SECTION 3

• SHELL PRESSURE
• PRESSURE AND VELOCITY

Most readers of this article will have a pretty good idea of the general shape of shotshell pressure curves, though they probably think they are more different from one another than they really are. Still, I think we should look at a typical pressure trace, see how it is obtained, and see what it can tell us.

A popular pressure transducer is the PCB model 167a, a two-by-three-eighths-inch threaded tube containing a tiny crystal which produces a voltage when it is deformed by a force. That voltage varies directly with the force producing it, i.e., twice the force generates twice the voltage. The sensor is screwed into a mount in a barrel so it touches the side of the shell about one inch forward of the rim. Wires carry the voltage to an amplifier, which sends the boosted signal to a computer, in my lab, to a Macintosh running Superscope II™ software. The mechanical setup is pictured below.

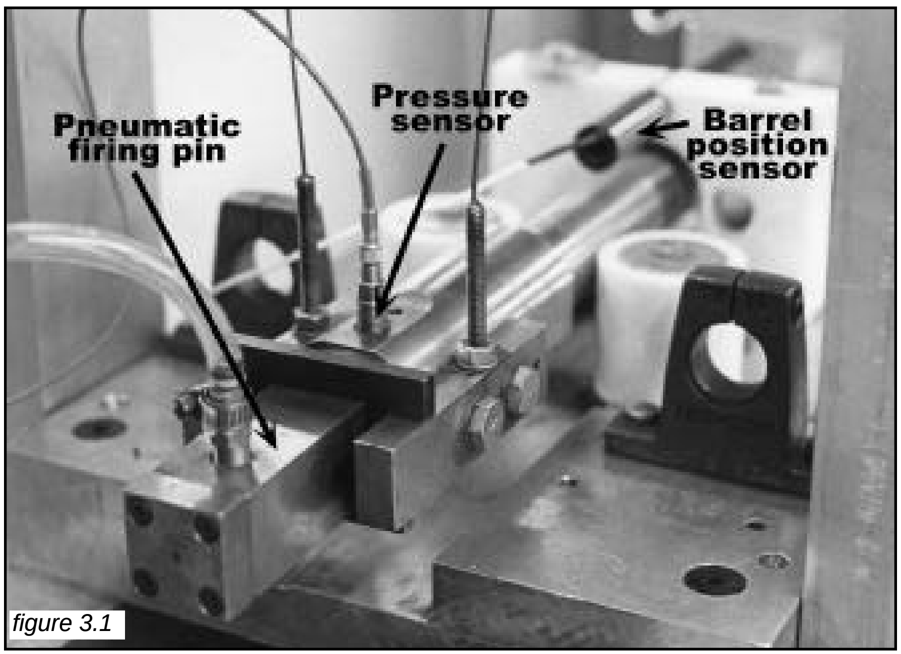

figure 3.1

The pressure sensor is the small object in the center connected to a thin insulated wire. To the left is the pneumatic firing mechanism. The barrel is a 30-inch, cylinder-choke product of H&S. The whole system is hung from wires. It can freely recoil and its position can be measured throughout the firing cycle. Pressure and location measurements are taken 23,168 times a second. Here are typical results:.

