and a few revolvers fire the same cartridge (the .45 ACP, for example), the auto-loading pistol will show a velocity substantially higher — up to 100 fps — than the revolver. However, the popularity of revolvers is such that this design "weakness" is accepted. (Revolvers have been made in Europe that blocked gas escape by camming the entire cylinder forward and flush against the barrel prior to firing, but they were too costly to ever sell very well.)

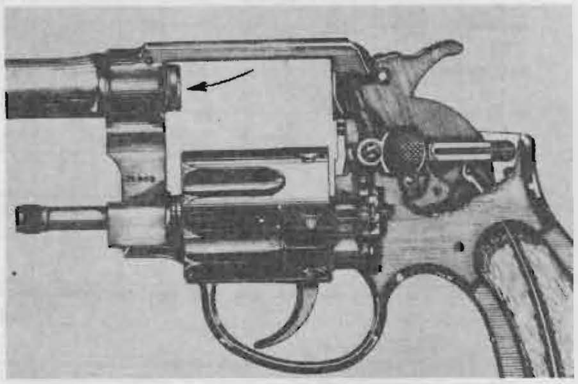


FIGURE 12 — Revolvers have a gap of approximately .005" between the cylinder and the "bell" of the barrel, through which gases escape, thus reducing velocity.

DOUBLE VS. SINGLE-ACTION REVOLVERS

A revolver fired double-action will usually group its bullets several inches lower than the same gun firing the same cartridge single-action. The reason has to do with firing pin fall. The harder a primer is struck (within limits), the greater the heat and the volume of primer flame. Because of design and construction (see Figure 13), the firing pin fall and impact is substantially less when a revolver is fired double-action. This is especially true of the .357 and .44 magnum guns where the relatively heavy cylinders require more of the energy or "moving power" provided by pulling the trigger, leaving less for cocking the piece.

Single-action firing permits the firing pin to indent the primer properly, resulting in better ignition and higher velocity.

FIGURE 13 — Revolvers like the S&W .44 magnum group bullets at a lower center of impact when fired double-action. Activation of the cocking mechanism by trigger pull "robs" the firing pin of much of its impact energy.

HANDGUN POWDERS AND BARREL LENGTHS

All handgun powders, because of the small case capacities and short barrels involved, are relatively small-grained and fast-burning. They must exhaust their energy potential in a very short time. The largest magnum handguns, when equipped with the longest practical barrels, burn the slowest handgun powders — which, conversely, are the fastest burning rifle powders.

Barrel length has more to do with a handgun's efficiency than a rifle's efficiency. The velocity loss per inch of barrel "removed" is proportionate, but because the handgun has so little velocity to start with and velocity falls off so rapidly, even a slight reduction is significant. As a rule of thumb, handguns lose from 25 to 50 fps velocity for each inch removed from a six-inch barrel.

FIGURE 14 — Snub-nosed "detective specials" like the .38 S&W shown bark worse than they bite. The short barrel significantly reduces muzzle velocity and energy while increasing muzzle blast.

How greatly a four-inch barrel reduction influences the "efficiency" of a handgun has been proved many times by police and sheriff departments. Tests of .38 Specials with two-inch "detective-length" and six-inch "service-length" barrels have shown that a bullet from the stubby gun will often fail to penetrate a car door at close range. A bullet from a six-inch barrel, driven by the same powder charge and fired from the same distance, usually whistles clean through and has sufficient energy remaining to ruin a felon's whole outlook.

Muzzle velocity figures published by handgun ammo manufacturers are usually taken with six-inch barrels.

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.

HANDGUN PRESSURE LEVELS

Compared to a rifle, everything to do with a handgun is smaller — including the operating pressures. Modern rifles average a chamber pressure of around 50,000 psi; modern handguns, with the exception of the magnums, operate at a pressure level of 12,000 to 18,000 psi. The magnum handguns sometimes have pressures as high as 40,000 psi — about that of a .30/30 rifle.

Revolvers manufactured for standard-intensity cartridges such as the .38 Special should never have their chambers reworked and run out the extra 1/10" necessary for conversion to .357 magnum caliber. The internal dimensions may be correct, but there's a whale of a difference pressure-wise, and the standard .38's are seldom stressed to safely handle the more powerful cartridge. The same holds true for extending the chambers on .44 Specials to accommodate the .44 magnum cartridge.

PROGRAMMED EXERCISE

3

1. True or false? The time from squeezing the trigger until the bullet leaves the bore includes lock time, ignition time, and barrel time. This entire process takes *less than* 1/100th of a second (.01 second) in even the slowest ignition system.

2. When revolvers and semi-auto pistols fire the same cartridge, the bullet fired from the auto-loading pistol has more velocity. Why is this true?

3. A revolver fired double-action will usually group its bullets several inches lower than the same gun firing single-action. Why is this true?

4. True or false? Handgun powders, when compared to rifle ammo, are relatively large-grained and slow-burning.

Answers on Page 12

ANSWERS

2

1. A blowback of hot gases would result if the firing pin ruptured the thin primer cup.

2. True.

3. False.

4. A small amount of gas may escape around the sides of the bullet before it reaches the rifling, delaying the seal, and the case neck will often be smudged on the outside.

5. a. Higher b. Lower c. Higher
   d. Lower e. Lower

6. The firing pin blow would not be likely to detonate the primer; if it did, pressure would be boosted so as to create a hazard to the shooter.

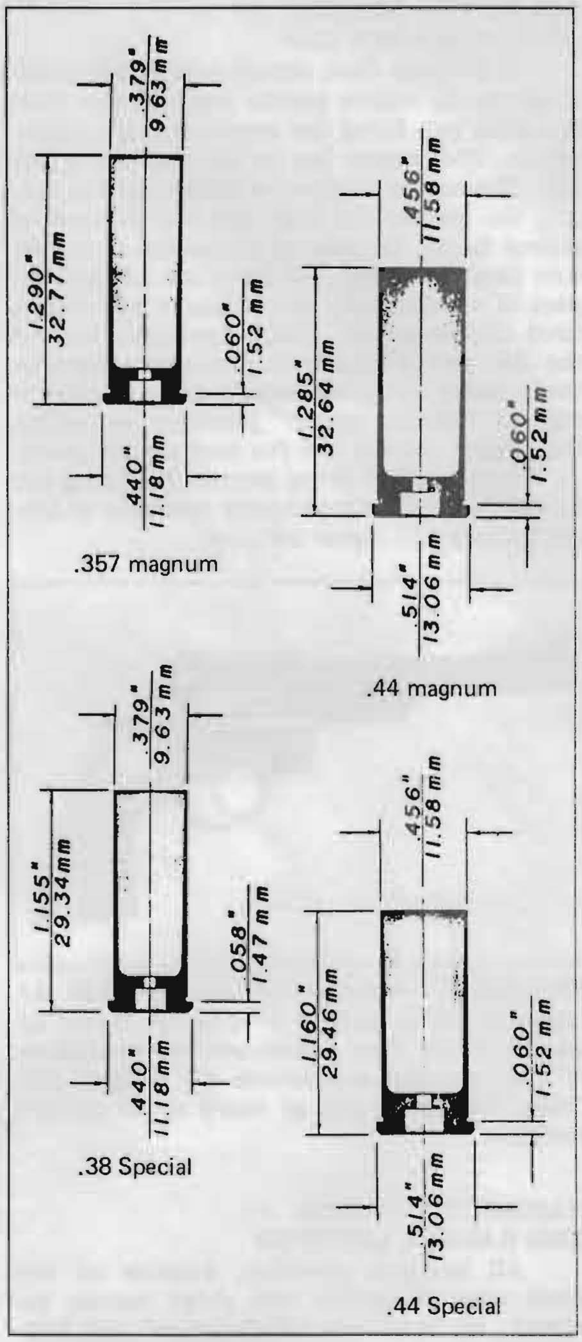


FIGURE 15 — Cartridges such as the .44 and .357 magnums shown at the top pack a lot more punch and pressure than their standard counterparts. Standard-caliber revolvers should never be rechambered for magnum, but same-caliber cartridges.

All magnum handguns incorporate stronger metallurgy and are stressed to absorb and withstand the shock of powerhouse cartridges. Even so, such guns often "shoot loose" after continued use and should be checked constantly to make sure that screws are tight and that there are no incipient fractures in the springs, frame, or other components.

HANDGUNS COMPARED TO RIFLES — BALLISTICALLY

Handguns function ballistically in the same manner as rifles. They use primers of lower intensity and with softer cups because the firing pin blow is lighter. Pistols utilize faster burning powders because most cases are straight-walled, fairly short, and used with short barrels. Bullets used in handguns are invariably of low sectional density and ballistics coefficient, and because of their comparatively low muzzle velocity are classified as short-range service or hunting guns.

Pressures are quite low as compared to rifles, with the exception of the magnums, which are similar to those of low-powered center-fire rifles. Handguns that are not made for magnum cartridges should never be altered to accommodate such cartridges. Now let's get on with our study of interior ballistics. Much of that which follows, excepting the section on the Powley computer, also applies to handguns.

SMOKELESS POWDER

Blackpowder was used for more than 600 years with little change or refinement other than grinding the basic commodity into various granule sizes. Smokeless powder, by way of contrast, was invented and developed to its present high efficiency in less than 100 years.

It all started in the mid-1840's, when two European professors decided to dunk ordinary cotton in nitric acid. The result was nitrocellulose, the basic ingredient of today's gunpowder. When dried and ignited, the substance blazed like the fires of Hades. The new "gun cotton," when stuffed into experimental small arms of the period, usually damaged or blew up the guns. It simply burned too fast and raised pressures too high to be a satisfactory propellant.

The First Powders Were Single-Base

In 1874 the French chemist Vieille came up with the idea of dissolving (colloiding) nitrocellulose in an ether alcohol solution. The resulting glue-like substance, when dried, rolled in thin sheets, and chopped into flakes, burned much slower than the original gun cotton. Other granule configurations, notably the extruded cylinder, were tried and found even more efficient, and smokeless single-base powder had arrived. (The fact that the new powder was "smokeless" was a happy happenstance. The goal was a more powerful propellant, and one that didn't badly foul bores!)

The present IMR (Improved Rifle Military) single-base powder series by Dupont consists of extruded cylindrical tubes of varying diameter and length and is similar to Vieille's basic invention. A single-base powder is one in which the *only* flammable ingredient is nitrocellulose.

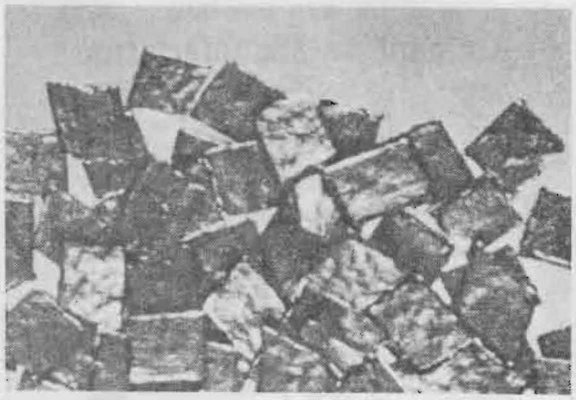


FIGURE 16 — The first smokeless powder was of the flake variety, similar in appearance to Rottwell No. 5, shown above. As fire-retardant coatings weren't yet invented, the flakes burned too fast for the guns of the period.

DOUBLE-BASE POWDERS

It wasn't long after Vieille's discovery that Alfred Nobel, the inventor of dynamite and nitroglycerine (dissolved dynamite), found that nitroglycerine was also a good solvent for gun cotton. The new mixture, when dried, rolled, and flaked or extruded, delivered a "double whammy." This figured. The solvent was about as explosive as the nitrocellulose itself! Because of the dual energy potential, Nobel's new powder was known as "double-base."

Today double-base powders, because of their high energy in relation to volume, are most often used in small rifle and pistol cases and in shotgun shells — all of which utilize relatively small amounts of powder in relation to heavy projectile weight.

Powder Granules, Shapes and Sizes

The first smokeless powder was flake-like, which burned too fast for most rifles of the time. As the concept of coating powder granules to deter burning hadn't yet arrived, early ballisticians sought a solution to the problem by varying granule shape. Productionwise, the extruded cylinder granule was easy to make in various diameters and lengths as spaghetti and provided a partial solution. The only problem was that burning rates were controlled solely by granule size, and the granules that burned "right" were frequently too large to conveniently load into a case neck. (The British called one of their early powders "Cordite" because of its chopped-cord appearance.)

FIGURE 17 — George Kynoch, an associate of Nobel, founded one of the world's first and largest ammo manufacturing firms. The above 1884 advertisement shows the scope of the Kynoch line over 90 years ago.

ANSWERS

3

1. True.
2. Gas leakage in the revolver, between the chamber and the barrel, reduces the pressure in revolvers. Since the chamber is part of the barrel in semi-autos, the leakage does not occur there.
3. Firing pin fall is less when fired from double-action as opposed to single-action because the heavier cylinders in the double-action require more energy to start motion upon trigger pull, leaving less remaining energy for the cocking piece and a weaker primer impact, resulting in less bullet velocity.
4. False.

Following the invention of the burn-retardant coating in the early 20th century, which represented the first really practical method of controlling burning, the science of powder engineering advanced rapidly. In the 1930's Olin Industries (Winchester) developed the first ball, or spheroid-shaped, powder. In the manufacturing process, the nitrocellulose was not extruded or rolled into sheets as with other powders; it was first dissolved in lacquer, then nitroglycerine was added. Then, as today, the solution of nitrocellulose, lacquer, and nitroglycerine was agitated under water, causing small balls of "slurry" (as it's called) to form. The size of the balls can be controlled by screening in manufacture. Some of these balls are left as is after drying; others are rolled and flattened; still others are mixed into a blend of spheroid and flattened granules.

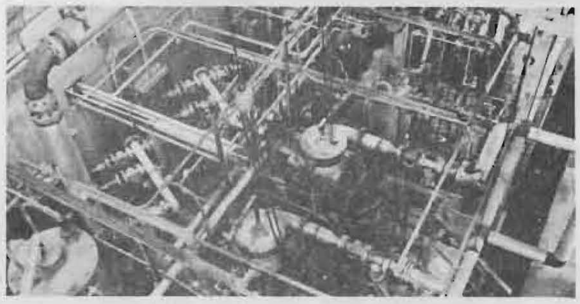


FIGURE 18a — The manufacturing process for ball powder begins with dissolving nitrocellulose in an organic solvent, which forms a thick lacquer of bread dough consistency. This is forced through a sieve-like plate and into a water solution, where spinning blades cut the strands into desired lengths. Granule size is controlled by the size of the "sieve holes" and the speed of the blades.

