Robert Hutton and Pressure Estimation

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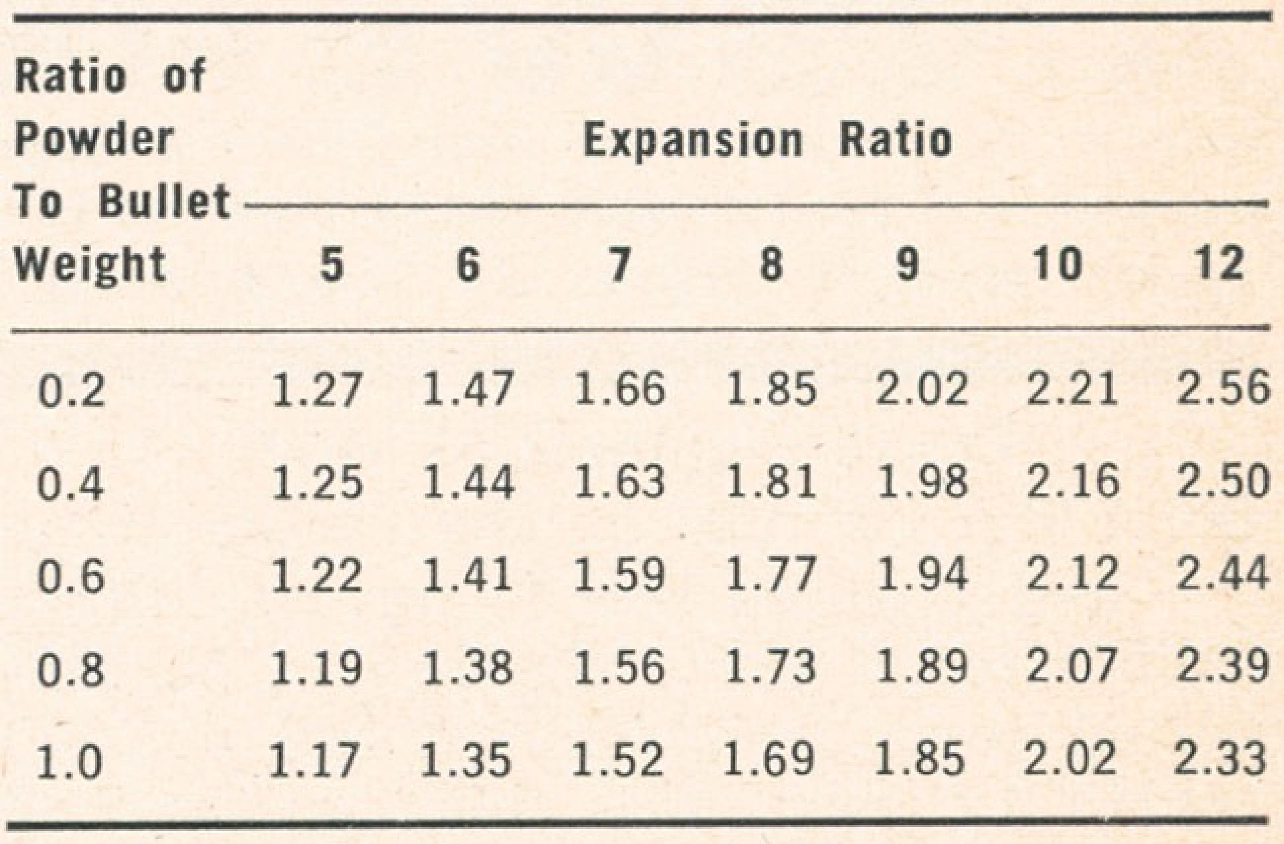

Ratio of Powder To Bullet Weight	Expansion Ratio						
	5	6	7	8	9	10	12
0.2	1.27	1.47	1.66	1.85	2.02	2.21	2.56
0.4	1.25	1.44	1.63	1.81	1.98	2.16	2.50
0.6	1.22	1.41	1.59	1.77	1.94	2.12	2.44
0.8	1.19	1.38	1.56	1.73	1.89	2.07	2.39
1.0	1.17	1.35	1.52	1.69	1.85	2.02	2.33

Bob Forker and Robert Hutton became friends after Forker and Homer Powley approached Hutton to help develop the Powley Computer for Handloaders, a revolutionary slide rule that calculated chamber pressure and velocity. Months later, Forker joined G&A as its first handloading editor. This story below, originally by Robert Hutton and Homer Powley, is about handloading and appeared in the March 1963 issue of Guns & Ammo.

