SECTION 2

- SPEEDS OF FACTORY SHELLS
- ERRORS
- CHOKE AND BARREL EFFECTS

If you hang around any gun club you will hear many pronouncements about the speed of this or that factory shell. The implication is that within one brand, the speed of one type of shell is a constant value you can count on. This experiment tests that proposition.

The equipment is the same as used in the previous section. A Remington 870 with a 30-inch, cylinder-choke barrel was fired from a rest over two Oehler 35P chronographs. Screen spacing for each chronograph was 2 feet; the distance from muzzle to the first screen was 4 feet.

Shells of five brands were tested: Winchester, Remington, Fiocci, Federal plastic, and Federal paper. Though the exact name varies by brand, the speeds tested were Handicap, Heavy (3-gram), Light (2-3/4-dram), and "Lite"(low recoil). For each shell in the test, boxes representing five different lots were obtained. (Shells were considered to be from different lots if the "lot numbers" stamped on the box were different.) Ten shells were fired from each box; the total fired was about 900. Many of the tested shells were from recent Grand Americans.

In the accompanying graph each separate figure represents the data from five lots of one speed, one brand. The vertical line shows the range from slowest to fastest and a short horizontal bar represents the average speed of one lot, based on 10 shots.

The figures are grouped together as a brand. The leftmost (and highest) symbols in any group are the "Handicaps"; the rightmost (and lowest) are the "Lights." The data for "Lites" are omitted from the graph since their presence or absence would help identify the shells by brand name.

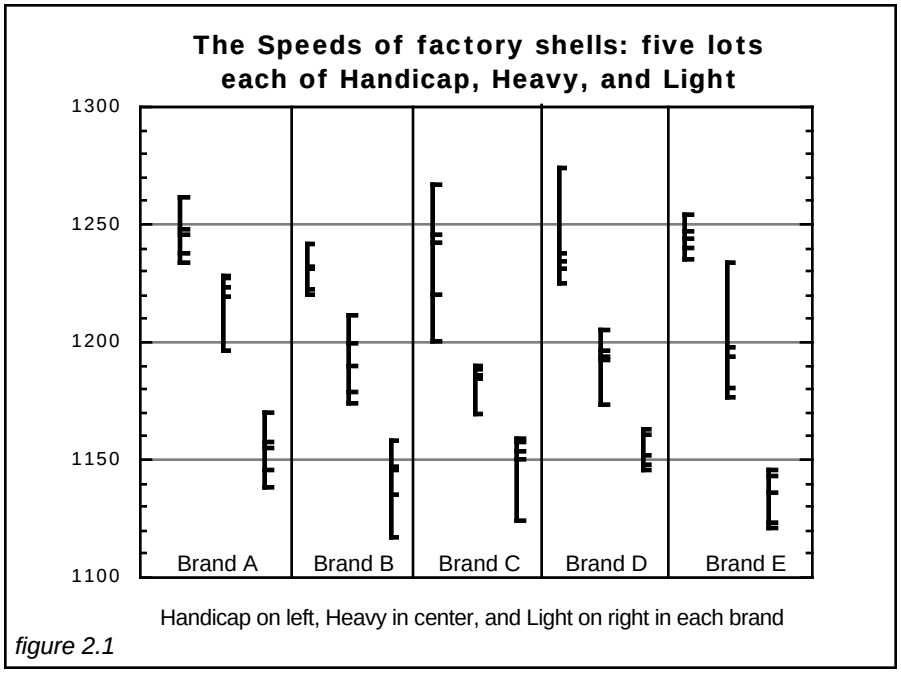

figure 2.1

In several cases there is a big variation in the speeds within one type of shell. The differences are large enough to explain why the shells which last week didn't seem to kick hard now do, or why one shooter says that such-and-such handicap shells just dish out too much punishment while another says they are the "softest shooting" on the market. The box each tried might be exactly as he described it.