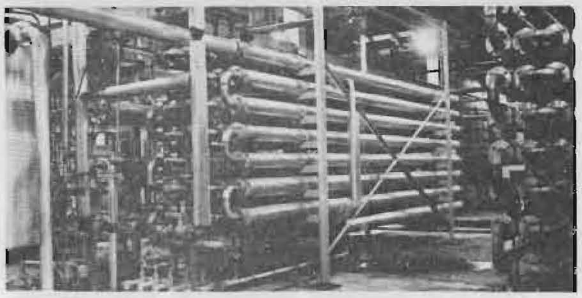


FIGURE 18b — Ball powders achieve their spheroid shape in these long pipes, where, carried in a water solution, they are rounded by their own surface tension, much as lead shot is rounded in a drop tower. A heat process then evaporates the solvent and the tiny powder balls are screened for size, flattened, impregnated with nitroglycerine, coated with a burn-retardant, and otherwise treated to produce the desired size and burning characteristics.

Today we have a great many powder granule shapes — the familiar extruded "stick" propellants with or without hollow centers, round or square flakes cut from sheets, and round and flattened balls (see Figure 19).

The granule shape, size, and coating determine the burning rate of any powder and its suitability for a given series of cartridges or shotshells. To a lesser extent, powder size and shape are governed by ease-of-loading requirements. Commercial ammo seldom, if ever, utilizes "stick-type" propellants unless very small because of possible "log jams" and/or inconsistent powder throws with automated loading equipment. This is undoubtedly the main reason why Olin developed the ball-type powders — they flow evenly and "drops" are uniform in commercial (and handloading) powder measures.

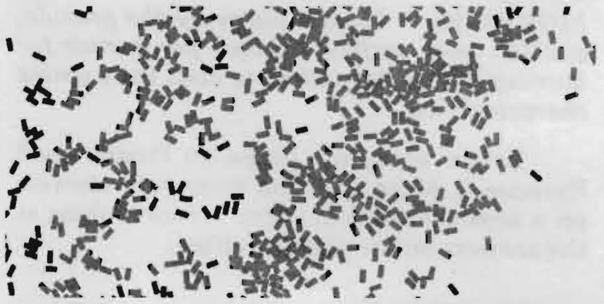
Modern smokeless powders, in addition to burn-retardant coatings, contain a number of additives to reduce muzzle flash, lengthen shelf life, and stabilize the volatility of the powder. Regardless of the *type* of powder, the final stage in manufacture is tumbling of the granules in graphite. This process is called *glazing;* it adds slightly to the burn-deterrent effect of the coating and reduces static electricity, thus permitting the granules to flow more evenly in powder measures.

Characteristics of Burning

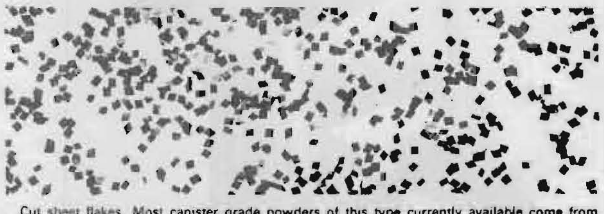
Smokeless powders are made in various sizes and shapes for one reason — to control the rate of burning in cartridges of a given case capacity with bullets of a given weight. The margins of optimum performance for one particular case/bullet combination are quite narrow, which is why we have so many different types of powder. For example, the most efficient powder for use with a .30/06 180-grain bullet is IMR 4350, for a 150-grain bullet, the faster burning IMR 4320. Parallels are found among all calibers and cartridges.

Smaller powder granules burn faster than larger granules because more surface area *per granule* is exposed to initial ignition, and powder burns by the granule. In other words, two granules, each 1/8" long, will burn twice as fast as one granule 1/4" long of the same diameter. The same energy is released, but the two small granules release it faster. This is why smaller granules are used in smaller cases. They don't have as much room (and time) for burning. Use too large a powder granule size in small cases and many of these granules will be blown out of the barrel unburned.

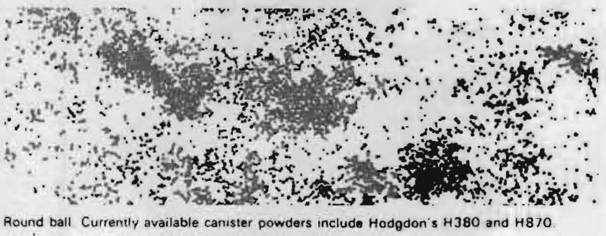
Conversely, when, say, 50 grains of a small, fast-burning powder are loaded into a case where 50 grains of a slow-burning powder *should* be used, the gun will probably



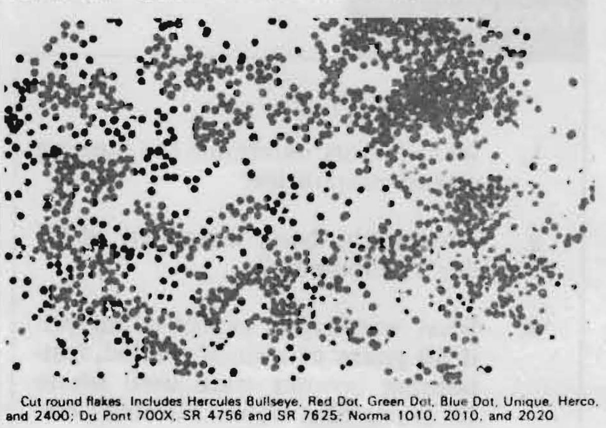
Extruded tubular kernel powder. This type includes the DuPont IMR 3031, 4065, 4198, 4227, 4320, 4350, 4895, 4831, and DuPont SR 4759; Norma 200, 201, 203, 204, 205, and 1020; Hodgdon H-4198, H-4227, H-4831, H-4895 and H-570



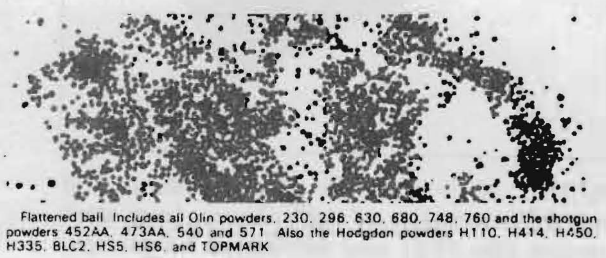
Cut sheet flakes. Most canister grade powders of this type currently available come from Europe. Only Alcan AL5, AL7, and AL8 are available in the U S



Round ball. Currently available canister powders include Hodgdon's H380 and H870.



Cut round flakes. Includes Hercules Bullseye, Red Dot, Green Dot, Blue Dot, Unique, Herco, and 2400; Du Pont 700X, SR 4756 and SR 7625, Norma 1010, 2010, and 2020



Flattened ball. Includes all Olin powders, 230, 296, 630, 680, 748, 760 and the shotgun powders 452AA, 473AA, 540 and 571. Also the Hodgdon powders H110, H414, H450, H335, BLC2, HS5, HS6, and TOPMARK

FIGURE 19 — Types of canistered powder.

blow up. The same *amount* of energy is released — but the small granules release it too fast, causing pressure to build up too rapidly. Therefore, small-granule, fast-burning powder is almost always used in small rifle and pistol cases; large-granule, slow-burning powders in large cases. There are exceptions, such as when a large case is combined with a large bore diameter, thus providing a lot of gas expansion area for fast-burning powders, but generally the foregoing applies.

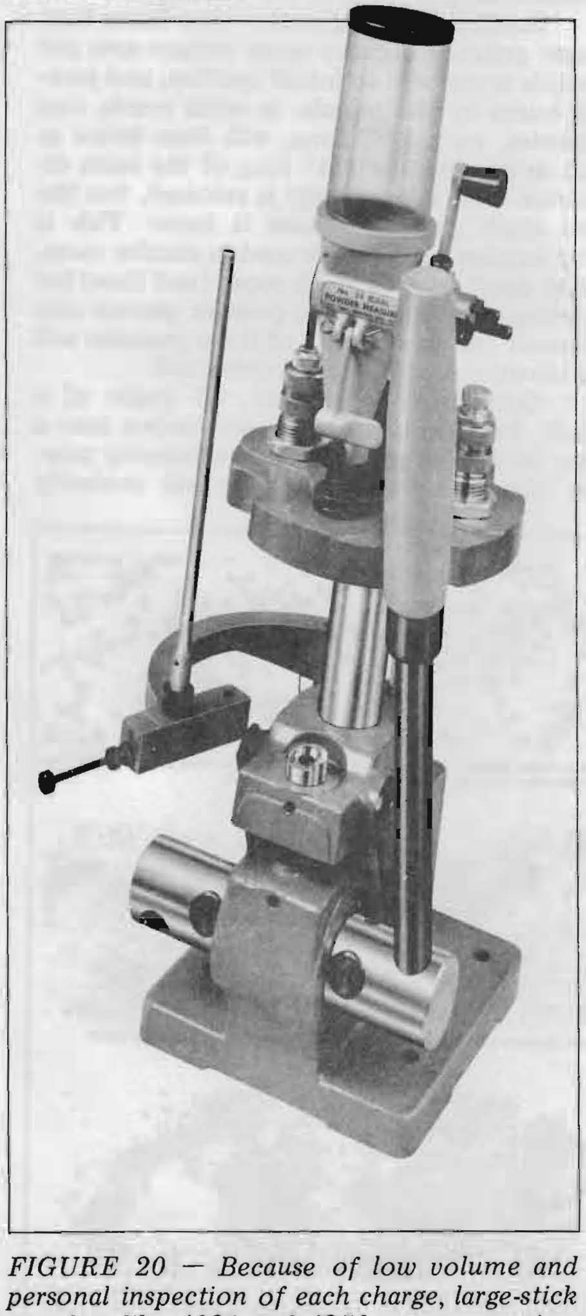


FIGURE 20 — Because of low volume and personal inspection of each charge, large-stick powders like 4831 and 4350 pose no particular problem in powder measures like the Lyman shown, designed for reloaders. Such powders, in automated powder measures, would jam up the works.

FIGURE 21 — Finished powder is placed in large cans and stored in magazines such as this prior to canistering for distribution. For safety, magazine buildings are situated a distance from each other.

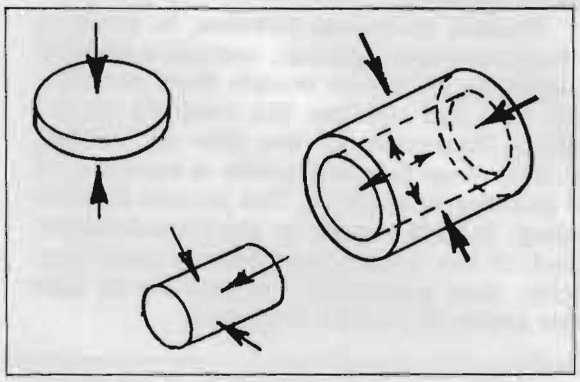


FIGURE 22 — Powder burns by the granule, and the more surface exposed per granule for burning, the faster and more even the burning characteristics.

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. What factors determine the burning rate of gunpowder?

2. What is the basic ingredient of today's gunpowder?

3. What would you expect to happen if 50 grains of a small-grained, fast-burning powder were used where 50 grains of a slower burning powder should be used?

Answers on Page 17

"Togetherness" Can Be Energizing

A group of powder granules can be likened to a potentially dangerous mob. Out in the open, one or two individuals might be fired up, but nothing much happens. Imprison them, let them communicate, and the pressure rises. The fire of one, adding to and feeding the fire of his neighbor (call it peer pressure), soon results in a conflagration!

Smokeless powder, when confined and ignited in a case, is of a different character entirely than when burned out in the open. The interaction of burning, with one kernel firing up the next, makes itself and its neighboring granule burn even faster. A charge of powder, ignited outside, might take a couple of seconds to burn. That same charge, "imprisoned" in a cartridge case, will burn completely in as little as one-thousandth of one second!

All smokeless powders have burning characteristics that place them in one of two basic categories:

Degressive Burning Powders. The most common of the degressive burning powders is the simple cylindrical, non-tubular "stick." Only the outside surface is exposed for ignition. As this surface burns, less and less area or "fuel" remains in the granule. As a result, the rate of burning, gas volume, and pressure tend to *decrease* as the burning progresses. Such powders reach their pressure peak almost immediately following ignition, and close to the chamber. By the time the bullet reaches the muzzle, burning has fallen off to the point where pressure is very low. Degressive cylindrical propellants are among the oldest modern powders. Pressure per weight of powder is usually much higher than that of other powders in producing a given velocity with a given bullet weight.

Modern ball or spheroid powders are also essentially degressive in that they have only one burning surface, which decreases as burning continues. However, ball powders release their energy much more slowly than solid, extruded sticks; also, they are invariably coated with a fire retardant. As such, they are degressive/progressive powders. Any coated powder is known as "progressive" because the coating causes burning to progress evenly.

Neutral Burning Powders. Neutral burning powders are represented by the tube-like extruded granules, by flattened ball powder, and by the various square or round flake powders. Regardless of shape, they all share double burning surfaces — the tube on the outside and the inside, the flat varieties on the top and bottom. As a result, more fuel surface or web, as it's called, is available at a given time, and the energy output is more constant, producing a more even pressure curve.

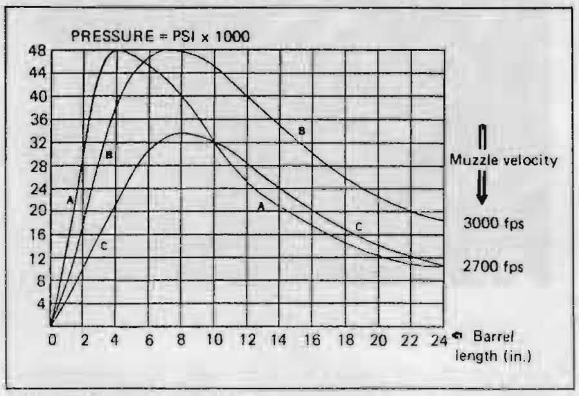


FIGURE 23 — Difference in burning rates of degressive and progressive powders. Degressive Powder A achieves its maximum pressure fast, but "poops out," producing a muzzle velocity of only 2,700 fps. Progressive Powder B reaches the same pressure "later," keeps pressure higher until the bullet exits, and produces an M.V. of 3,000 fps. Line C shows a lighter charge of progressive powder, achieving an M.V. of 2,700 fps at a very low pressure.

