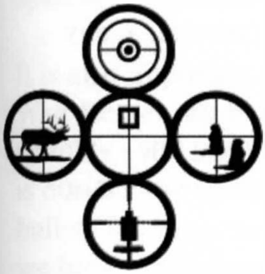
Berger Reloading Manual
1st Version, 2012

Berger Bullet Products

By: Eric Stecker



Berger Bullets came into existence because Walt believed he could make bullets that shot better than the bullets readily available at the time. This effort was focused on bullets he shot in benchrest competitions. Since he was successful at making bullets that shot better, his reputation spread outside of benchrest competition. Discerning rifle shooters of every type were asking Walt to make bullets for their applications as well. As Berger Bullets grew, we started adding different calibers and designs to satisfy these requests. From the beginning Walt made one position absolutely clear, "All bullets must be Match Grade". This means we use the best materials and tooling, and we focus on the details with persistence and discipline.

Berger Bullets produces and sells two products. The first, and a key reason why our bullets shoot better, is the J4 Precision Jacket. J4 Jackets are the cups that become the outside of the bullet. To shoot best, these cups must have consistent wall thickness. The consistency of this thickness has a tremendous influence on the balance of the bullet as it spins very fast on its way to the target.

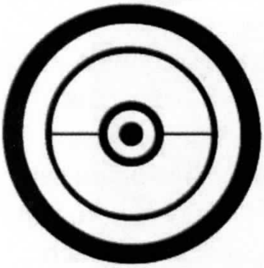
J4 Jackets are held to .0003 or less variation in wall thickness. Since we sell jackets to other bullet makers who use hand presses, we can prove that every lot is actually held to this tolerance. We know that other bullet companies boast .0003 or less variation in wall thickness, but try to buy jackets from them so you can confirm it. You will find them less than eager to sell jackets to you. Any bullet maker can hit this tolerance from time to time, but to do it each and every lot takes a discipline and effort no one but Berger achieves consistently.

The second product that Berger produces is the completed rifle bullet. At the time of publishing, Berger makes bullets from 17 caliber through 338 caliber. It is our plan to make bullets in all popular calibers from 17 caliber through 50 caliber. It is important to be clear that we make rifle bullets only. This is due to the ability for rifles to realize the benefit of very consistent bullets. Pistols have short barrels and typically are used at short range where precision is not a priority. Rifles, however, must use well-made bullets if they are to realize their full potential at any distance.

All of our bullets are designated to an application specific line (Varmint, Target, Hunting and Tactical). The following information goes into greater detail about each application based line.

Varmint Bullet Line

Our Match Grade Varmint bullet line includes those bullets that are most commonly used by precision oriented varmint hunters. These bullets are proven in the field to provide exceptional accuracy and a level of expansion that best suits a given varmint or predator application. The J4 Precision Jacket is thinner at the nose. These jackets are cut to length by a process known as pinch trimming. This pinch trim produces a bullet tip that is very thin and will expand quickly (impact velocity and animal size will effect expansion results). Our Varmint bullets are made with the same materials and process as all of our bullets. This produces a level of consistency that directly impacts a varmint hunter's ability to get more hits in the field. You can find our Varmint bullets in 17 cal, 20 cal, 22 cal and 6mm.



Target Bullet Line

Our Match Target bullet line is made up of the many legendary bullets that have been raising scores, winning matches and setting records for decades. A key characteristic of bullets in our Target line is that they are made with thicker jackets. This thicker jacket protects the lead core from heat that comes from the friction between the barrel's rifling and the bullet's bearing surface. Competition target shooters use long barrels, hot loads and shoot at a quick pace during competition shooting. Combine this with the fact that they may be out in the hot sun for several hours. These conditions can be very hard on bullets and can cause them to come apart before they hit the target (if the core melts). Our Target bullets have been purposefully made to withstand these tough conditions and since the thick jacket was introduced, no target competition shooter has reported a Berger coming apart in competition.