In spite of all the variation, it is still fair to say the factories provide nearly what they promise. If you buy Handicaps you'll get about 1250 feet per second (fps), Heavies about 1200, and Lights about 1140. With Lites expect 1100 or 1140. Of the 89 lots tested, the standard deviations of 36 were good (11 or below), 38 were average (12 through 16), and 15 were below average (17 or higher).

So what about the reloader who tries to match his shells to some factory offering? He's chasing a moving target. And if he just follows the book, weighing loads when opening a new keg to keep everything the same? Here's what happened to me: in switching to a different lot of powder: the charge dropped by my standard bushing increased by 0.3 grain, but the speed of the shells it produced dropped by 25 fps. If you want real consistency you have to use a chronograph. Without it you can get close, but that's all.

Errors (1)

All the tests reported so far used one cylinder-choked Remington 870 barrel. This was done to make the results comparable and to reduce errors. Errors in measurement—not just of shot speed but of anything—are inevitable. How can a chronographer recognize an error when it occurs?

There are two types of error that concern us, systematic and random. A systematic error occurs when the instrument adopts a bias reading, for example, 50 fps too fast all the time. A random error occurs when the number on the readout is not close enough to the actual speed of the associated shot.

Systematic errors can be reduced by using better technique. When I started this project I had no experience with light-operated chronographs, though I had used an inductive model for 14 years. As I look back at early entries in my notebook I see pages of data that now appear impossible. As I got better the results did too.

One defense against systematic error is to use "calibration shells" at the start and end of every session. If you find an exceptionally consistent factory load you can lay in a large supply of that particular lot for this purpose only. If you are a good reloader you can make your own—lots of them and all at once without changing anything. Shooting half a box at the start and end of every experiment will assure you that all is well or warn you when it isn't. I rarely have trouble now but sometimes it becomes clear that something has gone wrong and I might just as well quit for the day. It's usually better next time but sometimes the unit needs factory care.

Random error is a different problem. You're almost through with a test of good-looking ammo and a deviant shot speed slips in. It may be just unusually high or low or it may be way off the scale. Do you keep it or ignore it?

The only real solution is a second, independent measure of that questionable shot. With the Oehler Model 71 in my shop I measure the speed, pressure, and resulting gun recoil speed for every shell. If a shot reads way too slow, and the pressure is too low, and the gun recoils more slowly too, I see that everything matches up and I keep the data point. Using these criteria I find that the Model 71 makes very, very, few errors.

For outdoor work I use two chronographs. Here are typical results using factory Handicaps. Ten shots were fired with a cylinder choke (left side of graph), then ten more with a full choke (right side). The shots are arranged from slowest to fastest under each condition.