Neutral burning powders, like ball-type degressive powders, are customarily coated to delay the pressure peak. As such, all neutral burning propellants (unless not coated) are actually neutral/progressive powders.

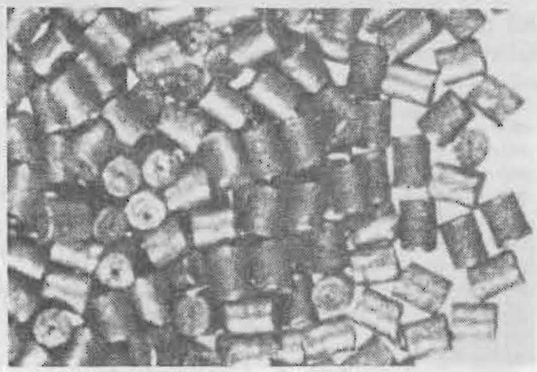
Most Powders Are Blended

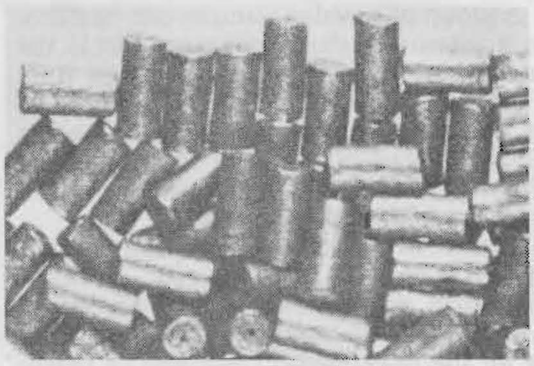
The vast majority of powders, like some whiskeys, are blended to assure uniform burning characteristics from one lot to the next. One batch is usually made up from a number of smaller batches, each usually slightly "off," with the characteristics of each group balanced to add up to a uniform standard for the whole. There are variances, of course, between cans of powder purchased, say, six months apart, but generally the difference is minimal.

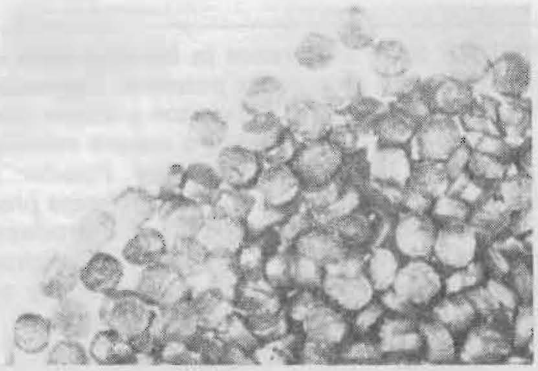
After blending and testing, the new powder is then canistered in various size cans, usually of one, eight, and twenty-pound capacity, and in kegs and drums for distribution to ammo manufacturers and ultimately to reloaders.

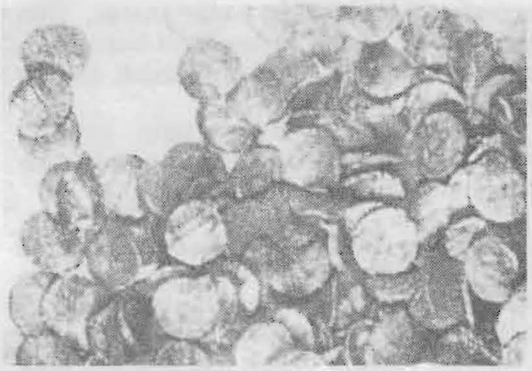
Powder Identification

Many smokeless powders look alike, but have vastly different burning characteristics. It is therefore the height of foolishness to use any powder that is in the least suspect. If you're not *positive* you know what it is, throw it away. (Discarded powder makes a good lawn fertilizer, providing it's spread thinly. Spread it thickly and a glowing cigarette









Hercules 2400 Hercules Unique

FIGURE 24 — The above powders are all "neutral burning," in that the tube-like cylinders burn from the inside and outside, the flattened flakes from the top and bottom.

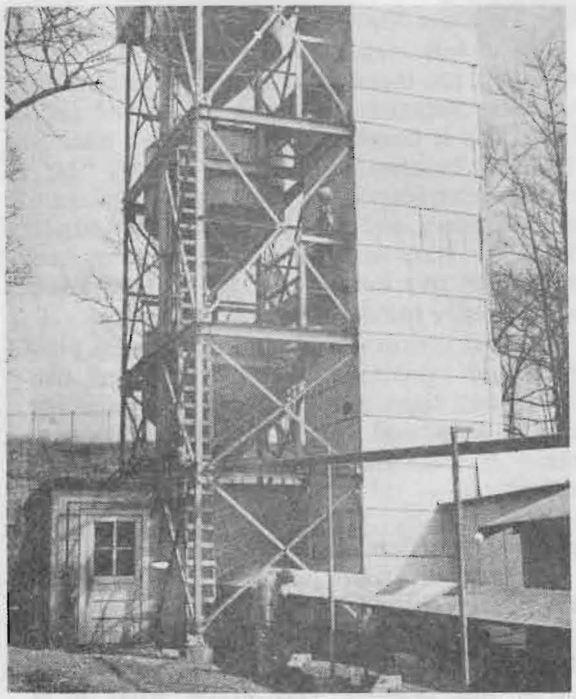


FIGURE 25 — Following glazing, the finished ball powder is blended to assure uniform burning characteristics, in this blending tower.

butt may "burn" your lawn like no nitrogen fertilizer you've ever seen! A better idea is to float it down the sewer.)

Take a chance on "gift" or mixed-up powder and you may wind up ruining a valuable gun or worse. Always make sure powder cans are properly and immediately labeled, especially when transferring bulk powder to small cans or vice versa.

POWDER STORAGE

Smokeless powder can be stored almost indefinitely, providing it is kept in a cool, dry place. Excess moisture or heat can accelerate decomposition, making the powder worthless in a surprisingly short time. Powder should never be stored in glass containers for the same reason — sunlight and heat can render it worthless in as little as three or four months. Keep your powders in their original factory metal or fiber containers. The manufacturers know what they're doing, and their packaging provides the protection needed.

All powders eventually deteriorate, but their "life" can be long indeed. There are examples of smokeless powder manufactured in 1910 which are still in perfect condition.

FIGURE 26 — Finished and blended powder is canistered for the reloader in various size cans, all of which are prominently labeled by powder number.

World War II surplus powders are, for the most part, already deteriorating. The evidence that powder is decomposing is a fine red or brown dust-like film on the inside walls of the canister. Such powder will usually ignite, but pressures and velocities are way down. Better throw it away. Powder isn't that expensive. Yet.

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

PROGRAMMED EXERCISE

5

1. True or false? The coating done to gunpowders has the effect of *delaying* the pressure peak.
2. True or false? When compared to degressive burning powders, neutral burning powders produce a more constant supply of energy and a more even pressure curve.
3. How can you tell if your stored powder is decomposing?

Answers on Page 18

ANSWERS

4

1. Granule shape, size, and coating.
2. Nitrocellulose, or gun cotton.
3. The too-quick release of energy would likely be too much for the gun, causing a blowup.

ANSWERS

5

1. True.
2. True.
3. A fine red or brown dust-like film forms on the inside walls of the canister.

CANISTER-GRADE SMOKELESS PROPELLANTS GENERALLY AVAILABLE IN THE U.S. – FROM FASTEST TO SLOWEST (Courtesy Speer, Inc.)

HERCULES BULLSEYE is the fastest burning smokeless powder available to handloaders. It is used widely in .38 Special target loads, though it is equally suitable for light loads in most other handgun calibers.

OLIN 230 is another fast burning handgun powder intended for light handgun loads. It is a ball powder, the granules having been rolled to flake form.

NORMA 1010 is an imported, round flake powder used primarily for handgun target loads.

HODGDON TOPMARK is a spherical powder suitable for both shotshell and handgun target loads.

HERCULES RED DOT has long been a favorite for light to medium target shotshell loads. It is also used for light handgun loads.

DU PONT HI-SKOR 700X is another target shotshell powder that is also useful for target handgun loads. It is the only canister, double-base powder made by Du Pont.

HERCULES GREEN DOT is similar to, but slightly slower than Red Dot. It is a good choice for moderate handgun loads.

DU PONT SR 4756 is listed by the manufacturer only as a shotshell powder. But it is a very clean burning powder useful in some light to medium-power handgun loads.

HERCULES UNIQUE was introduced in 1898 under another name. The name is appropriate as this powder is unique in its versatility. It is suitable for medium to heavy shotshell loads and much-reduced rifle loads. As a handgun powder, it is our most versatile. It provides optimum performance in many handgun cartridges and does very well in light to medium-heavy loads in others.

DU PONT SR 7625 is used for both medium handgun and shotshell loads.

AL5 is an imported powder long noted for its clean burning qualities. It is best suited to medium-power handgun and shotshell loads.

HODGDON HS5 is a spherical powder for shotshells that is usable in some handgun loads.

AL7 is slightly slower burning than AL5, but nearly the same in other characteristics.

HODGDON HS6, a flattened, spherical propellant, performs best in medium to heavy shotshell loads. It can also be used in some moderately heavy handgun loads.

OLIN 540 ball powder is made for magnum shotshell loads and can be used in some magnum handgun loads.

HERCULES HERCO is one of the oldest powders for high-velocity shotshell loads. It is a useful powder in 9mm Luger and other higher performance handgun loads. It is similar to, but lacks the versatility of Unique.

HERCULES BLUE DOT is the newest magnum shotshell powder from this company. It provides top performance in the 9mm Luger. In magnum revolver cartridges it produces velocities nearly as good as 2400, but also gives cleaner burning and often better ballistic uniformity than 2400.

AL8, primarily a magnum shotshell powder, is also a fine magnum handgun powder. Like the other imported Alcan powders, it is very clean burning.

NORMA 1020 is an imported powder that provides near-optimum performance in .357, .41, and .44 magnum cartridges.

OLIN 630 is usable in a number of standard and magnum handgun cartridges and provides nearly optimum performance. It is a ball powder with relatively large granule size.

HERCULES 2400 was introduced many years ago expressly for reloading the .22 Hornet and works well in some other small-capacity rifle cases. It is widely used in magnum revolver cartridges.

HODGDON H110, a spherical propellant, was originally intended for .30 M1 carbine loading and is also used for magnum handgun cartridges.

OLIN 296 is a new magnum handgun ball powder. In many instances it gives the highest velocity obtainable in .357, .41, and .44 magnum loads.

DU PONT SR 4759 is manufactured expressly for reduced loads in rifle cartridges. It was reintroduced in 1973 after having been off the market for several years. For most common rifle calibers, it is the best reduced-load powder available. It can be used in some large-capacity handgun cartridges, but offers no particular advantage as a handgun powder.

DU PONT IMR 4227 is a relatively fast rifle powder intended for .22 Hornet and similar small-capacity rifle cartridges. It may also be used in some magnum handgun cartridges and in .410 shotshells.

OLIN 680 is a ball powder suitable only for small-capacity rifle cartridges.

NORMA 200 is an imported powder meant for small rifle cartridges like the .222 Remington and with light bullets in medium-capacity cases.

DU PONT IMR 4198 is suitable for a wide variety of small to medium rifle cartridges – from .222 Remington to .30/30 Winchester. It is also a good choice for large, straight cases like the .444 Marlin and .45-70, and can be used for reduced-velocity loads in some larger cartridges.

DU PONT 3031 was one of the first IMR powders and a very flexible one that can be used throughout a broad range of rifle calibers.

NORMA 201 is a bit slower than Norma 200 and is intended for .30/30 and similar medium-capacity cases.

OLIN 748, a flattened ball powder, is best suited for rifle cartridges of smaller capacity than the .30/06.

HODGDON H335 and HODGDON BLC2 are both spherical powders very similar in appearance and performance. Both are useful in cartridges from .222 Remington to .308 Winchester.

DU PONT IMR 4895, HODGDON H4895. The latter was available to handloaders long before DuPont offered it as a canister powder. 4895 is one of the most flexible rifle powders available. It may be used in most cartridges from .222 Remington to .30/06 in 1/3-reduced to full-power loads.

NORMA 203 is a very dense powder suitable for cartridges in the .30/06 class.

DU PONT IMR 4064 is similar to 4895, but somewhat slower and perhaps a little less versatile. It is still a very good powder and one of the most widely used today.

DU PONT IMR 4320 is a fine-grained powder similar to 4064 in application, but slightly slower burning than 4064.

HODGDON H380 is a favorite of benchrest shooters for cartridges ranging from .222 Remington magnum to .308 Winchester. It is a spherical powder.

OLIN 760, with a flattened ball shape, is the slowest of the rifle ball powders available from this source at this time.

HODGDON 414 is a relatively new, fine-granuled, spherical powder useful in the medium to large cartridges.

DU PONT IMR 4350 was for many years this firm's slowest canister powder. It is widely used in 6mm and larger cartridges. One of the most widely used rifle powders.

NORMA 204 is a dense, relatively slow burning rifle powder for use with heavy bullets in cases about .30/06 size and larger.

DU PONT IMR 4831 was introduced as a canister powder in 1973. In burning speed, it is slightly slower than 4350, but faster than H-4831. It is important that IMR 4831 not be used in charge weights recommended for H-4831.

HODGDON H450 is a very slow burning spherical powder for use in cases of medium to large capacity.

HODGDON H-4831 is a very popular and widely used surplus powder. Because of its general availability and low cost, it is probably used by more rifle cartridge reloaders than any other powder. It is a good choice for full-charge loads with heavier bullets in cartridges from .243 Winchester up through the more popular belted magnums.

NORMA 205 is the slowest in the Norma series. It is very dense and occupies less space than H-4831 or IMR 4831 in equal weight charges. Variations from lot to lot have been reported.

HODGDON H870 is a large-granuled, spherical powder with very slow burning characteristics. Best performance is in the larger belted magnum cases with the heaviest bullets. When used in smaller-capacity cases, it will not produce velocities as high as some faster burning propellants.