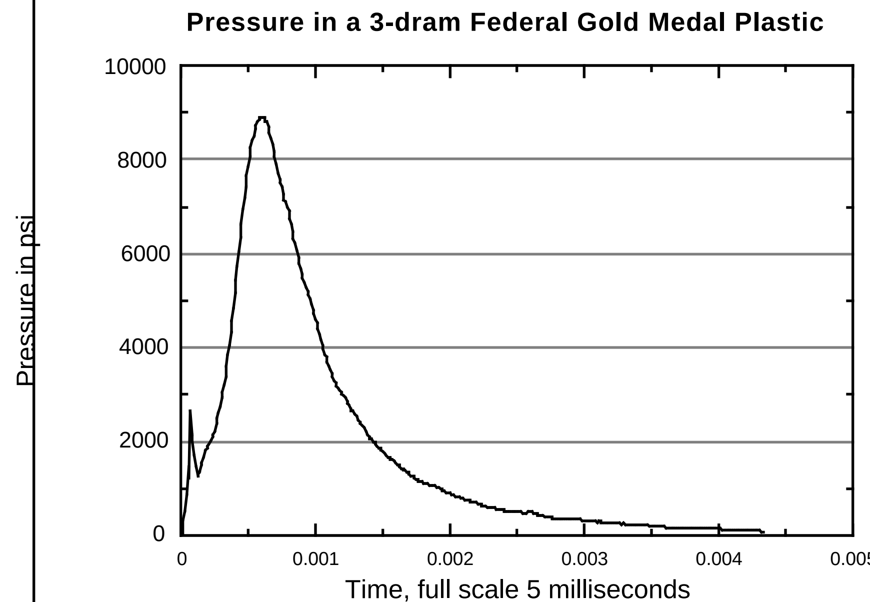

figure 3.2

Although for most purposes it is best to start recording the pressure at a later point in the rising powder pressure wave, the graph above results from starting earlier, just at the point the primer starts to ignite. The primer pressure peaks at about 1/10,000 second; the pressure then drops a bit before climbing again as the powder burns. In this case a peak of about 9000 pounds per square inch (psi) begins to drop at about 7/10 of a millisecond. The shot leaves the barrel at about 3.5 milliseconds after ignition.

The general contour of this curve—a primer peak, a dip, then a rapid rise in pressure and an equally rapid fall—is typical of almost any trap load. Subsequent graphs will omit the primer mark at the beginning; just keep in mind that it (usually) would be there.

Pressure curves for different powders

The fanciful pressure curves of shooting magazines and gun-club talk, existing as they do largely in thin air, can take any shape that will buttress an argument. Let's consider the ubiquitous "sharp jab vs. sustained push" descriptions. Proponents of slow-burning powders describe the benefits of low, extended pressure curves; users of Red Dot™ are advised to switch to Green Dot™ to enjoy the latter's more gentle curve.

Let's see how different these powders really are. Once-fired AA hulls were loaded with amounts of Red Dot and Green Dot to give about 1190 feet per second (fps) as measured by an inductive chronograph. The following graph compares typical results for each powder.

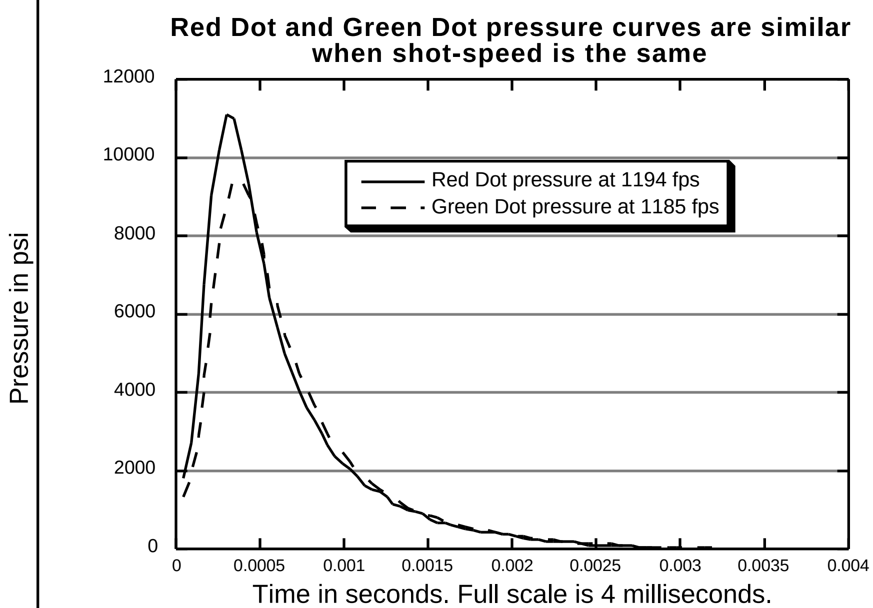

figure 3.3

The Red Dot pressure peak goes about 1500 psi higher than the one for Green Dot but with respect to time they are virtually the same, differing by no more than 1/10,000 of a second and generally far less. I just don't believe that anyone could tell the difference when shooting them. The people who experience Red Dot as a jab, Green Dot as a push, must be relying more on their own preconceptions than any differences in the pressure curves produced by the two powders.