Pressure estimation has long been a difficult problem for handloaders. Safety, accuracy and barrel life depend to such a great extent upon pressure that some way to measure the pressures developed by handloads is very important. Much has been written about the inaccuracy of attempts to estimate pressures by primer appearance, case extraction ease or difficulty and by other rules of thumb. The unreliability of these methods has been established beyond any reasonable doubt. The most useful information that can be gained from these tests is that the pressure is too high and sometimes this knowledge comes too late.

See Photo Gallery

The commercial ammunition manufacturers have for many years used special pressure rifles that use the chamber pressure created by the burning powder to crush a small copper cylinder. The degree of crushing can be measured with a micrometer and the pressure required to cause this crushing can then be read from tables. Even these readings are 10 to 20 percent below the actual pressures found in the gun but are accurate and consistent enough to control the quality of the ammunition produced. There are scientific methods of improving the accuracy of this method but they are so elaborate that they are only used for research and development work.

Now, thanks to the availability of Electronic Counter Chronographs such as the Avtron, it is possible for the handloader to make reasonably good estimates of pressure through the use of muzzle velocity. It isn't difficult to calculate the average pressure required to push a bullet out the muzzle of a gun at a certain velocity. The problem is very similar to taking a compression check on an automobile engine to see if the piston rings and valves are sealing the cylinder well. In the case of a gun, the bullet replaces the piston in the cylinder. If we know the muzzle energy of the bullet we can find the "compression" necessary to produce this energy. This "compression," or average pressure, is simply the muzzle energy of the bullet divided by the volume of the barrel through which it was pushed. Life is never that simple, however. In the actual gun the pressure is not the same all the way down the barrel. When the powder starts burning and shooting off gas, it burns quite rapidly and the pressure builds up to a quick peak before the bullet has moved more than a few inches down the barrel. At this peak pressure, almost all the powder has already been burned and the pressure drops as the bullet is pushed toward the muzzle. It is the peak pressure that we are trying to find and it is fortunate that this pressure is also closely related to the muzzle velocity.

Several other factors also affect peak pressure. The amount of powder for a given weight of bullet, the volume of the case filled by powder, the number of times the hot gases expand as the bullet moves down the barrel all influence the muzzle velocity and the peak pressure.

All we need do to find the pressure our handloads develop is measure the muzzle velocity with a chronograph, make several suitable corrections involving only simple arithmetic, and arrive at an excellent estimate of the chamber pressure.

Here is a step-by-step description of how to figure the pressures developed by your favorite loads. At the Guns & Ammo range, we worked out the pressure for two very common and popular loads. One was for a 1903-A3 Springfield .30-06 loaded with 55 grains of 4350 behind a 180 grain Hornady bullet. The other was for a .300 Weatherby Magnum using 79 grains of 4350 with a 180 grain Hornady bullet. The chart on page 57 shows all the calculations required for both loads. It is helpful to make up a form on which to work. Number the spaces just like the chart and you will then be able to follow each step while filling in your own numbers. Before starting the actual computations there are several things you should learn. These are the first six items listed below. You will not be able to complete the pressure calculation until these figures have been determined.

WORK SHEET FOR PRESSURE ESTIMATION

ITEM		.30-06	.300 WEATHERBY MAGNUM
1		2670	3280
2		180	180
3		.308	.308
4		55 grains 4350	79 grains 4350
5	Filled	430.2	503.1
	Empty	− 368.9	− 412.8
	Net	61.3	90.3
6		20⅝ + 1¼ = 21⅞"	21⅜ + 1¼ = 22⅝"
7		55 ÷ 61.3 = 0.897	79 ÷ 90.3 = 0.875
8		2670 ÷ 100 = 26.7 26.7 × 26.7 = 712.9	3280 ÷ 100 = 32.8 32.8 × 32.8 = 1075.8
9		55 ÷ 180 = 0.305	79 ÷ 180 = 0.439
10	a	.308 × .308 = 0.095	.308 × .308 = 0.095
	b	.095 × 21.875 = 2.078	.095 × 22.625 = 2.149
	c	2.078 × 198.6 = 412.7	2.149 × 198.6 = 426.8
	d	412.7 + 61.3 = 474.0	426.8 + 90.3 = 517.1
	e	474.0 ÷ 61.3 = 7.732	517.1 ÷ 90.3 = 5.726
11		.53 ÷ .305 = 1.74 1.74 + .26 = 2.00	.53 ÷ .439 = 1.21 1.21 ÷ .26 = 1.47
12		7.732 − 1.000 = 6.732 .897 ÷ 6.732 = 0.133	5.726 − 1.000 = 4.726 .875 ÷ 4.726 = 0.185
13	a	142.2 × 712.9 = 101,374	142.2 × 1075.8 = 152,979
	b	101,374 × .133 = 13,383	152,979 × .185 = 28,301
	Avg.	13,383 × 2.00 = 26,766	28,301 × 1.47 = 41,602
Peak Pressure		26,766 × 1.81 = 48,446	41,602 × 1.44 = 59,907