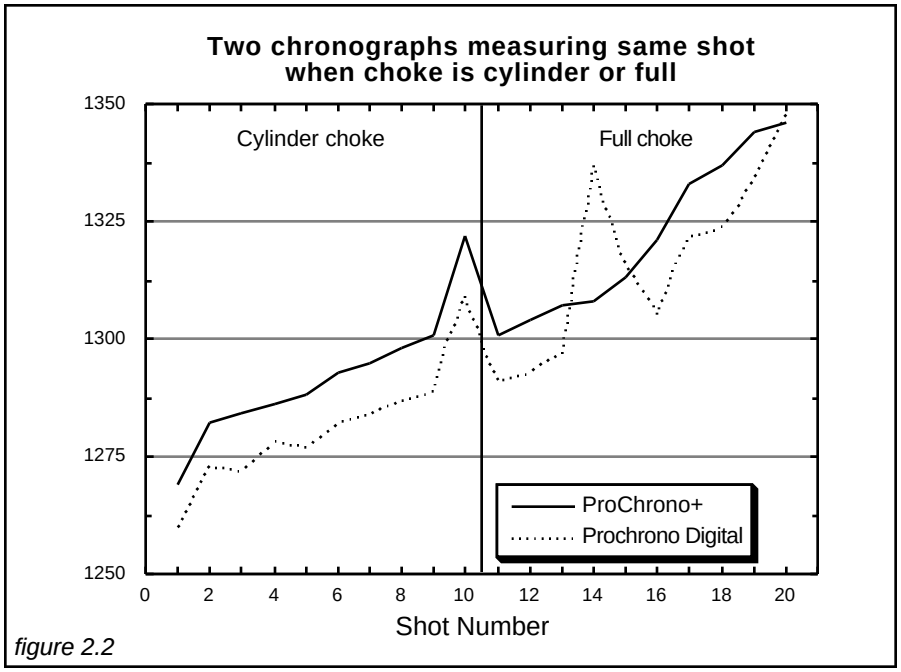

figure 2.2

What do I call an error? My standard is a disagreement between two chronographs of more than 10 fps when bias has been taken into account. As a rule, the ProChrono Plus indicates about 10 fps faster than its Digital stablemate. If the Digital reads as fast as the Plus, or more than 20 fps below it, it's an error.

The graph illustrates why you can't just throw out data which doesn't "fit." Shot #10 is an extreme value from the cylinder choke but it isn't an error: both ProChronos agree. Shot #14 is an error by one of them, but it is not an extreme value. Shot #20 is both an error (the Digital reads higher than the Plus) and an extreme value. Nothing about the results from either chronograph, viewed in isolation, will tell you what information is valid, what isn't.

Here the errors are small and don't effect the results; you can keep them or throw them out. But large errors are common, as are large deviations which are valid data. Just hitting the "Omit" button when something seems too far off can blind you to problems you should be aware of and really subverts the whole point of chronographing.

The effect of choke on speed and consistency

The results of shotgun chronography are dependent on the degree of choke in the gun firing the shells. In the following experiment five brands of "Handicap" loads were tested. A Remington 870 fired over two ProChrono chronographs. The two barrels were both Remington 30-inch trap barrels with 0.729 inch bores. The choke of one was the original "full" with a constriction of 0.040 inches; the choke of the other had been entirely reamed out leaving a "cylinder" choke.

With each brand of shell, 10 shots were fired with a cylinder choke (left side of graph), then 10 more with a full choke (right side). The shots are arranged from slowest to fastest under each condition.