There's some comfort for slow-powder theorists when more extreme differences in burning-rate are compared. In the graph below, Red Dot is compared to PB at speeds just below those being sold as "Handicap." The PB peak is lower and displaced to the right, that is, it is centered later in the firing event.

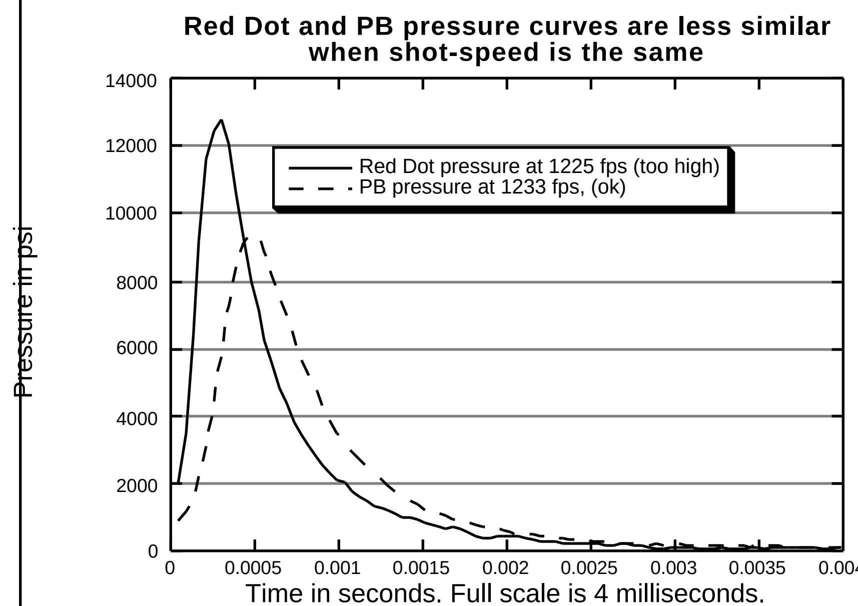

figure 3.4

There are three points to notice about this graph:

1) PB delivers the same speed as Red Dot with about 75% as much pressure.

2) The PB pressure curve is wider than the one for Red Dot and peaks later. It's wider by how much? I'd say 2/10,000 of a second. And by how much is it delayed? Only about 3/10,000 second. The big extended tail that's supposed to be on the PB pressure curve, the presumed source of the "push," doesn't show up. So I have to ask again, who could tell the difference?

3) Don't use AA hulls and Red Dot for shells this fast; the pressure is too high. This load is not in any reloading manual. Its pressure underscores the fact that even small departures (and this one was small) from published recommendations are dangerous.

Peak pressure and velocity

One of the intriguing things about the foregoing graphs is the fact that different powders can develop similar shot speeds and yet their peak pressures can differ by as much as 33%. Is there really no relationship between pressure and velocity? There are three ways we are going to look at this question, and we're going to get a different kind of answer in each case.

As the reloading manuals tell us, more powder leads to higher pressures. Paging through such a handbook we see that each powder has a relatively narrow range of recommended loadings—two, maybe three grains from least to most, a range of 100 fps if we're lucky. Powder needs pressure to burn efficiently. Below 6,000 psi the burn is unreliable, while pressures above 12,000 bring their own problems, including a tendency to climb a *lot* higher in a hurry. But for a particular powder viewed over a wide range of loadings, the relationship between peak pressure and velocity is robust.

The horizontal axis of the following graph represents shot speed, the vertical axis, pressure. Each data point represents one shot.