It is also important to restate that Berger Bullets was started because Walt Berger wanted better results while competing in target shooting matches. Making Match Grade bullets for target competition shooters is our core competency. All of our success as the producer of consistent bullets for varmint, target, hunting, and tactical stems from the efforts we have made to produce the best bullets available for the extreme, precision oriented, target competition shooter.

There is a tremendous amount of pride knowing that we make a product that competition shooters all over the world trust when they go to the firing line. There is no better test of a bullet's quality than to be used in a target competition where everyone is shooting to win. As competition shooters ourselves, we understand all the tough challenges and considerable effort it takes to be an active target competition shooter. It is our thorough understanding of this effort that heavily influences all the bullets we make.

Hunting Bullet Line

The Hunting bullet line is made up of Match Grade bullets that are proving to be the most quickly lethal, game hunting bullets available. All of our hunting bullets are made with the VLD design. The VLD design incorporates a sharp nose that allows the bullet to penetrate 2" to 3" before it starts to expand. After the bullet starts to expand, it will shed 40% to 85% of its weight as it fragments into the surrounding tissue (internal organs). The combination between the fragments and the hydrostatic shock produces a massive wound cavity within the vital area (internal organs) that will be 13" to 20" long (depending on impact velocity and animal size).

This massive wound cavity results in the animal dropping fast since most go into shock after such a tremendous blow. Those animals that don't go down immediately will soon succumb to blood pressure loss and/or organ failure producing a quick, ethical kill. Our bullets don't poke through like an arrow (high weight retention, deep penetration bullets) but instead dump their energy where it is most effective, inside the animal.

Using the Berger VLD will result in an animal that goes down fast, so you can enjoy the results of your hunt without having to track the wounded animal after the shot. An added benefit in using the Berger VLD Hunting bullets is that they are made to the same exacting standards as all of our bullets. You get the combination of a precise bullet (more consistent shot placement) and effective terminal performance (quickly lethal after impact). Our Hunting bullets are available in 6mm, 25 cal, 6.5mm, 270 cal, 7mm, 30 cal, with 338 cal bullets coming soon.

Tactical Bullet Line

Our OTM (Open Tip Match) Tactical bullet line bridges the gap between functionality and the highest possible ballistic performance. Each Tactical bullet is designed with a specific cartridge and rifle type in mind that is used most commonly in tactical competition and against bad guys. Bryan Litz, our Chief Ballistician, analyzed the cases and the rifles shooting that case. He then designed the bullets so that they are functional in these rifle's magazines while still being capable of superior ballistic performance. Additionally, these bullets are made with thicker jackets allowing them to perform reliably under the most abusive conditions found in tactical competition, tactical situations and in combat.

The ogive design for these bullets are optimized for their specific application and rifle, which means some have a Hybrid ogive while others have a pure tangent ogive. The Hybrid design incorporates two shapes that work together to produce the best trajectory performance while at the same time they do not have to be tuned to a specific seating depth like the VLD bullets. Tactical bullets will be successful at either magazine feedable lengths or loaded long for single shot firing situations which can allow for more powder capacity and higher velocities. These bullets truly give the Tactical user the best possible results for whatever situation in which they find themselves.

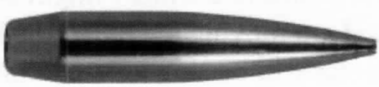
`Bullet Designs:

Each bullet line contains several designs. When designing bullets, there is a lot of give and take. You usually don't add something beneficial without taking something of value away. As an example, our VLD bullet design produces bullets with the highest BC available (depending on nose length). This high BC is great for external ballistic performance, so these bullets gain a lot in this area. Unfortunately, the secant nose shape that is a key part of the VLD design makes these bullets sensitive to seating depth. Once you tune them they shoot great, but you have to tune these bullets to get the best performance.

Compare this to our "BT" or "Boat Tail" design. This design does not have the long secant nose like the VLD. For this reason, these bullets have lower BC's and do not perform as well in the wind. Even though this is true, these bullets are not sensitive to seating depth. You can use a wide range of cartridge overall lengths (COALs) and still get exceptional precision performance. You have to watch the wind a little closer but no other design is as easy to tune quickly.