STUDY UNIT 7 – PART 2

PUTTING INTERIOR BALLISTICS TO WORK FOR YOU

LET'S GET DOWN TO CASES

It is time to get down to the "nitty gritty." We have gone into the generalities of interior ballistics, which are about as far as the average or even semi-sophisticated shooter goes in his study of ballistics. What you have learned is useful in working with data prepared by others, such as that found in the various loading manuals. However, as a gun pro, your knowledge should go beyond that of working with "canned figures." You're about to learn just *why* certain loads are better than others; you'll learn how to develop your own bullet/powder combinations for standard or wildcat cartridges; and you'll learn to calculate the velocity and pressure of a given load before you even fill a case!

The Powley computer and PSI calculator which are included with your course materials are simple to use, once you understand the principles involved. These calculators, as we promised, require a minimum of math ability. Homer Powley, one of the greatest ballisticians of our time, developed these "tools" with the assistance of Robert Hutton, Technical Editor of *Guns & Ammo* magazine, and Robert Forker, former *Guns & Ammo Handloader* editor. These computers have been proved astonishingly accurate, time after time.

FIGURE 1 — Practically all reloaders work with "canned" data furnished by the loading manuals. You will be able to develop the best loads on your own for standard and wildcat cartridges, and, as you will see, it's just not that complicated. (Photo courtesy RCBS)

Now let's get on with the various factors that influence and govern the performance of modern rifles and cartridges, and, just as important, their relationship to each other.

DETERMINING CASE CAPACITY

It all starts with case capacity — the amount of powder a given case will hold. Even *minute* differences are important in ballistics calculations, and the capacity of a case made by one manufacturer may have a slightly different capacity than one made by another. Even if outside dimensions are the same, variations in wall thickness can create differences in capacity. And the *web* (that is, the solid portion of cartridge case between the primer pocket and case interior) also varies in thickness, and influences case capacity. The differences between military and commercial brass, .30/06 and .308 Winchester (7.62 NATO), and in cases modified for different calibers from these "parents," are often considerable. A military case has much thicker brass than its commercial counterpart, and will generally hold two to three grains less powder when fully charged. A maximum safe load of, say, 59 grains of powder in a commercial .30/06 case may, when crammed into a .30/06 military case, raise the pressure by 7,000 to 10,000 psi — well past the danger point. Capacity therefore has much to do with pressure, and pressure can only be accurately predicted for given loads when the exact case capacity is known.

The capacity for a given cartridge is determined by weighing the amount of water the case will hold. This is done by taking a new unprimed case and seating a bullet to the exact seating depth you will be working with. Ideally, the bullet will be seated with its base flush with the base of the neck. However, use of long bullets often requires that the bullet be seated deep in the case to fit the magazine and action. This, of course, reduces case capacity.

After seating the bullet to the proper depth, weigh the empty or dummy cartridge with a bit of tape over the primer hole, on an accurate reloader's scale. Make sure the scale pan is clean and dry. Write down the weight.

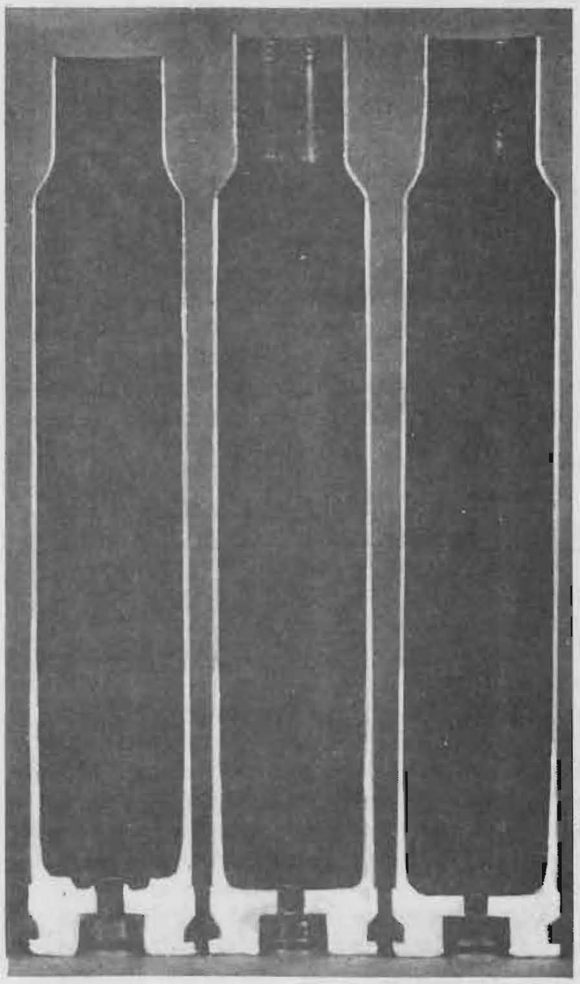


FIGURE 2 — Cases from different manufacturers vary in web and wall thickness. From left: Remington, Winchester, and Weatherby brass, all of identical exterior case dimensions (except neck). Note the extreme thinness of the Weatherby brass; also, the web does not come up to the top of the belt. The Weatherby case holds more powder, is weaker, yet creates less pressure for a given powder charge.

Next, remove the tape and slowly fill the case with water through the flashhole with a blunted hypodermic needle for safety. When filled, wipe off any excess water on the case exterior, place the tape over the primer hole, and weigh it again. If any water seeps out of the flashhole and into the pan, so what? It's still being weighed. The difference in weight (the weight of the water) between the unfilled and filled case is, of course, the case capacity in grains. The water can be removed from the case by sucking most of it out with an empty hypo, then blowing out the remainder with air pressure from the empty hypo.

If you don't have or can't get a hypodermic needle, there is another way to check case capacity. It's simpler and faster, but not as exact. Take a fired case with the primer still seated and weigh it. Then fill the case to the bottom of the neck — where the bullet is normally seated. Next, trickle the water into the pan and weigh it together with the case. The capacity, again, is the difference between the empty case and the case and the water. If you use this method, fill and weigh the case three or four times, then take an average. You'll be very, very close. If your bullet will be seated deeper than the case neck, forget it. Go hunt up a hypo. Your family doctor or vet will probably oblige. (He will believe your reason for wanting it — who could make up a reason like yours??)

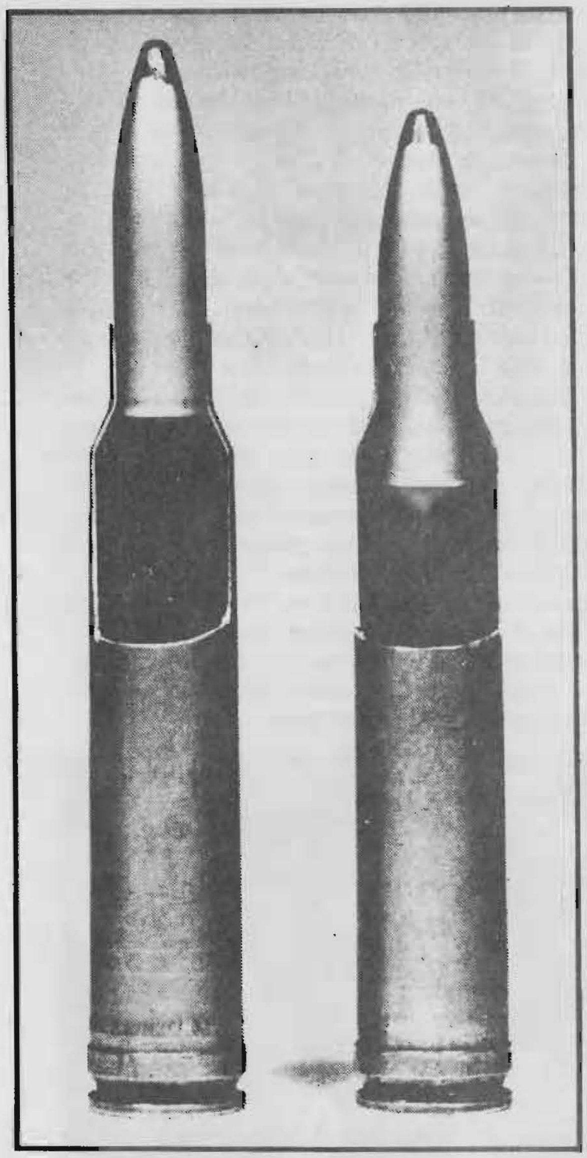


FIGURE 3 — Bullet seating depth has a lot to do with case capacity. The .300 Apollo handload at left seats the bullet flush with the case neck; the .300 Winchester magnum factory load at right has the bullet deep-seated to fit standard-length actions and magazines.

FIGURE 4 — To determine case capacity, first weigh the case with the bullet seated to the proper depth. Affix a bit of tape over the base. After getting this weight figure, fill the case with water and weigh it again. (The tape keeps the water from leaking out.) (Photo courtesy "Handloader Magazine")

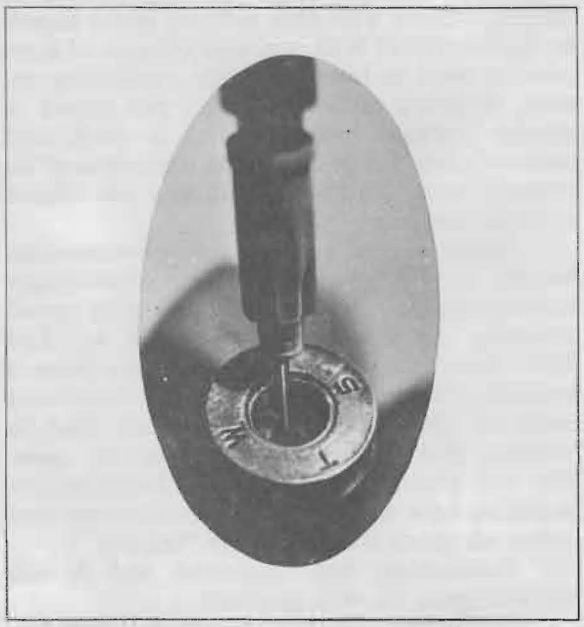


FIGURE 5 — The best way to fill a case is with a hypodermic needle. Fill the case slowly through its flashhole. When the hypo is empty, it can be used to blow out the water from the case, permitting two or three measurements for an average.

Remember, the figures you come up with are measurements of weight — *not* powder "grains." Don't get the idea that because a case holds 60 grains of water, it will also hold 60 grains of powder. It won't, because of the bulk of the powder. Case capacity is closely related to . . .

LOADING DENSITY

Loading density is a relationship (ratio) between the volume of the powder charge and the volume of the case. It is a ratio between the amount of powder in the charge compared to the amount of powder that the case would hold if it were full. This ratio is most important in selecting the proper *type* of powder for a given load. Ideally, a case should be filled to the base of the neck or close to it to achieve maximum velocity at a safe working pressure. (Why use a big case if you don't fill it?) Theoretically, one could use a fairly fast burning powder in a large case and get the proper pressure with the case perhaps half full. However, because of the air space between the bullet and the powder, the smaller powder granules would shift around when the rifle was raised for firing, resulting in erratic primer ignition and pressure. Tests with such loads have revealed that pressure varies as much as 3,500 psi between firing with the barrel angled sharply upward and then downward. Accuracy under these conditions is something you can forget about.

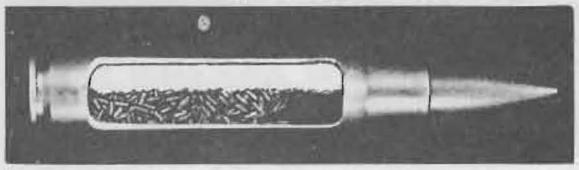


FIGURE 6 — Light powder charges settle at the bottom of the case when the rifle is in firing position, resulting in erratic ignition, pressure, and accuracy.

A full case of this same fast-burning powder would, of course, probably blow up the gun.

At the other extreme we could have a case filled to the proper level, but with too slow burning a powder. Insufficient pressure caused by woefully incomplete powder burning results in a low velocity level. Such loads aren't dangerous, and are sometimes surprisingly accurate (if you account for a lower velocity and more curved trajectory). A few years back, when surplus H4831 was available for as little as 50¢ a pound, many reloaders used this slowest of all IMR powders behind 150-grain bullets in .30/06 rifles. Velocity was 200 to 300 fps slower than could be achieved with the correct and faster burning IMR 4320, but so what? The accuracy was acceptable and the price was right!

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. True or false? If the outside dimensions of two cases are identical, you know that they will hold the same amount of powder.

2. How can you measure case capacity?

3. Why is it *not advisable* to load a case to less than capacity?

4. What is the result if you use slower burning powder than recommended, but a full case load?

Answers on Page 6

Compressed loads, whereby a given powder charge must be compressed (by trickling powder into the case neck and then shaking it down) to fit into the case, generally aren't desirable. Because the granules are compressed, less than normal air space exists between them, thus primer ignition and powder burning (and pressure) are often erratic.

There are shooters who swear by compressed loads, but most — after experimenting — swear *at* them. One is usually better off going to a slightly faster burning powder, and a more reasonable loading density, than using a compressed charge of the slower variety to gain maximum velocity.

How compressed loads often create pressure hazards brings to mind the German "Big Berthas" of World War I. These guns, with long 60-foot barrels, were mounted on railway flatcars and hurled 300-pound "bullets" at more than 4,000 fps! To reach a target 75 miles away (Paris), the barrels were angled sharply upward. On several occasions the ponderous projectiles were slightly undersize in diameter, permitting them to slide back and compress the powder when the barrel was raised. Because of increased pressure, the guns blew up, killing their crews.

The lowest (and acceptable) loading density is encountered in reduced squib or "spritzer" charges, usually used with gas-check lead alloy bullets for target shooting and on small game with high-powered rifles. Here, a light charge of fairly fast burning powder is usually used, with the powder kept in place against the primer with a bit of kapok or dacron filler. Accuracy is often as good as with fully charged loads.

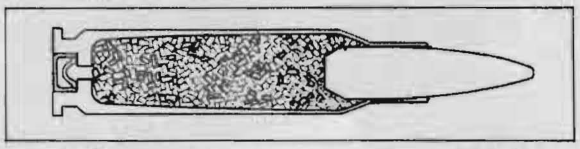


FIGURE 7 — Compression can result from the combination of deep bullet seating and a maximum powder charge, or use of too slow-burning a powder. Lack of air space between granules slows ignition and burning, and sometimes causes excessive pressure.

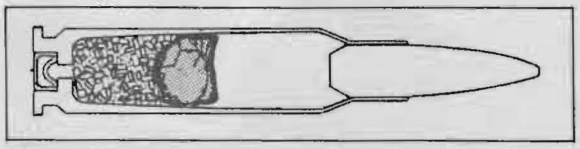


FIGURE 8 — Reduced loads usually produce good results when a small amount of fast-burning powder is held in place against the primer with a "filler."