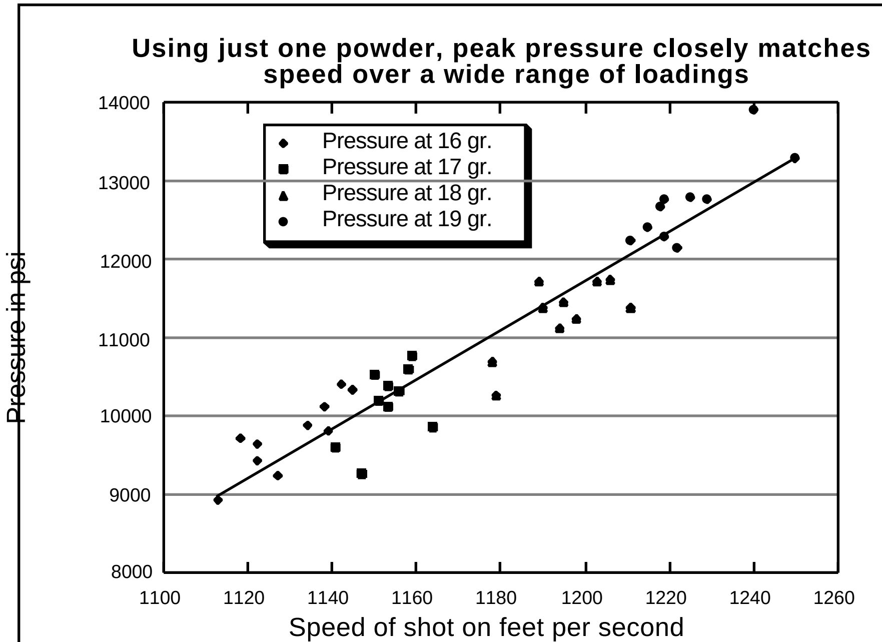

figure 3.5

Viewed this way, peak pressure and speed rise in lockstep; the high correlation means you could make a close prediction about one by knowing the other. The four-grain range of this test is more than this powder can handle: for the 19-grain charge all the pressures are too high, and the one-shot excursion to 14,000 psi is definitely forbidden territory.

When you look at the results for a single loading the results are somewhat different. Here is an enlarged look at the previous graph, looking at just the 17-grain loading.

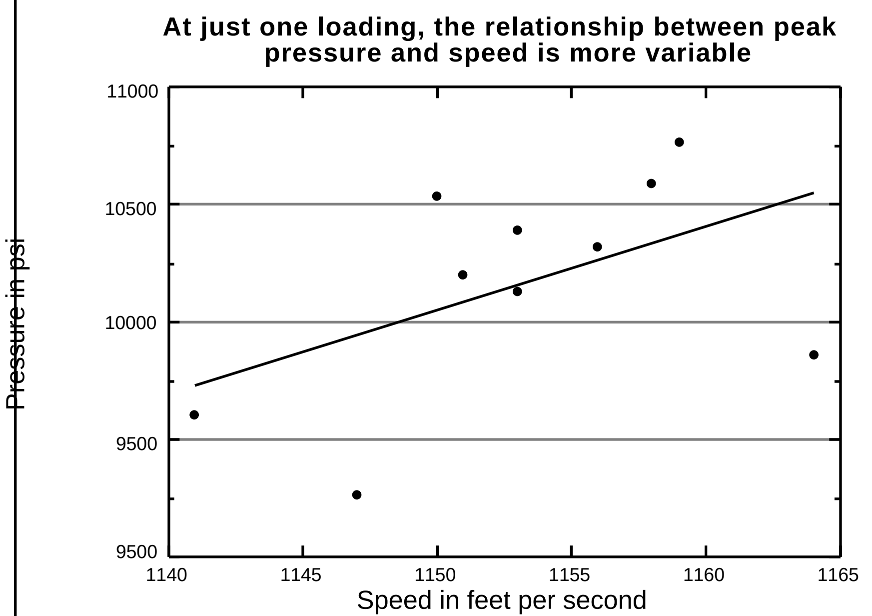

figure 3.6

Here the correlation between peak pressure and speed is weaker. In part this is just a statistical artifact—correlations always drop when the range is restricted—but this is a typical picture of what you can expect within one box of ultra-carefully assembled handloads. Shells only 3 fps apart in speed were 1200 psi apart in pressure; the fastest shell was only third-highest in pressure. In general this means that with any particular shell you can't make good predictions of speed from pressure or vice-versa. There is one exception. Sometimes a shell will clock an exceptionally low speed, one you might consider a chronograph error. If, however, the pressure is also unusually low, you know there was something wrong with the shell.