Below are expanded explanations of each specific design. Keep in mind that even though each has its advantages, one must also compare the shortcomings to determine which design is best for their type of shooting.

VLD Bullet Design



The VLD (Very Low Drag) bullet design is a combination of two very specific features. The first is a boat tail, which is common on long and heavy bullets. The second and most important design feature is the long secant ogive. It is this ogive shape that allows the bullet to experience less drag as it flies to the target. This reduced drag is how the VLD shoots flatter and is less affected by wind (less drift) than other bullets of similar weight. Reduced drag also translates into higher retained velocity. These are important results if you want your bullet to help improve your accuracy by requiring less sight adjustments when conditions change.

VLD bullets can be sensitive to seating depth and it has been found that these bullets shoot best in a COAL "sweet spot." This sweet spot is a

COAL range that is usually .030 to .040 wide. The following is from an article called “Getting the Best Precision and Accuracy from VLD Bullets in Your Rifle,” which is posted on our website blog page. It explains in detail how to get the VLD bullets to shoot best in your rifle.

Getting the Best Precision and Accuracy from VLD bullets in *Your* Rifle

This information has been verified by numerous shooters in many rifles using VLD bullets of different calibers and weights, and is consistent for all VLD bullets. What has been discovered is that VLD bullets shoot best when loaded to a COAL that puts the bullet in a “sweet spot”. This sweet spot is a band .030 to .040 wide, and is located anywhere between jamming the bullets into the lands and .150 jump off the lands.

Note: When discussing jam and jump, I am referring to the distance from the area of the bearing surface that engages the rifling and the rifling itself. There are many products that allow you to measure these critical dimensions. Some are better than others. I won’t be going into the methods of measuring jam and jump. If you are not familiar with this aspect of reloading it is critically important that you understand this concept before you attempt this test.

Many reloaders feel (and I tend to agree) that making COAL adjustments to tune a load is typically done in .002 to .005 increments. Every once in a while I might adjust the COAL by .010, but this seems like I am moving the bullet the length of a football field. The only way a shooter will be able to benefit from the situation described below is to let go of the opinion that a COAL adjustment of more than .010 is too much (me included).

Trying to find the COAL that puts you in the VLD sweet spot by moving in .002 to .010 increments will take so long that the barrel may be worn out by the time you sort it out, if you don’t give up first. Since the sweet spot is .030 to .040 wide we recommend that you conduct the following test to locate your rifle’s VLD sweet spot.

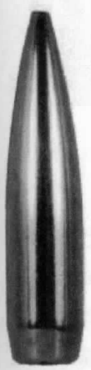
Load a total of 24 rounds at the following 4 different COAL’s if you are a rifle shooter (typically target shooter) who does not worry about jamming a bullet in the rifling:

1) 0.010 into (touching) the lands (jam) 6 rounds
2) 0.030 off the lands (jump) 6 rounds
3) 0.070 off the lands (jump) 6 rounds
4) 0.110 off the lands (jump) 6 rounds

Load a total of 24 rounds at the following 4 different COAL if you are a rifle shooter who does not want to jam a bullet into the rifling. Pulling a bullet out of the case by trying to extract a cartridge while in the field can be a hunt ending event. Pulling a bullet during a match can be resolved, but it can make it very difficult for a target shooter to finish a string before time expires.

1) 0.010 off the lands (jump) 6 rounds
2) 0.050 off the lands (jump) 6 rounds
3) 0.090 off the lands (jump) 6 rounds
4) 0.130 off the lands (jump) 6 rounds

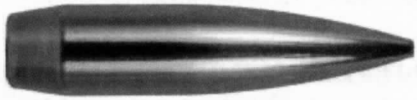
Shoot 2 (separate) 3 shot groups in fair conditions to see how they group. The remarkable reality of this test is that one of these 4 COAL's will outperform the other three by a considerable margin. Once you know which one of these 4 COAL's shoots best then you can tweak the COAL +/- .002 or .005. Taking the time to set this test up will pay off when you find that your rifle is capable of shooting the VLD bullets very well (even at 100 yards).