The Mystery of "Detonation"

You might well ask, why shouldn't one use a medium or smallish charge of slow-burning powder for reduced loads rather than fussing around with fast powder and a kapok or dacron filler? Well, reduced charges of slow powder tend to burn unevenly, producing uneven accuracy. Also, the cost per round is greater because more powder is used, and powder costs about the same, regardless of its burning rate. And isn't economy the object of using lead alloy bullets?

There is also a mysterious phenomenon known as "detonation" which discourages knowledgeable riflemen from using small amounts of slow-burning powder in .220 Swift size and up cases. There have been a number of recorded instances in which reduced loads of IMR 4350 or 4831, when used in medium and large cases, blew up the guns. The U.S. Ordnance and DuPont ballistics laboratories have duplicated this occurrence and excess air space is believed the "trigger."

Detonation has happened and it will happen again. So why gamble?

To sum up, loading density is simply the ratio of powder used to the amount of powder the case could theoretically hold. To determine this ratio, divide the powder charge by the case capacity. Water is used to determine case capacity, and the weight of water the case will hold is compared to the weight of powder in the charge to establish loading density. For example, if your case holds 86 grains of water, and your powder charge is 75 grains of powder, your equation is as follows:

> Weight of powder charge divided by weight of water case will hold equals loading density.

$$\text{So: } 86 \overline{)75.00} = .872$$

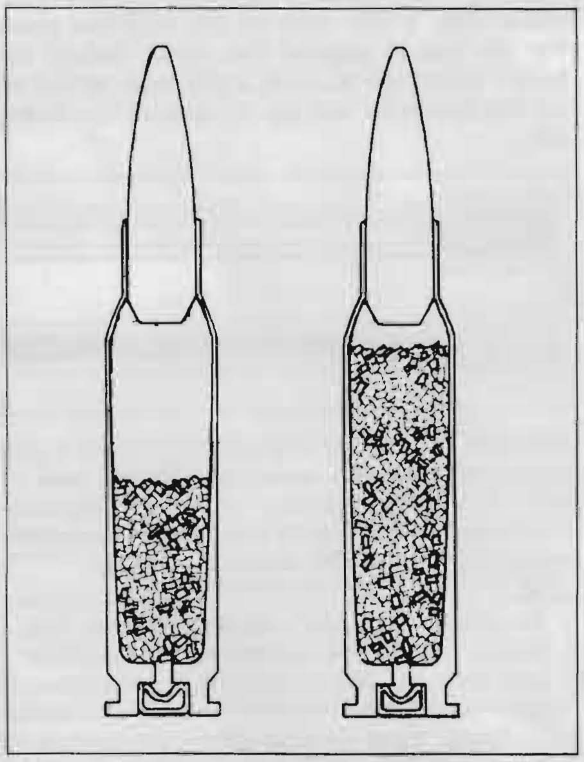


FIGURE 9 — Proper and improper loading density. The drawing at the left, with the case only half full, indicates use of too fast a powder. The correct density justifies the size of the case and results from the choice of a powder with the right burning rate.

The loading density is thus 87.2%, meaning that the powder occupies 87.2% of the available space in the case. Commercial cartridges are usually loaded with a density of 80% to 90%. The top limit is considered to be about 95%, as some air space is necessary for optimum primer ignition and powder burning.

Both the *amount* of powder and the type of powder used in a given case must be related to the weight of the bullet, which brings us to the ratio of charge to bullet weight.

Before going on, however, 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. How about compressed loads — where you shake the powder down into the case to compress it and thus overload the case. What is the result?

2. What are two reasons you might select a small quantity of a faster burning powder and a dacron filler rather than a slightly reduced charge of a slower burning powder?

Answers on Page 7

RATIO OF CHARGE TO BULLET WEIGHT

The *ratio of charge to bullet weight*, often referred to as RCBW, refers to the relative weights of the powder charge and the bullet. If you used 70 grains of powder to drive a 70-grain bullet, your ratio would be 1.0, meaning that the weight of the powder charge is equal to (or 100%) the weight of the bullet. Use 70 grains of powder behind a 140-grain bullet and the ratio is .50; the weight of the powder is equal to 50% of the weight of the bullet. The higher the ratio, or the closer the powder weight approaches the bullet weight, the greater the velocity. A given amount of powder will drive a light bullet faster than a heavy bullet.

> To get the RCBW, divide the weight of the powder charge by the weight of the bullet.

RCBW (ratio of charge to bullet weight) isn't based on a particular *type* of powder, only on the weight of the powder involved. Regardless of bullet weight, the case should contain about the same amount or weight of powder to achieve the proper loading density.

For example, a maximum load for a .30/06 with a 180-grain bullet would be 59 grains of IMR 4831 (RCBW = .328). The maximum load for the same gun, but using a 150-grain bullet, would also be 59 grains of powder — but of IMR 4350 (RCBW = .393). An even better maximum load for the 150-grain bullet (where higher velocity is attained at the same pressure level) would be 51 grains of IMR 4320 (RCBW = .340). In the last two examples, the RCBW's are nearly identical; in the first example, the RCBW is somewhat lower. All are satisfactory.

FIGURE 10 — Small cases don't always use fast powders and large cases slow powders. The 6mm cartridge at the left has a heavy bullet (for its size), a high RCBW, and uses slow-burning powder. The .458 has a much lower RCBW and uses a faster powder than the 6mm.

To reiterate, the amount of powder used for light or heavy bullets should be about the same. Only the *type* of powder, and its burning characteristics, change — to keep chamber pressure at about the same level, regardless of bullet weight.

RCBW, when related to sectional density of the bullet and to loading density, points up the *type* of powder that will produce optimum velocity at proper pressure levels. In this application, sectional density of the bullet has to do with acceleration, the force required to "get the bullet going."

If you have a degree in math, you *may* be able to figure out the interrelationships of these factors, using complicated formulas. The Powley computer, which we'll deal with a bit later, does the job for you in about 30 seconds — telling you precisely which powder is best relative to the variables discussed so far.

EXPANSION RATIO

The term "expansion ratio" sounds a good deal more complicated than it is. Expansion ratio (or ER, as we'll tag it hereafter) deals with the "room" the innards of a given rifle provide for the expansion of powder gases. This space is made up of the chamber and the bore, both of which serve as expansion areas for gases before the bullet flies out of the muzzle. The ER compares the case capacity (or chamber capacity) with the chamber capacity *plus* the bore capacity. To put it another way, a rifle with an ER of 5 has room for the gas to expand five times before the bullet leaves the muzzle; a rifle with an ER of 10 has space for the gas to expand ten times, etc.

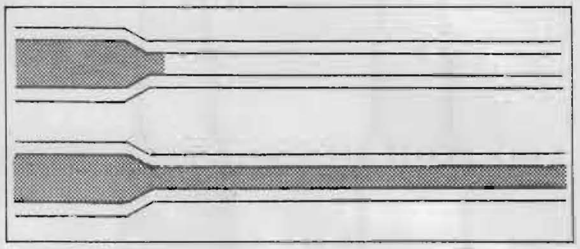


FIGURE 11 — The expansion ratio of a gun compares the case capacity (shaded area at top) with the chamber and bore capacity (bottom) — all of which serve as gas expansion area before the bullet leaves the muzzle.

To determine a gun's expansion ratio, you simply divide the volume of the chamber and bore by the volume of the chamber.

Swell. How do you figure the volume of a compound-tapered cylinder (the chamber) and the volume of a long, straight cylinder (the bore)? You don't. Again, Powley comes to the rescue. With his computer, you can figure the ER of any gun in about ten seconds flat!

ANSWERS

1

1. False.
2. Determine how much water it will hold with the bullet seated.
3. The powder shifts around in the case and you get variations in pressure and erratic groups.
4. You get substantial loss in velocity.

Rifles with low ER's (5 to 6) generally have large chambers and long, narrow bores, and are best exemplified by the .257 Apollo and Weatherby magnums. Rifles with medium ER's (6 to 8) include the .30/06 and the .300 Savage. Those with high ER's (10 to 11) are represented by such oldtimers as the .30/30 and .32 Winchester Special.

Generally speaking, the lower the ER, the flatter shooting the rifle. This is because, the smaller the bore in relation to the chamber, the higher the RCBW and the less expansion space. Conversely, large-caliber rifles, but with short bores and small cases, aren't conducive to high velocity. Also, rifles with low ER's are generally less efficient than those with high ER's — for reasons we'll explain a bit later.

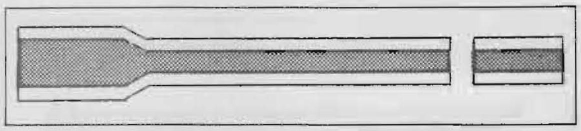


FIGURE 12 — A rifle's expansion ratio can be increased by "adding" to the barrel length, decreased by shortening the barrel. More or less gas expansion space increases or decreases velocity, respectively.

WHY RAISING THE "ER" CAN INCREASE VELOCITY

Now that we've got this down pat, let's confuse the issue. The velocity of some rifles can be increased, sometimes by raising and sometimes by lowering the ER. To show you what we mean, let's take a .30/06 rifle with a 20" barrel. The ER is 6.3. By rebarreling this gun with a new 24" barrel, we provide four more inches of bore in which the gases can expand. The ER is now 7.5, and the velocity is considerably faster. (Conversely, when a barrel is chopped, the ER decreases and so does velocity.)

Now let's take this same .30/06 rifle and increase velocity even more, but decrease the ER. This time we reduce the bore expansion area in relation to the chamber by increasing the size of the chamber. We rechamber the gun to .300 Winchester magnum caliber. The bore volume remains the same, but because the chamber is now larger in ratio to the bore, the gases generated in the larger chamber have a proportionately smaller area in which to expand, and we have a lower ER. Velocity increases, but efficiency drops.

Expansion ratio is always related to RCBW (ratio of charge to bullet weight) in determining velocity. In other words, ER is concerned with the size of the chamber (case) and the length and diameter of the bore. It says nothing about bullet weight. Yet the weight of the bullet has everything to do with velocity. As we pointed out earlier, the higher the RCBW number, the lighter the bullet compared to the powder charge — and the faster it goes.

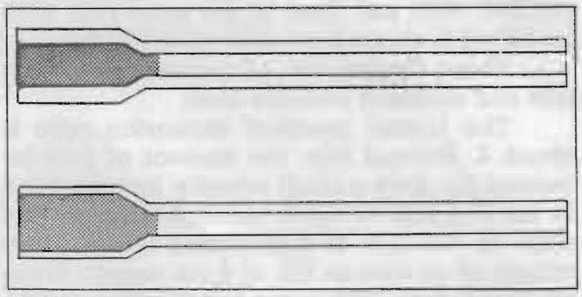


FIGURE 13 — The expansion ratio can be decreased, but the velocity increased, by chambering a given rifle for a larger cartridge. The ER is lower because more gases are produced, but they have no more bore area in which to expand.

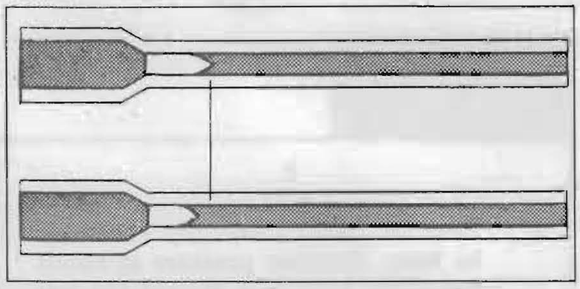


FIGURE 14 — Both expansion ratio and ratio of charge to bullet weight determine velocity. When the ER is identical for two rifles, and both are loaded to the same pressure level, the light bullet with a high RCBW (bottom) moves faster.

ANSWERS

2

1. When you compress powder, you get less than normal air space, with the result that primer ignition and powder burning are often erratic.

2. (1) Reduced charges of slow-burning powder tend to burn unevenly; (2) the cost per round is greater for the greater quantity of slow-burning powder when compared to the amount of fast-burning powder required.

The velocity of any load is therefore dependent on (1) the RCBW as related to (2)

the ER. For example (and as your Powley computer will show), a cartridge loaded with a heavy bullet (RCBW .45) and an ER of 6 will show a muzzle velocity of 3,030 fps. That same cartridge loaded with a light bullet (RCBW .60), and fired in the same rifle with an ER of 6, shows a velocity of 3,430 fps.

These figures are, of course, based on a safe and constant pressure level.

The lowest practical expansion ratio is about 4. Beyond this, the amount of powder burned for only a small velocity increase (and at the expense of rapid barrel erosion) comes close to the law of diminishing returns. Cartridges at or near an ER of 4 are usually termed "overbore" with some *justification*, meaning that chamber capacity is too much "over" the bore's gas capacity.

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. True or false? Generally speaking, to keep chamber pressure at about the same level you should use *less* powder to drive a lighter bullet, as opposed to using a full case of slower burning powder.

2. Choose the correct answer: Rifles with low ER's generally have: (a) large chambers and small, narrow bores. (b) average-size chambers and long, medium-sized bores. (c) small chambers and long barrels. (d) small chambers and relatively short barrels.

3. Choose the correct answer: Generally speaking: (a) the lower the ER, the flatter shooting the trajectory for a rifle. (b) rifles with low ER's are less efficient than rifles with high ER's. (c) both A and B above are true. (d) neither A nor B are true.

4. True or false? *Overbore* means that the chamber capacity is *too much* over the gas capacity of the bore.

Answers on Page 10

MEASURING ACTUAL BARREL LENGTH

As the ER of a given gun depends on its barrel length, it's important that the *actual* length be ascertained. And that length isn't the factory figure. To determine the barrel length used in ballistics calculations, insert a dummy round with the bullet seated correctly into the chamber. Then, using a cleaning rod or soft rod (without ferrule), insert it down the muzzle until it butts up against the tip of the bullet. Measure this distance, then the length of an identical bullet. The total of these two measurements is the barrel length, which is usually about 1½ inches less than the overall exterior measurement by the factory, with 24" barrels; about 2½ inches less with 26" barrels.