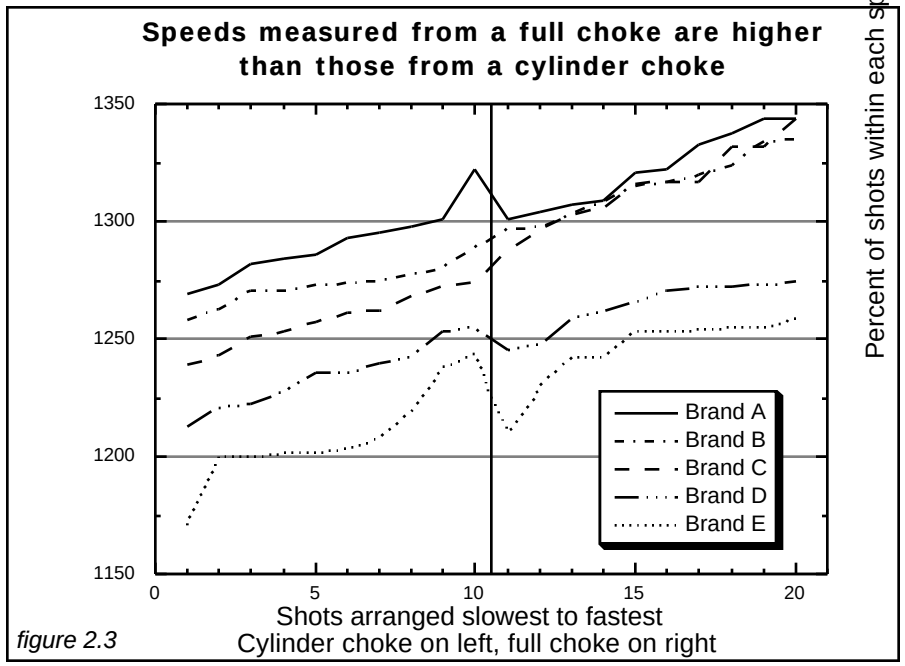

figure 2.3

The average increase in the measured speed through the full choke compared to the cylinder choke is about 50 fps. There is another effect evident here too, and that is that not all the brands are affected equally by the change in constriction. Under the cylinder choke condition the five brands are distinctly different. With the full choke, in contrast, the three fastest are all about the same.

One thing is sure. Three brands of shells look ATA-legal on the left and ATA-illegal on the right, and all we've done is change the barrel.

It is counter-intuitive that a full choke leads to faster chronograph readings—shouldn't the shot, hitting the constriction at the end of the barrel, be slowed down? Is this something that always happens or was this experiment an exception? The following study, in which 100 shells were fired using a cylinder choke, then 100 with a full choke, show how pervasive the effect is.

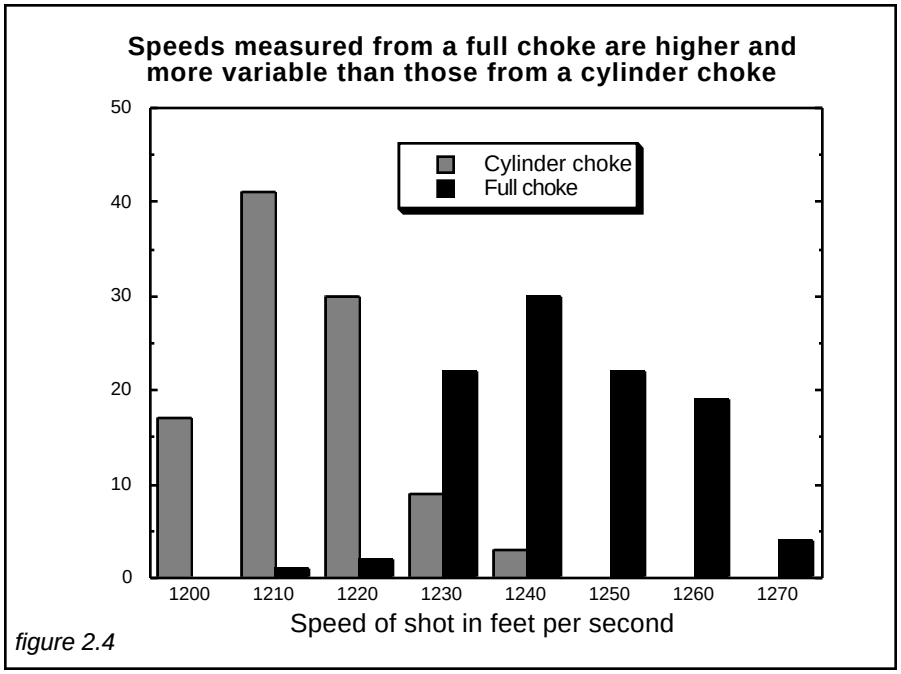

figure 2.4

In a December 1989 article in The American Rifleman, Ed Lowry, the dean of American ballisticians, explained that some of the leading pellets through a full choke are accelerated relative to the main body of the shot; this may be what we are seeing here.

In this test the average speed is increased by 25 fps. The lower peak and wider spread of the full-choke speeds illustrates another typical, but not universal finding: full-choke results are more variable.

An earlier experiment with an inductive, rather than light-operated, chronograph had different results. With the same barrels it was the *cylinder choke* which read 25 fps faster, a reversal of the findings above. The different way the two types of machine sense the passage of shot accounts for these contrasting outcomes.

Effect of choke (2)

Shooters use a variety of chokes when chronographing their own shells, chokes other than those tested so far. Can we fill in some of the gaps between the two end points—cylinder and full—used in the last two trials?