Boat Tail Bullet Design

The bullet design that we refer to as our "Boat Tail" or "BT" is a design that includes a boat tail of course. More importantly, these bullets include a tangent ogive. This is an important distinction because our VLD design includes a boat tail but is made with a secant ogive. The tangent ogive boat tail bullet is a common design among many manufacturers. These bullets are easy to make shoot accurately and can perform very well as dependable target and varmint bullets.

The tangent ogive does not cut through the wind like a similar length secant ogive will, but it more than makes up for this with precision that is easy to achieve in most rifles. Some of our Long Range BT bullets are made with extra long tangent shape noses, which make them perform better in the wind. However, these extra long nose BT bullets must be used by those who have a clear understanding of COAL layouts, changes, chamber dimensions, how these things are measured and how they influence precision.



Boat Tail Long Range Bullet Design

Our BT Long Range bullets were designed for long distance competitive target shooters. These bullets are made with extra long tangent ogives. This gives these bullets the combined advantage of a high BC, while at the same time, they are easier to make shoot than bullets with a secant ogive. The BT Long Range bullets have proven themselves by setting records and winning major competitions all over the world.

Hybrid Bullet Design

The latest design style to be added to the Berger line is the Hybrid design. For years, shooters have been asking for bullets that shoot as well in the wind as the VLD, but that were not as sensitive to seating depth as the VLD (easier to tune). Bryan Litz went to work on this request. He was successful in creating a design that incorporates the best from both the VLD and BT designs.

As the bearing surface ends, the nose begins with a tangent ogive (BT type nose) shape. This shape makes the bullet easier to tune, but is not as good in the wind. At a certain point, the ogive shape changes to that of a secant ogive (VLD type nose) shape, which gives the bullet the ability to perform better in the wind.

Some might say, "That seems easy enough, why don't all bullet brands make bullets this way?" It may sound like a simple design; however, I can assure you that this is far from the reality. Anyone can put together two curve shapes, but it takes special expertise and understanding to determine the best shapes for a given bullet. Bryan Litz worked very hard on this project, and the proprietary Hybrid designs that he has created for these bullets is truly a revolutionary improvement.

Fortunately, we have the ability to make Bryan's design into reality, so in this case the partnership between the ballistician and the bullet maker has produced a truly unique and beneficial improvement to the performance of rifle bullets. It is important to mention that an equal length secant ogive will outperform the Hybrid ogive in the wind; but the benefit of having higher level wind performance (over straight tangent nose shapes) while at the same time having a bullet that does not need excessive tuning is a powerful combination. The huge surge in popularity of the Hybrid bullets is evidence that we are successful in creating a bullet design that is genuinely better.

Flat Base Bullet Design

Berger produces a full line of flat base bullets in several calibers. We consider the flat base bullet a staple of the extreme precision bullet maker. These bullets are used most often by short range target and varmint shooters who are focused on the tightest possible accuracy.

Flat base bullets are the easiest to make consistent since flat is always flat. No boat tail tooling or forming considerations during the manufacturing process need be made. The vast majority of flat base bullets are made with a tangent ogive, which is easier to produce than the secant ogive. The tangent ogive is also easier than a secant ogive to make shoot well. A tangent ogive of the same length as a secant ogive will not perform as well in the wind; however, these bullets are used primarily for 300 yards or less, so this is of little concern.

High BC Flat Base Bullet Design

We make a few bullets which will be listed on the box as "High BCFB." These bullets are made with a special design that works best as a short to medium range varmint/predator bullet. These bullets are only available in 6mm (.243 diameter). They are made using a flat base and a secant ogive, just like our VLD bullets. Those who like using the 6mm for predator hunting at ranges past 150 yards find that these bullets are very effective.