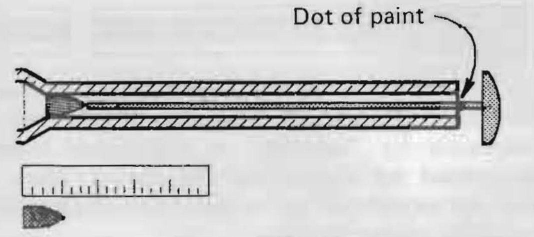


FIGURE 15 — The barrel length for ballistics calculations with the Powley computer is determined with a cleaning rod as shown. The distance from the bullet tip to the muzzle is added to the overall length of the bullet. The total is the "ballistics barrel length."

CARTRIDGE EFFICIENCY

The term "cartridge efficiency" doesn't, in our present context, refer to game killing or knock-down power. Here, we are talking about how well or how poorly a cartridge utilizes the energy potential of the powder it burns.

All IMR (Improved Military Rifle) powders are essentially of the same composition, and contain the same amount of latent energy. The burning rates differ according to the length and size of the granules, the amount of coating applied to slow down their burning, and the size case in which the powder is used. (Smaller cases generate more pressure and hasten the burning of a given powder.)

Through controlled burning of IMR powder inside pressure bombs and measurement of the heat generated, government ballisticians discovered long ago that one pound of any IMR powder — whether 4064, 4320, 4350, 4831, etc. — has an energy potential of 1,246,000 pounds. This figures out to 178 pounds per grain. And remember, a grain is a unit of weight; it is not an individual granule of powder.

FIGURE 16 — Efficiency isn't the only yardstick for measuring a cartridge's merit. The .30/06 is in the "medium" efficiency range. The lowly .22 short is probably the most "efficient" cartridge ever developed.

As an example of how "efficiency" is calculated, let's take a .30/06 with a 24" barrel. We use 53 grains of IMR 4320 to drive a 150-grain bullet at a muzzle velocity of 2,940 fps with a muzzle energy of 2,878 foot pounds. The potential energy of that 53-grain powder charge is 9,434 foot pounds (53 x 178). However, we achieved only 2,878 foot pounds.

> To determine efficiency, or the percentage of energy utilized, divide the muzzle energy by the potential energy.

Thus we divide the muzzle energy of 2,878 foot pounds by the potential energy of 9,434 foot pounds:

$$\text{So:}\quad 9434\,\overline{)\,2878.00}\;\; = .30$$

The efficiency rating for this particular gun and load is thus 30%, meaning that 30% of the potential energy was utilized. The ER of this gun is 7.5, which places it in the area of "medium-good" efficiency. (Few, if any, rifles achieve a 40% efficiency.)

HIGH PERFORMANCE USUALLY MEANS LOW EFFICIENCY

By way of contrast, let's take the .220 Swift, a notoriously "inefficient" cartridge. Because of the large chamber in relation to bore diameter, the ER with a 24" barrel is 5.6. Here, we'll propel a 55-grain bullet at 3,685 fps with a charge of 44 grains of IMR 4831. Muzzle energy is 1,658 foot pounds. However, the potential energy of this powder charge is 7,832 foot pounds (44 x 178). Our efficiency is thus 21% (1,658 ÷ 7,832).

This bears out the general rule that the lower the ER, the lower the efficiency and the higher the velocity.

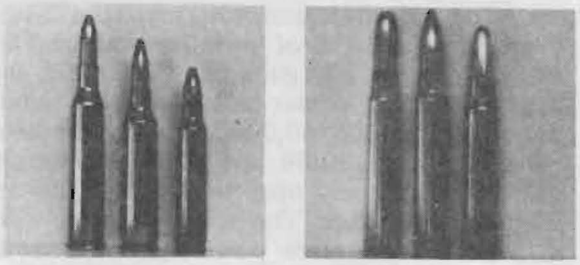


FIGURE 17 — High-velocity center-fire .22's such as the .220 Swift, .22-250 Remington, and .222 Remington (at left) are all relatively "inefficient" cartridges, in the 20% to 27% range; the big-bore .358's, like the Apollo and Norma cartridges at right, are in the 36% to 38% efficiency bracket.

Exceptions are the big-bore magnums that drive heavy slugs at high velocity. An example would be the .358 Apollo, which achieves a velocity of nearly 3,000 fps with a 250-grain bullet. The ER is about 8.5, the efficiency 36.5%. Most ultra-high-velocity magnums have ER's in the 5 to 5.5 range. The extra powder required isn't all that expensive, and the rifles aren't usually shot often enough for barrel wear to become a cause of worry. The bellowing magnums are here to stay, and for the same reason the "efficient" 60HP. Ford motors of 1937 are less preferred for speed and power than the woefully "inefficient" modern V-8's performance.

Now, then, we have been considering factors and concepts which constitute the "heart" of internal ballistics and relate to the *principles* used in determining correct powder/bullet combinations and calculating velocities for given loads without need for a chronograph. You'll soon be given specific instructions for using your Powley computer and PSI calculator. The latter enables you to determine chamber pressure of any load developed with the computer. Before getting into the use of these computers, there are a few other facets of internal ballistics that should be discussed.

BARREL EROSION

Some guns, like the old "thutty-thutty" and the .300 Savage, retain their original accuracy for years, even when shot frequently. Other rifles, especially high-intensity magnums, can lose gilt-edged accuracy in 1,000 rounds or less. Contrary to what a lot of shooters think, a barrel isn't "worn out" by the friction of high-velocity bullets. The least wear in any barrel, including those of magnum persuasion, is at the muzzle — where the bullet is moving the fastest. The "wear" occurs just ahead of the chamber where the pressure peaks.

The culprit is pressure, and to a lesser degree the amount of powder contained in the cartridge. Older guns like the .30/30 use relatively little powder and generate a maximum pressure of 40,000 psi. Intermediate rifles like the .30/06 and .270 have larger powder charges and operate in the 48,000 to 50,000 psi bracket. The new magnums, with at least a third more power, generate from 53,000 to 55,000 psi. At a given pressure level, barrel wear is proportionate to the amount of powder burned because more powder generates more heat. As powder charges and pressures increase, so does the erosion factor.

Above 40,000 psi, the flame temperature of a powder charge is always higher than the melting point of alloy steel. This is why older guns were designed for a maximum chamber pressure of 40,000 psi. The newer "intermediate" carbon and carbon/nickel steels used in the .30/06 and other early high-velocity rifles had a melting point allied with the 50,000 psi pressure bracket. Barrels of the fairly recent magnums are made of chrome/moly steel, and sometimes of stainless steel, which have even higher melting points, permitting the use of loads generating up to 55,000 psi.

RAPID-FIRE COMPOUNDS THE PROBLEM

The problem is that many shooters load their cartridges to the maximum or slightly over, with pressures right at the melting point. When a barrel is allowed to cool be-

ANSWERS

3

1. False.
2. A
3. C
4. True.

FIGURE 18 — It is virtually impossible to shoot out the barrel of an oldtimer like the Winchester Model 94 .30/30 at the top. A newer gun, like the Weatherby, can be shot out in 1,000 rounds or less if the barrel isn't allowed to cool between rounds.

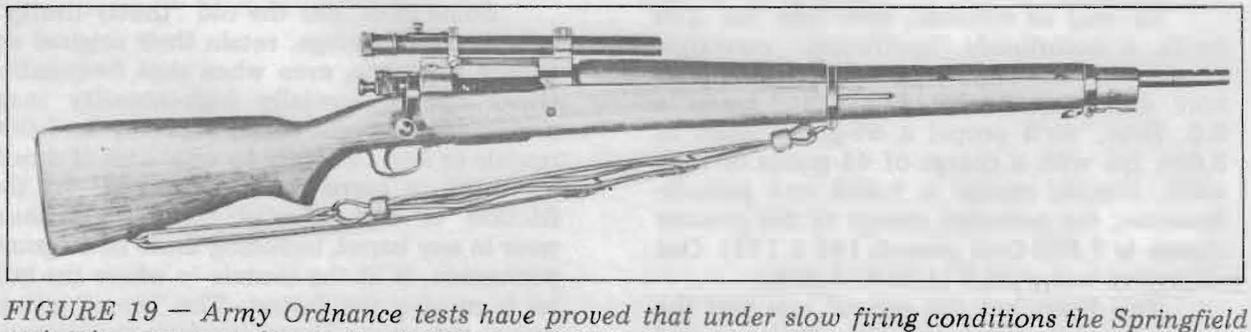


FIGURE 19 — Army Ordnance tests have proved that under slow firing conditions the Springfield maintains accuracy for up to 15,000 rounds. But, when shot rapid-fire, the accuracy deteriorates in around 2,000 rounds.

tween rounds even moderately, accuracy-affecting erosion takes a long time to develop — several thousand rounds on the average. It's a different story when a shooter lets off rounds rapid-fire, or spaced only a few seconds apart. The heat generated by each new cartridge boosts and keeps the bore temperature well past the melting point. Rifles fired in this manner, especially the magnums, can be shot out in as little as 200 rounds!

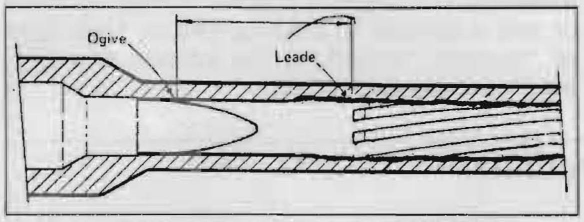


FIGURE 20 — Hot gases, under "blowtorch" pressures, cut away at the rifling up to three inches beyond the leade, making gilt-edged accuracy an impossibility.

For maximum barrel life, always back off a grain or two from maximum and permit the barrel to cool for a full minute, preferably two, between shots. The best accuracy is seldom achieved with maximum charges, and it's better to sacrifice maybe 100 fps in velocity and be on the target. Your deer or elk will never know the difference!

BOAT-TAIL BULLETS ARE THE PRIME OFFENDERS

Boat-tail bullets, all else being equal, will erode a barrel faster than a bullet with a flat base. The reason is that the tapered design of the base tends to funnel gas up the sides of the bullet before it has a chance to enter the rifling. Once in the rifling, the tapered base takes longer to "expand" and fill the bore, thus closing off further leakage. Gases jetting up the sides of such bullets cut away metal in short order. Fortunately, boat-tails are most commonly used for long-range target shooting, where the comparatively long wait between shots minimizes the erosion factor.

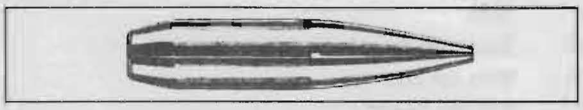


FIGURE 21 —Boat-tail bullets are favored for long-range accuracy because the tapered base creates less turbulence and therefore less long-range drop. However, boat-tails hasten barrel erosion.

The new Lapua tapered and stepped boat-tail bullet was probably designed as a compromise — to provide some of the ranging ability of the boat-tail configuration while reducing some of the erosion problems.

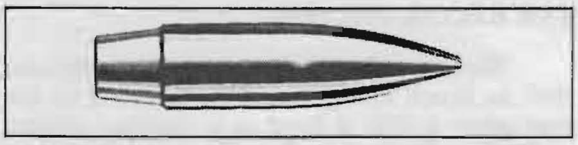


FIGURE 22 — The new Lapua is a modified boat-tail and represents a compromise: less ranging ability, but less erosion potential.

Undersize bullets cause the same problem and for the same reason — gas racing up the sides and ahead of the bullet.

Rifles with low ER numbers are, of course, more prone to rapid erosion than rifles with a high ER. The reason is that the pressure and heat developed by the large cases must be channeled down a relatively small bore. This "constriction" results in a given amount of heat being applied to a small area, with consequent gas cutting.

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

Match the descriptions in the bottom list with the terms or abbreviations from the top list by placing the letters in the blanks provided.

_____ 1. ER

_____ 2. Loading density

_____ 3. RCBW

_____ 4. Efficiency

A. Divide weight of powder in charge by weight of water case will hold.

B. Divide weight of powder in charge by bullet weight.

C. Divide volume of the chamber and the bore by the volume of the chamber.

D. Muzzle energy divided by potential energy.

Answers on Page 14

THE RECOIL FACTOR

The law of action and reaction dictates that as much energy must be directed to the rear when a rifle is fired as is directed toward propelling the bullet. Heavier powder charges and heavier bullets generate more energy, so they "kick" harder. A cartridge that develops 3,000 foot pounds of muzzle energy actually develops 6,000 foot pounds of total energy (which is why no cartridge can be even 50% efficient at the muzzle). That other 3,000 foot pounds of butt energy is for you, or for your shoulder. The only thing that prevents the rifle from hurtling back at the same speed the bullet is moving forward is the weight of the gun. In effect, the force that drives a 150-grain bullet at 3,000 fps drives the rifle (an eight or nine-pound "bullet") a lot slower.

It follows that the heavier the rifle, the less the recoil for a given cartridge. Now we will see how to calculate the recoil of rifles of any reasonable weight, relative to bullet weight and velocity. You'll see that with high-intensity cartridges it's often better to make or sell a sporter of slightly greater than light or "normal" weight, in the interest of reducing recoil and flinching.

CONVERSION FACTORS

Multiply	By	To Obtain
Atmospheres	14.70	Pounds per square inch
Kilograms per square centimeter	14.23	Pounds per square inch
Pounds per square inch	0.07032	Kilograms per square centimeter
Drams	1.772	Grams
Drams	0.0625	Ounces
Grains (Troy)	1	Grains (Avoirdupois)
Grains	0.0648	Grams
Grams	15.43	Grains
Grams	0.03527	Ounces
Kilograms	1000	Grams
Kilograms	2.205	Pounds (Avoirdupois)
Ounces	16	Drams
Ounces	437.5	Grains
Ounces	0.0625	Pounds (Avoirdupois)
Ounces	28.35	Grams
Pounds	7000	Grains
Pounds	453.6	Grams
Pounds	16	Ounces
Centimeters	0.3937	Inches
Centimeters	0.01	Meters
Centimeters	10	Millimeters
Inches	2.540	Centimeters
Meters	100	Centimeters
Meters	3.281	Feet
Meters	39.37	Inches
Meters	1.094	Yards
Feet per Second	0.3048	Meters per Second
Feet per Second	0.6818	Miles per Hour
Meters per Second	3.281	Feet per Second
Miles per Hour	88	Feet per Minute
Miles per Hour	1.467	Feet per Second
Liters	0.2642	Gallons
Liters	1.057	Quarts
Liters	1000	Milliliters
Square Centimeters	0.1550	Square Inches
Square Inches	6.452	Square Centimeters

TABLE 1

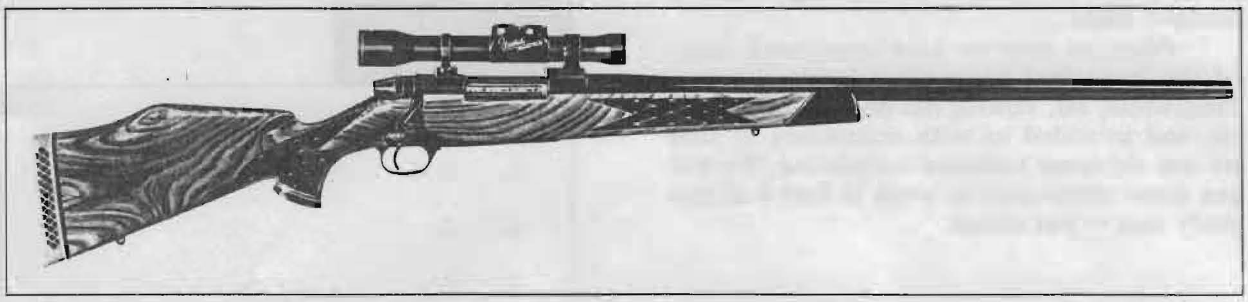


FIGURE 23 — Rifles chambered for "powerhouse" cartridges, such as the Weatherby .460, invariably weigh from 10½ to 12 pounds to help minimize the king-size recoil.