I machined a series of choke tubes for a Beretta 303 with the following constrictions: 0, 0.005, 0.010, 0.020, 0.030, and 0.040 inches. These correspond roughly to the designations cylinder, skeet, improved cylinder, modified, improved-modified, and full. The experimental question is whether the speed-increasing effect of choke fades in step-by-step or appears all at once at some point in the series.

The Beretta with an unported 32-inch barrel (bore diameter 0.723 inches) was used in the usual arrangement; two Oehler 35P's measured speed. Twenty shells from an especially consistent lot of light 7-1/2's from the 2001 Grand American were fired through each choke

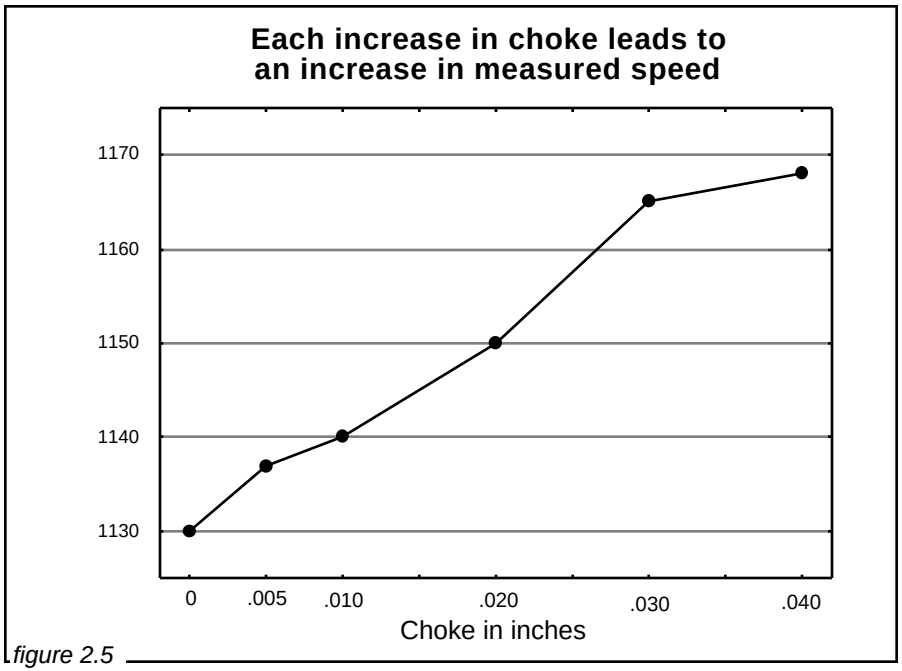

figure 2.5

The speed-increasing effect of choke began with the smallest constriction, 0.005 inches. As the degree of choke increased, so did the speed, though the effect began to taper off once the choke exceeded 0.030 inches. Four other full choke 303 barrels produced speeds from 1151 to 1168 fps. The difference in speed from cylinder to full—about 35 fps—was a typical outcome for the dozens of experiments of this kind that I conducted.

More about errors

In an earlier section I discussed my criteria for determining what was an error. I said that if two chronographs differed by more than 10 fps (when systematic bias was accounted for) there was an error. I didn't mean I'd automatically throw the data out, just that there was an inconsistency which I should look into.

With a cylinder choke such differences seldom occurred, perhaps one time in a hundred. If there was an error, it was usually large and could be narrowed down to one chronograph or the other. If one reported an "average" value and the other said the speed was off by 100 fps, it was pretty clear where the error lay. Transcribing the data from the printed output of the chronographs into a notebook was easy: the printouts could just be laid side by side and each number had its natural counterpart on the other strip of paper.

With a full choke the picture was entirely different. In the first place, the "error rate," instances where the values differed by more than 10 fps, jumped from 1 percent to over 25 percent.