For the third look at the pressure/speed relationship we'll compare factory shells from three different manufacturers. One is a "Light" (2-3/4 dram-equivalent), the other two are "Handicap" shells which are widely used and are accepted as ATA-legal.

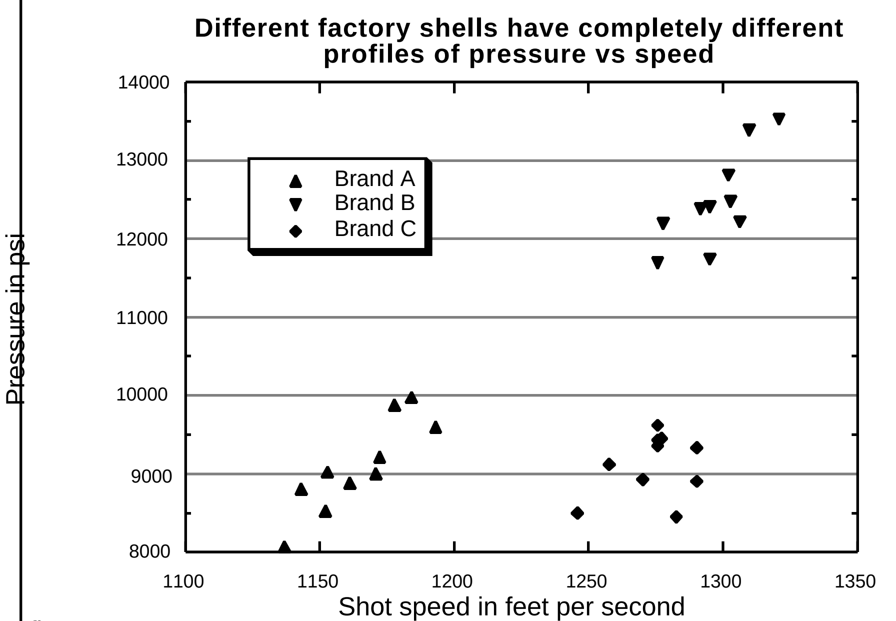

figure 3.7

The graph above shows how little shot speed depends on peak pressure. In the lower half of the graph we see similar pressures producing average speeds of either 1170 fps or 1270 fps; on the right side handicap speeds are achieved with either 9000 or 12,500 psi.

The data in the upper right of this graph reinforce the importance of measuring speed and pressure together rather than either one alone. If I'd tested Brand B and recorded the moderately-too-high speeds or way-too-high pressures in isolation, I would have had to doubt my instruments, but when they occur together, as they did here, I accept my readings as accurate. These high speeds and pressures, by the way, are not typical for this or any other manufacturer; they only showed up in this particular lot.

The high pressures shown in figure 3.5 and elsewhere make another important point: nothing that is written here should be taken as reloading advice. You can only reload safely from manufacturers' handbooks and other recognized publications.

You may think you can guess what powder I was using and may then further conclude that if I lived through it, so will you. **Don't believe it!** The barrel I use has chamber walls about half an inch thick and additionally I use a blast shield when loading at the upper ranges or when using a modified standard barrel under any conditions. Many reloaders think there is a "safety cushion" built into the published manuals; I don't think there is.

Summary of Section 3

The pressure curve in a shotgun shell starts with a very rapid rise and fall in pressure caused by the primer. The burning of the powder then takes over. It reaches a peak in about 1/2 millisecond, drops to less than half its maximum in the next 1/2 millisecond, and trails off thereafter.

Powders closely related in "speed" have very similar pressure curves. More distantly related powders have more different curves, but the time differences between them remain very, very small.

When using one powder over a wide range of loadings there is a strong relationship between pressure and shot speed. For an individual shot, pressure is a relatively poor predictor of speed and vice versa.

Within broad limits, effective shot shells can be assembled with any combination of speed and pressure the maker wishes, be he factory technician or home reloader.