CALCULATING RECOIL

A comparatively easy way to calculate the recoil of any rifle or shotgun, when using Dupont PB and SR, and either Dupont or Hodgdon IMR powders, has been worked out by Homer Powley, who should now be familiar to you. Mr. Powley's method is based on the energy of the powder (not bullet velocity), as related to the weight of the powder, bullet, and gun. Consequently, the use of other powders, where the kinetic energy is slightly different, sometimes provides close but not precise data. Stock design and muzzle blast, factors which greatly influence apparent recoil, are not, of course, taken into consideration. Mr. Powley's equation, in his own words, is as follows:

"Add the powder charge, in grains, to the weight of the bullet (or shot plus wad), also in grains. Multiply the total by the powder charge in grains. This product is then divided by 80 times the gun weight in pounds to get the answer (recoil) in foot pounds."

As an example of how the Powley method works, let's take a .30/06 rifle weighing 8½ pounds. Our cartridge consists of a 150-grain bullet in front of 59 grains of IMR 4350 powder. (The velocity is about 2,900 fps, which isn't pertinent.)

First we add the weight of the powder (59 grains) to the weight of the bullet (150 grains). The result (59 + 150 = 209) is then multiplied by the powder charge (209 x 59 = 12,331).

The rifle weighs 8.5 pounds. We next multiple the rifle weight by 80 (8.5 x 80 = 680).

Our last step is to divide 12,331 (the weight of the powder charge and bullet, multiplied by the powder charge) by 680 (the rifle weight multiplied by 80):

$$680\,\overline{)\,12{,}331.0} = 18.1 \text{ foot pounds of recoil}$$

Shotgun Recoil

Shotgun recoil is figured in the same way except that the weight of the wad(s) and shot replaces the bullet weight in the calculation. For example, let's take a 20-gauge shotgun that weighs 7 pounds. Our charge is one ounce of shot which weighs 437.5 grains (see conversion table) backed by 19 grains of Dupont PB powder. The plastic wad weighs 25 grains.

First we add the weight of the powder (19 grains) to the weight of the shot (437.5 grains) and the weight of the plastic wad (25 grains):

$$\begin{array}{r} 19.0 \\ 437.5 \\ \underline{25.0} \\ 481.5 \text{ grains} \end{array}$$

We next multiply this 481.5 by the weight of the powder:

$$\begin{array}{r} 481.5 \\ \text{x} \quad \underline{19.0} \\ 9148.5 \end{array}$$

The shotgun weighs 7 pounds, so we multiply 7 by 80 (7 x 80 = 560). The final step is to divide 9,148.5 (the weight of the powder, wad, and shot, multiplied by the weight of the powder) by 560 (the shotgun weight multiplied by 80):

$$560\,\overline{)\,9148.5} = 16.4 \text{ foot pounds of recoil}$$

But, Check Your Powder . . .

In any loading manual listing, where the charge of a ball-type or other non-Dupont powder is close to the charge recommended *for* a Dupont powder, this recoil calculation works fine. For example, a Speer manual listing for the .308 Winchester 165-grain bullet loading specifies 51 grains of IMR 4350, *or* 50 grains of the spherical H414, for slightly less velocity. Other alternatives are 44 grains of IMR 4064, *or* 44 grains of spherical H335 at virtually identical velocities. Obviously, the Powley system also applies, in most cases, to non-Dupont powders — concerning rifle and shotgun loads.

Okay, so now we have considered many of the important happenings inside the gun. Meanwhile, Mr. Powley has done the math for us, and provided us with computers so that we can do some ballistics calculating. We will put these computers to work in Part 3 of this study unit — just ahead.

ANSWERS

4

1. C
2. A
3. B
4. D

NOTES

NOTES

STUDY UNIT 7 – PART 3

HOW TO USE YOUR POWLEY COMPUTER AND PSI CALCULATOR

PSI WITH RELIEF – IT'S MATHEMAGICS

The Powley computer and PSI calculator constitute a complete "ballistics laboratory." With these simple yet sophisticated devices, you can figure for yourself the best powder/bullet combinations for any high-powered rifle of standard or wildcat caliber, using standard or non-standard bullet weights. You'll know the muzzle velocity and pressure of any load you develop, and how to increase that load to maximum within safe pressure limits. We will also show you how to compute the muzzle energy of any load you select.

The remarkable thing is that you perform these feats of "ballistics legerdemain" at your desk or kitchen table, where, in effect, you "load test rounds and fire for velocity and pressure" readings. But you get the answers *before* filling a case! These procedures would normally involve hours of complicated math calculations and a costly pressure gun and chronograph setup. Not now. Everything you need to perform interior ballistics, predicting cartridge performance without trial and costly or dangerous error, is in your hands!

In calculating loads in this lesson, it is important that you get plenty of practice. That way the terms used will become very familiar to you, and you will be more likely to handle the computations easily, without error.

It is also important that you *verify all of your findings.* Check your results with those given in reputable loading manuals for comparable loads. Then, when you have mastered the use of the Powley computer, you will be better prepared for the handloading section of your Course, Gun Shop 10, where you will be able to put the ballistics to practical use. Right now your job is to learn to use the Powley computers so you can handle your calculations with them easily and well.

Your two slide rules are true computers, relying on programmed input. You feed in known factors (case capacity, bullet weight, barrel length, etc.) and the computers correlate this information with "stored" data, then provide the answers. In minutes. You *can* use these computers without really understanding the principles involved (you can also train a chimp to punch buttons by rewarding him with bananas), *but why?* The way one ballistics factor affects another isn't that difficult to comprehend. The ballistics "language" may sound uncommonly complicated, but it refers to procedures which boil down to common sense!

FIGURE 1 — The Powley Computer for Handloaders (left) gives you a "reading" on powder charge. loading density, RCBW, and muzzle velocity. The Powley PSI Calculator (right) determines muzzle energy and chamber pressure.

Let's delay the fun for a few minutes. Before actually *using* the computers, refresh your memory and reread Part 2 of this study unit. Then the meaning of the various terms used by the computers will be fresh in your mind. By doing this, then following the simple, step-by-step instructions provided, you'll be doing interior ballistics in no time at all!

STEP-BY-STEP INSTRUCTIONS ARE BEST

You'll note that an instruction booklet accompanies your computers. This was written by Homer Powley, inventor of the computers, who is recognized as the most resourceful and innovative ballistician of our time. His booklet contains a wealth of supplementary and explanatory material which will be most valuable *after* you understand the basic operation of the computers. We have knocked those instructions down into basic 1-2-3, step-by-step procedures to assure quick and easy learning, and easy reinforcement.

So be sure to follow the "1-2-3" instructions that follow. Later, after you've mastered the basic operation of your computers, we urge you to read Mr. Powley's booklet thoroughly. His remarks will then greatly contribute to your understanding.

The following instructions are based on Mr. Powley's. We have merely rearranged the presentation.

GENERAL INFORMATION — WHYS AND WHEREFORES

The Powley computer and PSI calculator were designed for use with modern high-powered rifles, generating pressures in the 40,000 to 50,000+ psi range. This includes guns from the .30/30 bracket on up to the magnums. The powder charges your computer will indicate all produce relatively mild pressures, at levels where accuracy and barrel life are usually optimum. As we go through the examples, you'll see how you can raise pressures (and velocities) to maximum. In other words, the computer's first "read-out" can serve as either the recommended mid-pressure load for a given cartridge or as a starting point from which you can work up to maximum.

Now find a pad and pencil and let's get started!

STEPS TO FOLLOW IN USING THE POWLEY COMPUTER

Example 1: You have a .308-caliber Winchester rifle with a 24" barrel and want to develop a good-accuracy load using a 150-grain bullet.

Selecting the Powder

Step 1. After determining case (water) capacity to the base of the bullet — it's 51.5 grains — move the computer slide until the 51.5 CASE CAPACITY point is directly under START. Arrow 1 shows that 44.3 grains of powder is the recommended charge (see Figure 2). Jot down "Charge, 44.3 grs." on your pad.

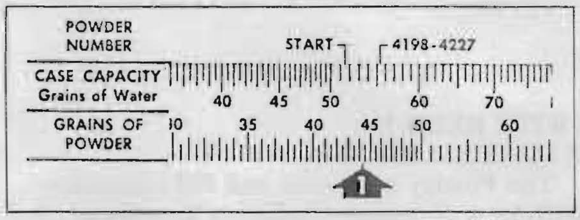


FIGURE 2 — Step 1: Set your case capacity at 51.5 and you get a recommended powder charge of 44.3 grains (indicated at Arrow 1).

Go ahead and determine loading density at this point, too. To get loading density, divide the powder charge (44.3) by the case capacity (51.5). Jot this down on your pad also.

$$51.5 \overline{)\,44.30} \quad = .8601$$

Loading density is therefore 86%, meaning that we're using 86% of the available space in the cartridge case.

Step 2. The next thing to determine is the RCBW (ratio of charge to bullet weight). Leave the computer slide at the previous setting and find the bullet weight (150 grains) on the line directly under the second "opening" in the computer. Directly above this "150" point, read .295 (see Figure 3). This tells you that the powder weighs 29.5% of the weight of the bullet. Jot down "RCBW, .295" on your pad under the charge number.

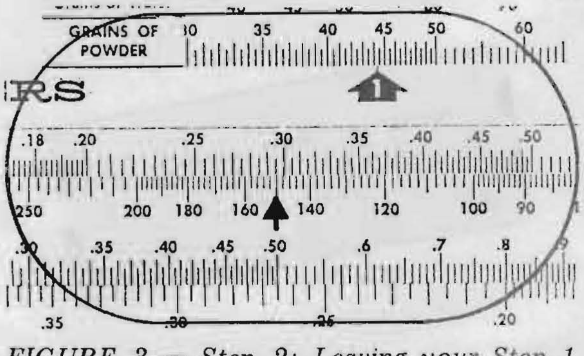


FIGURE 3 — Step 2: Leaving your Step 1 slide setting in place, *you determine your RCBW by seeing what that value is at the BULLET WEIGHT (150 grains). Here, the RCBW is .295.*

BOOSTING PRESSURES AND VELOCITIES

As you've seen, the Powley computer usually "recommends" fairly mild loads, for safety, long barrel life, and good accuracy. You may, however, wish to boost computer-recommended loads to higher velocities — which, of course, also raises pressure. It's time to present a basic axiom of interior ballistics:

> When a powder charge is changed by a given percentage, the velocity changes by the same percentage. In other words, if you add 10% more powder, you add 10% more velocity. Reduce the powder charge by 10% and velocity drops 10%. However, pressure changes by *twice* this percentage. For example, if you increase your powder by 5%, your velocity increases 5%. But, pressure increases by 10%. Reduce the powder charge 5% and velocity drops 5%, while pressure drops 10%.

Let's relate this axiom to your 150-grain bullet, 44.3 charge of IMR 4064, loading. The indicated pressure was 45,500 psi. Let's say you want to increase pressure to maximum, to about 50,000 psi. This would represent a 10% increase in pressure.

$$\begin{array}{r} 45,500 \\ \times \quad .10 \\ \hline 50,050 \end{array}$$

The present psi plus 10% would thus be 50,050 psi.

And, increasing pressure by 10% gives you a chamber pressure of 50,050 psi, which is right at maximum. Because you've increased pressure by 10%, you can increase your powder charge by 5%. Your original charge was 44.3 grains, so 5% of this figure gives you an extra 2.2 grains (.05 x 44.3 = 2.215) for a total charge of 46.5 grains.

As velocity also rises 5% (.05 x 2,700), you've gained an additional 135 fps. Your muzzle velocity at maximum pressure is therefore 2,835 fps.

Once you calculate a given "starter" load, you go on from there — adding (or subtracting) velocities and pressures in the ratio explained. You don't have to refigure the whole thing with the computers.

EXPLAINING THE POWDER NUMBERS

Now that you've had a chance to "get your feet wet" and understand the basic functions of the Powley computer and PSI calculator, it's time to explain something about the powder "alternatives" listed. Pick up your computer and find the POWDER NUMBER heading at the left. To the right of this heading and on the slide is a sequence of letters and powder numbers starting with "A, 5010" and ending at the right with "4227." These letters and numbers represent the powders your computer will specify for various cartridges, with the slowest burning powders at the left. The farther to the right they appear, the faster burning the powder.

Obviously the letters aren't powders. They represent theoretical powders with burning rates that would place them in these positions on the scale, *if* they existed. Unfortunately they don't, so we have to compromise. In instances where Arrow 2 points to a letter, you select the slower burning powder to the *left.* Because this "compromise" powder is *slower,* we use 5% more than the computer calls for to reach the proper pressure level. When Arrow 2 points to D, E, or F, there is no problem (see Figure 13). There *is* a powder to the left. Now let's see what you do when Arrow 2 points to selections on the extreme left of the scale (see Figure 14).

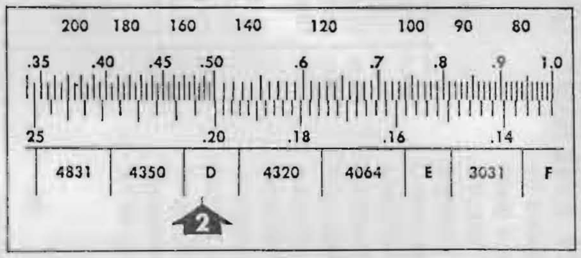


FIGURE 13 — When Arrow 2 points to D, E, or F, you select the slower burning powder to the left, but use 5% more to maintain the desired pressure level with the slower burning powder.