1. The velocity obtained with the load. This must be the actual chronograph velocity checked with YOUR load, YOUR gun and YOUR cases. The figures from the tables in the various handloading guides are either averages or are the results of tests conducted with one particular gun. Without checking your combination with a chronograph you can't be sure of the velocity YOU are getting.
2. The weight of the bullet in grains.
3. The diameter of the bullet in inches.
4. The weight of the powder charge in grains.

5. The volume of the powder space in the case in grains of water. This is easy to determine although it does require a scale somewhat larger than the regular handloading scale to weigh the bigger cartridges. Take one of the bullets you are using and with a small three cornered file, cut a shallow groove lengthwise from the base of the bullet far enough up along the side so that the groove will extend past the mouth of the case when the bullet is seated. Weigh a sized and primed case and the bullet carefully and record the weight. Then fill the case with water and seat the bullet into the case with your loading press to the seating depth you are using with your loads. The groove lets the excess water out of the case past the bullet and prevents bulging the case. Wipe the excess water from the outside of the case and bullet and weigh them again. Subtract the weight of the empty case and bullet from the weight after filling and you have the volume of the powder space in grains of water. Dry and oil your seating die after this operation.

6. The volume of the gun in grains of water. It isn't necessary to fill the gun with water to learn this. For now, we need only to find the length of the barrel measured from the base of the bullet of a chambered round to the muzzle. Take your water filled case or a dummy round and chamber it in your rifle. Put a cleaning rod down the barrel until it touches the point of the bullet. Put a pencil mark in the cleaning rod at the muzzle and them pull the rod out and measure from the tip of the rod to the mark. Measure the length of the bullet and add this length to the length of the rod. Record this number for later use as item 6. Now you have all the information you need to complete the figuring of the peak pressure developed by your loads.

7. The next step in finding pressure is to figure the density of loading. This is simply the powder charge in grains divided by the weight of water in grains needed to fill the powder space. On our chart this is item 4 divided by item 5. Record this answer as item 7.

8. Next, divide the velocity obtained from the chronograph by 100 and multiply this number times itself (square it). For instance if your velocity was 3000 feet per second, 3000 divided by 100 is 30 and 30 times 30 equals 900. Enter your number on the chart as item 8.

9. We now need to find the ratio of powder charge to bullet weight. This again is just the weight of the powder charge divided by the weight of the bullet in grains. In terms of the chart, item 4 divided by item 2. The result is item 9.

10. Here comes the hardest part of the whole calculation. The number we want to find now is the expansion ratio. Expansion ratio is the number of times the burning powder expands as it pushed the bullet down the barrel toward the muzzle. We already know the volume of the powder space. All that is necessary is to find the volume of the rest of the gun, add it to the volume of the powder space to find the total volume and then divide by the volume of the powder space to obtain expansion ratio. Start with the length of the barrel and bullet, item 6, and the diameter of the bullet, item 3. Now multiply the number in 10b by 198.6 and record this answer as 10c. 10c is the volume of the barrel and bullet space in grains of water. Now add item 5, the powder space volume to item 10c and you have the total volume of the gun. Divide the total volume of the gun by the volume of the powder space (item 10d divided by item 5) and you know the expansion ratio. Call expansion ratio 10e.

11. The next number doesn't have any name but divide 0.53 by item 9 and add 0.26 to the result. Record this number as item 11.

12. We have only one last division to perform. Divide the density of loading by the expansion ratio minus one. (Subtract 1.00 from item 10e and divide the result into item 7). This answer is item 12.