Second, the kind of errors changed. Rather than matching speeds interspersed with an occasional huge difference, discrepancies of 20 or 30 feet fps became common. I could hardly tell where the printouts matched up anymore. It was as if using a full choke resulted in some moderate random number, positive or negative, being combined with every value. Because the effect really was random, and small in comparison with the speeds being measured, the average speed was little affected. Two printouts which hardly looked the same at all would report nearly the same average, at least over a string of 20 shots. But strings of 10 shots became less similar between the two chronographs and 5-shot strings even less. As a result, I suggest that if a full choke is used, the minimum sample size for dependable results should be greater than the 10 shots which sufficed in the cylinder-choke tests.

Other Barrel effects

There are more ways barrels can differ than just in choke; among those ways are length, bore diameter, and chamber length.

Fourteen Remington 870 barrels encompassing all of the above differences were used in the next experiment. All were 30-inch except as noted. Twenty of the same excellent factory shells used in the last experiment were fired from each test barrel over two Oehler chronographs under the conditions described earlier.

The most open choke, cylinder, was tested at the start and end of the experiment and recorded speeds of 1154 and 1159 fps. The modified choke produced a speed of 1162 fps.

There were 5 full-choke "trap" barrels with bores ranging from 0.727 to 0.733 inches. They produced speeds from 1179 to 1188 fps. Two more with magnum chambers also fell within that range. A single 34-inch trap barrel clocked 1201 fps.

The two "overbore" barrels (diameter 0.745 inches) on veteran Competition 870's produced speeds of 1189 and 1187 fps, at the upper range of their standard-bore stablemates. The two modern factory overbore barrels with extra-full Remchokes™ were significantly slower at 1168 and 1171 fps. There was no tendency for the overbore barrels to shoot faster as is commonly asserted.

An earlier experiment with an inductive chronograph produced contrasting results. In that test, the overbore barrels were faster, and the magnum chambered tubes slower, than any of the standard "trap" barrels they were compared with. I cannot account for this difference.

All the barrels of the Beretta 303 produced slower speeds than their Remington 870 counterparts. Was this due to the fact that the Beretta 303 is a semiautomatic, and uses part of its gas pressure to operate the action? The same shells, fired by a Remington 1100, produced 870-like speeds. For this reason I think it's unlikely that the lower speeds from the Beretta 303 are a consequence of its action.

One last thing about barrel differences. We've all heard that "Every barrel is a law unto itself." While this may have validity in respect to patterns, there is a limit to its application to shot speed. According to the inductive Oehler 71, if a particular shell is faster than another through one barrel, it's faster through them all.

Summary of Section 2

There are large speed differences among different lots of the same brand and type of factory shells. This makes it impossible to "calibrate" chronographs with commercial ammunition or for the reloader to "duplicate" a factory load.

There are two main types of error a chronograph can fall prey to, systematic and random. Systematic errors can be reduced by care and experience; random errors are best addressed by using two chronographs and checking for disagreement between them.

The speed readings from a full choke are faster and more variable than readings from a cylinder choke firing the same shells. This speed-increasing effect is reliably related to the degree of choke: the tighter the choke, the faster the reported speed. Chronographers using full chokes should plan on firing more shots to get dependable data.

The five 870 barrels that measured the same shot the same. Tests of overbore barrels gave conflicting results: one type was similar to standard-bore tubes; the other type was significantly slower.

The semi-automatic Beretta 303 produced consistently slow readings with all barrels but the 1100's results were faster and about like the 870's. Thus there was no evidence that gas being bled off to operate the action had a measurable effect on shot speed.

The final picture of barrel effects is this: choke is almost, but not quite, everything. "Not quite" because there are differences, some consistent and some inconsistent, that are yet to be explained.

I wrote in the introduction to Section 1 "The shot velocity reading you get from a chronograph is not merely influenced by, but is *largely determined* by, the particular chronograph setup which is used, and changing anything about the test will change the results." It is what I learned doing these experiments that lead me to make that statement.