The arrow will never indicate A. Such a powder is not only theoretical, but the rifle that could use it probably doesn't exist. The same holds true for 5010. This powder was used in large, 50-caliber machine gun cases during World War II and is no longer available. About the only instance in which you'd use such a powder would be when necking down a .300 Weatherby case to 6.5mm, or maybe a .300 Winchester magnum case to 6mm. Forget it for the present.

If the arrow points to B, use Hodgdon's H870, which comes very close to the theoretical burning rate of B. In most instances the load indicated will be a bit lighter than the computer average, especially with light bullets. You may wish to work up such loads 2% to 3%. (The computer was designed for IMR extruded powders, and H870 is spheroid. Therefore, its recommendations cannot be as precise with H870.)

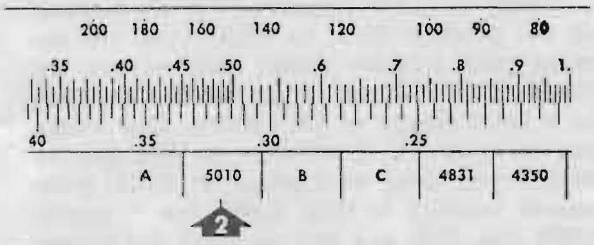


FIGURE 14 — Arrow 2 will never indicate powder A or 5010 (unless you've made an error); powder A is theoretical, and 5010 was used for the World War II large 50-caliber machine guns.

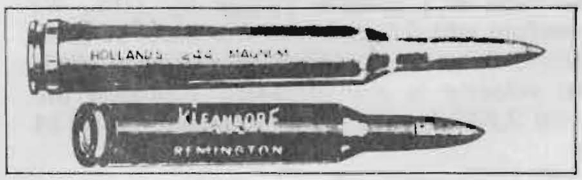


FIGURE 15 — A borderline "overbore-capacity" cartridge is the .244 H&H magnum (top), utilizing the huge .375 H&H case necked down to 6mm. Case capacity far exceeds that of the 6mm Remington, yet velocity is nearly identical. Cases this large (in relation to bore) require the slowest burning powders obtainable.

If the arrow points to C, select the compromise powder to the *right*, 4831. Because 4831 burns faster than theoretical powder C, you must use 5% *less* powder than the computer calls for to maintain the desired pressure level. This is the only instance in which you move to the *right* in selecting a compromise powder.

The numbers 4198 and 4227 at the extreme right of the slide, and the same numbers appearing opposite START at the top of the computer, may be disregarded. They are "off-scale" and for experimental use only.

When Arrow 2 falls "on the line," always select the powder to the left, except in the case of C.

HOW TO USE YOUR COMPUTER WHEN YOU MOVE TO THE LEFT OF AN INDICATED LETTER

Example: You're working up a load for your .30/06 using a 180-grain bullet. You've determined that case capacity is 61.5 grains of water and that the bullet's sectional density is .272. You've used these figures to work through Steps 1 to 3, and Arrow 1 specifies 52.9 grains of D powder.

Procedure: The rule is to add 5% to any powder selected to the left because it is slower burning. In this instance the powder is 4350. The computer specified 52.9 grains. Therefore, a 5% increase is 2.6 extra grains of powder (.05 x 52.9). The correct charge is 55.5 grains of 4350.

However, because the powder volume has now changed, you have to find a new ratio of charge to bullet weight number. Set Arrow 1 at 55.5 opposite GRAINS OF POWDER. Over your bullet weight figure of 180, you see that your new RCBW number is .308. Write it down on your pad; you'll need it in the final step of calculating velocity.

You then proceed as before, starting with Step 4 to determine expansion ratio, and continuing through Step 7.

HOW TO USE YOUR COMPUTER WHEN YOU MOVE TO THE RIGHT OF INDICATED LETTER "C"

This is the only instance, when C is indicated, that you select a powder to the right.

Example: You have a .264 magnum Winchester rifle and want to select a load for a 100-grain bullet. Case capacity is 82 grains of water and sectional density of the bullet is .206. You've worked through Steps 1, 2, and 3 and found that the computer specified 70.5 grains of powder C.

Procedure: Because the powder to the *right*, 4831, is faster burning than theoretical powder C, you must *subtract* 5% from the recommended charge. This means that you will reduce that 70.5-grain charge by 3.5 grains, to 67 grains. Because the powder volume has changed, your ratio of charge to bullet weight (RCBW) has also changed. Reset Arrow 1 to 67 grains of powder which, with a 100-grain bullet, gives you a new RCBW of .67. You then go on, starting with Step 4 and continuing through Step 7.

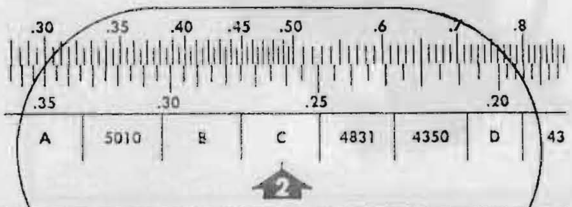


FIGURE 16 — The only instance when you select a faster burning powder is when powder C is called for. When this happens, select powder 4831 to the right, but remember to reduce your charge by 5% to maintain your pressure level.

USING YOUR COMPUTER
FOR MAGNUM LOADS

The Powley computer isn't designed to recommend loads producing pressures in excess of 50,000 psi. While the maximum safe pressure for magnums is 55,000 psi, few if any manufacturers load hotter than 52,500 psi. Let's run through an example of what happens when you use your computer to calculate a magnum load, and how you "build" the mild recommended load to magnum pressures and velocities.

Example: You have a 7mm Remington magnum rifle with a 26" barrel and want to develop a reasonably fast 160-grain bullet loading. You've determined that the case capacity is 80 grains of water. That 26" barrel, ballistically speaking, is 24.5" long.

Procedure: By working through Steps 1 through 3, you discover that the computer specifies 69 grains of powder C. Here you move to the right and reduce the 4831 charge by 5%. Your initial powder charge is thus 65.5 grains of 4831. Reset Arrow 1 to 65.5 grains, and your new RCBW is .41. You move on to Step 4 and learn that your ER is 5.75. Your velocity is then calculated at about 2,840 fps at the muzzle. The PSI calculator tells you that this velocity is achieved at 44,500 psi — too low to really justify that magnum size case.

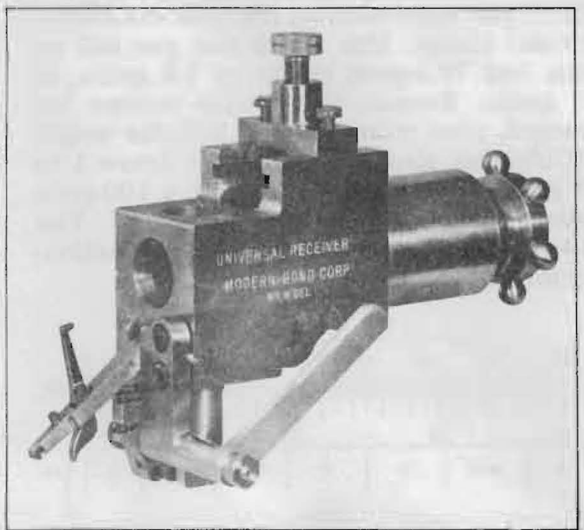


FIGURE 17 — Actual chamber pressures are determined with pressure guns in which the receiver (above) is universal. Barrels of any caliber (from .17 to .50) are screwed into the unit and tightened down with the "wheel" at the right. Here, the receiver is open, permitting chambering of the test cartridge. The "copper crusher" chamber measuring instrument is at the top of the unit.

First raise the pressure 10%. By increasing the pressure 10%, to 48,950 psi, you increase your powder charge and velocity by 5%. Okay, a 5% powder increase is 3.2 grains, for a total charge of 68.2 grains. This brings you an extra 5% in velocity, or 142 fps. At 48,950 psi, using 68.2 grains of 4831, your muzzle velocity is thus 2,982 fps — nearly 3,000 fps. Still not fast enough? Let's raise the pressure a full 20% from our starting pressure of 44,500 psi. The result is 53,400 psi, which is crowding the magnum maximum of 55,000 psi.

Because we raised the pressure 20%, we can raise our powder charge by 10%. We therefore add 6.5 grains to our basic 65-grain charge, for a whopping 71.5 grains of 4831. Our velocity is also increased 10% over the initial 2,840 fps, so our new velocity is 3,124 fps.

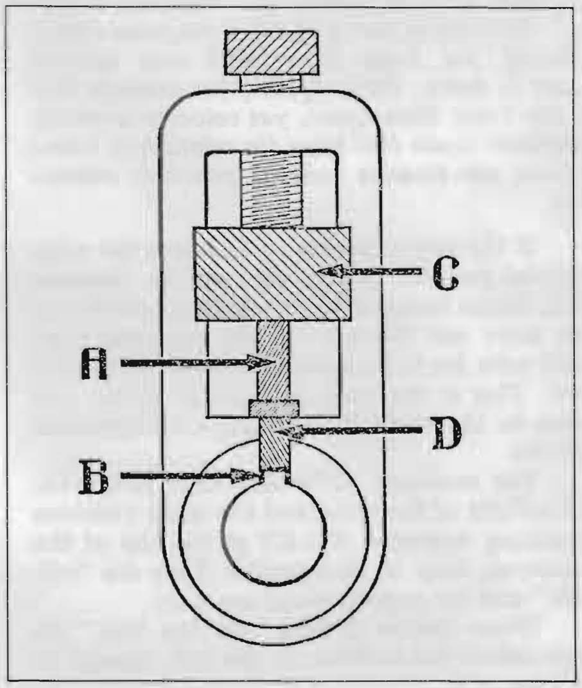


FIGURE 18 — The copper crusher-type gauge shown above mounts on the receiver of the pressure gun. A copper cylinder of a known compressibility factor (A) is compressed by the gas escaping from a hole in the bore (B), which drives a piston (D) up against the copper cylinder. The cylinder is held in place by the anvil (C), which is adjustable for different-length copper cylinders. The amount of compression, measured against a scale, shows the chamber pressure.

The only problem is, 71.5 grains of IMR 4831 won't fit into the case. So we move to the right on the Powley scale and select the finer-grain IMR 4350 which will fit with a bit of cramming. Because IMR 4350 is faster burning, we reduce the charge from 5% to 68 grains. This is a maximum charge by any standard.

Never start with maximum loads, whether computed or taken from a loading manual, when actually making up rounds for firing. Rifles can vary slightly in chamber and bore dimensions, causing big differences in pressure. The Powley computer is based on "norms," and if a given rifle doesn't correspond to that norm, then trouble could lie ahead.

In the foregoing example, you should start with the mild recommended load, or boost pressure only 10% when actually commencing your firing. You work up from there, watching for high-pressure signs. Never, never *start* with maximum loads, regardless of their source!

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.

CONCLUSIONS AND AFTERTHOUGHTS

After wading through the foregoing, get some brass cases of as many different cartridges as possible and check them for water capacity. If you don't have the actual rifles for measuring the "ballistics lengths" of the barrels, use an average of 22.5" and 24.5" respectively for 24" and 26" barrels: Then figure loads for each cartridge with a number of different bullet weights. Check your findings against the loads (and barrel lengths) listed in a reputable reloading manual.

You can expect minor discrepancies, but major differences mean you goofed somewhere. After gaining practice, you will be ready to make up some loads for your own rifle, but, *once again*, check out your figures in a loading manual. Always verify your figures by doing the calculations *twice*, *correctly*. Then check out your figures to make sure you're close to values given in a loading manual for comparable loads. The computers don't make mistakes, but you *might* — especially when you're just getting familiar with your new slide rules.

An error on paper is one thing, but an error in loading can be quite another!

A big help in working with the computers (unless you've got eyes like an eagle) is a good magnifying glass or magnifier which rests directly on the computer. Matching up the graduations can be a bit mind-blowing — until you get the knack of it.

Master the Powley computer and PSI calculator, and we know you will, and you'll soon have a "working" understanding of interior ballistics.

WARNING! The 4831 powder used by the computer is Hodgdon's 4831. The newer IMR 4831 is faster. When actually loading cases, back off 5% on recommended loads if you are using the new IMR 4831.

PROGRAMMED EXERCISE

1

1. Calculate the load for a .30/06 rifle with a 26" barrel, firing a 165-grain bullet which chambers a case with a 61.5-grain capacity. Facts given:

   Cartridge — .30-caliber
   Barrel — 26" (24.5" for ballistics purposes)
   Bullet — 165 grains
   Case capacity — 61.5 grains

Step 1:	Determine powder charge and loading density	________ ________
Step 2:	Determine RCBW	________
Step 3:	Determine sectional density and powder selection	________ ________
Step 4:	Determine expansion ratio	________
Step 5:	Determine muzzle velocity and muzzle energy (17.04 x 165)	________ ________
Steps 6 & 7:	Determine chamber pressure	________

2. Calculate the load for a .30-caliber rifle with a 24" barrel, firing a 180-grain bullet and chambering a case with a 51.5-grain capacity. Facts given:

   Cartridge — .30-caliber
   Barrel — 24" (22.5" for ballistics purposes)
   Bullet — 180 grains
   Case capacity — 51.5 grains

Step 1:	Determine powder charge and loading density	________ ________
Step 2:	Determine RCBW	________
Step 3:	Determine sectional density and powder selection	________ ________
Step 4:	Determine expansion ratio	________
Step 5:	Determine muzzle velocity and muzzle energy (13.99 x 180)	________ ________
Steps 6 & 7:	Determine chamber pressure	________

Answers on Page 12

ANSWERS

1

1. Powder charge, 53 grains
   Loading density, 86.2%
   RCBW, .32
   Sectional density, .249
   Powder selection, 4320
   Expansion ratio, 8.3
   Muzzle velocity, 2,770 fps
   Muzzle energy, 2,811.6 foot pounds
   Chamber pressure, 45,800 psi

2. Powder charge, 44.3 grains
   Loading density, 86.0%
   RCBW, .246
   Sectional density, .272
   Powder selection, 4320
   Expansion ratio, 9.0
   Muzzle velocity, 2,510 fps
   Muzzle energy, 2,518.2 foot pounds
   Chamber pressure, 44,500 psi