13. We are finally ready to find Average Pressure. Multiply the number 142.2 times item 8. Then multiply this result (called item 13a) by item 12. The answer (item 13b) is then multipied by item 11. The answer is item 13c and is the Average Pressure. The actual calculation of peak pressure would be pretty difficult so the small table below has been prepared to reduce the arithmetic required. Look across the top of the table until you come to the expansion ratio nearest to the ratio found in 10e above. Move down the column at left until you are on the line nearest the ratio of charge to bullet weight (item 9). At the intersection of this line and the expansion ratio column read the number to multiply times average pressure to find the peak pressure for your load. This then is how the job is done. If the arithmetic involved was too tedious for you, or if you would rather do things the easy way, the Powley Pressure by Chronograph Charts can be obtained from Marian Powley, 17623 Winslow Road, Cleveland 20, Ohio.

How accurate are the pressures estimated by this method? To answer that, let's examine the problems encountered when measuring pressures with a standard pressure gun. Small changes in barrel diameter from one gun to another produce noticeable changes in pressure. As we have already seen from the calculations, the barrel length also has a very important effect on the average pressures developed. It would not be practical to build a pressure gun for every possible barrel length in every caliber and chambering that shooters might use. It would be simply out of the question to build a gun to test every wildcat cartridge that comes along. As a result, the figures published as pressures for the loads you might wish to use are not necessarily correct for your gun. For a wildcat cartridge they are not even available. These factors that affect pressure also affect velocity, however, and to our good fortune, the changes in velocity are easily measured. Changes in cases, primers, powder lots, etc. all produce changes in pressures but at the same time also produce changes in velocity. In short, anything that produces a change in pressure will produce a corresponding change in velocity. Therefore, since changes in velocity are much easier to measure than changes in pressure itself, if we can obtain a reliable chronograph result we can have considerable confidence in our pressure estimate.

Comparison of the results obtained by this method with the actual pressures measured with pressure guns of known dimensions indicates that the pressures found by the chronograph method will usually be accurate within plus or minus five percent. Whereas we cannot expect to check all published figures with exactness, using this method will necessarily give very good values for the differences in pressures resulting from deliberately made changes in loading.

Please note that the pressures obtained by this method are accurate ONLY for DuPont's I.M.R. powders which are nitrocellulose single-base powders. The results cannot be used for double base powders without using what today is an unknown correction factor. Ball powders are appearing on the market but some are single-base and others are double-base so for the time being we are unable to obtain sufficient data to establish a reliable correction factor. As soon as enough data is available, new table can be prepared to allow our pressure estimates to be extended to these new powders, too.

What does all this mean to the handloader and cartridge designer?

It means that some of the mystery, which always is interesting, has been removed from cartridge testing and development, and from selecting handloads.

It means that hundreds of theories believed firmly by shooters with no technical background whatever, have been cast aside and their places taken by scientific breakthrough which has answered old questions and therefore opened up new vistas for the ballistic explorer. Like the bear, we have now looked over the mountain top, and, of course need another mountain.

All of this development has been brought to light suddenly, and without apparent warning.

In the March 1962 issue of Guns & Ammo, the Powley String Chart and Ballistics Computer were discussed. (See Technically Speaking.) With these two devices a .30/06 cartridge was loaded, without reference to any handbook or to memory, and then its trajectory was traced from the muzzle to a point 500 yards away. Accuracy was within one inch of actual shooting all the way.

In the February 1962 issue ("Big Bore Blasters") three wildcat cartridges were tested carefully by the Guns & Ammo staff. The loads were chronographed and fired at targets and given drop tests. Also, the breech pressures were calculated by the method herewith described and this believed to be the first time a new wildcat cartridge has ever been reported upon with pressure included.

Let us say you are a rifleman intensely interested in knowing how and why your cartridges perform the way they do, and that also you would like to apply logic and technical experience rather than over-the-fence gossip in creating new loads and new cartridges.

If you are an engineer or mathematician you will have the "British Textbook of Small Arms of 1929" and other technical books such as the revised edition of General Julian S. Hatcher's "Note-book" at your beck and call.

But if you do not have a flair for higher mathematics, these tables and theories will confuse you. The new Powley charts eliminate practically all mathematics.

Someone once asked a speaker at a gun club meeting how you load a cartridge from scratch.

The speaker, Jack Henninger, gave some complicated formulas and the need of determining case capacity in terms of water, and then fearing some minds were wandering, he said:

"Damned if I know! Ask Robert Hutton." 'I did," the questioner replied, "and he didn't know either."

Today, anyone may load a cartridge from scratch. We may calculate the exact load, trace the bullet route through the air, and determine the breech pressure. Next time someone tells you he has designed a new cartridge, just ask him those questions about what the bullet will do.

But with this information about our rifles, our target shooting should improve. On game or paper. There's still no substitute for shooting.