Powder - Lot to Lot Variation Discussed
By: John Barsness

Many handloaders believe in a certain "conspiracy theory," or rather an "anti-conspiracy theory"; getting upset over the differences in loading data between the various sources available today. They find loading data isn't "reliable," and even believe the velocity numbers are exaggerated. I have even heard more than one handloader say he doesn't "agree" with one manual's data. This is much like saying he doesn't agree with the gas mileage a neighbor's F250 gets on the highway, just because his own F250 doesn't get the same mileage.

Once in a while, some of the anti-conspiracy theorists even suggest the loading data companies should get together and standardize all their data, so the poor home handloader doesn't get so confused. The big reason for this, of course, is that these days so many handloaders have their own chronographs, and can compare their velocities with those listed in various sources. When a certain charge of Warp Speed 40-Million powder and a 130 grain bullet in their .270 go 100 fps slower than the Warp Speed Manual No. 3 lists, some handloaders see this as proof that something's fishy.

Before we look at some information on loading data, let's make a list of all the reasons the numbers in the Warp Speed manual might not match those of the "same load" shot from your rifle over your chronograph:

Your chronograph isn't all that accurate. Modern "personal" chronographs are marvelous inventions, especially for the price, but light screens aren't infallible, since not so oddly their results often vary according to light. Even with diffusers above the screens, readings can and will vary depending on the light from the heavens, even in

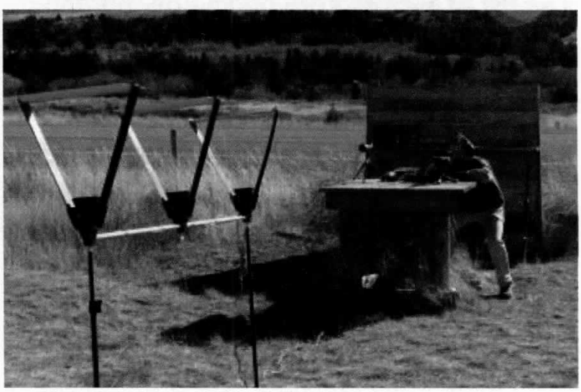


Image 1: Even a professional-grade chronograph, such as this Oehler, will give slightly varying readings depending on light conditions.

chronographs costing far more than $100—though in the higher-priced models, the variations will be smaller.

In contrast, the chronographs used in ballistic labs are all top-of-the-line. Sometimes, they're not even available to home handloaders, or the price is too steep. The spacing between the screens is longer, making readings more accurate and the chronographs are set up indoors, under consistent lights.

The assumption that all 130 grain .270 bullets are all the same is a hold-over from the days when many bullets were simply cups and cores, producing similar pressures. Today's engineered bullets vary enormously.

The main pressure factors are bullet material and bearing surface, the amount of bullet that actually touches the bore. Pure copper jackets or bullets tend to produce more pressure than the far more common gilding metal, a combination of copper and a little zinc, because copper is softer and hence "grabbier."

Bullets with softer cores and flat bases also tend to produce more pressure. This happens because the core can be "bumped up" in diameter by the powder gas, sealing the bore far more than a boat-tailed bullet, which tends to let a little gas slip by, especially just after it leaves the case mouth.

The list of factors goes on and on, but the main point is that you can't substitute data for one 130 grain .270 bullet for another and expect identical results. More or less pressure produces more or less velocity.

Powder varies in burning rate from lot to lot. Powder makers can't make each batch of powder identical because of variations in atmospheric moisture. The powders sold to handloaders, however, usually come pretty close because different batches are normally blended, so a new batch of Warp Speed 40-Million comes within 2-3% of previous batches.

Even then, however, how you store powder can affect burning rate. Let's say you live in the dry West, storing powder in typical 1-pound canisters in your garage. Every time a canister gets opened, the powder loses some moisture. After a few reloading sessions, that powder is going to weigh less. When you weigh 60 grains of H4831 six months from now, there'll be slightly more powder in the pan of your scale.

However, lot-to-lot variation is the main reason for the differences. As an example, look at loading manuals that list both Hodgdon H414 and Winchester 760. These are exactly the same powder, made in the same factory, but are put in different canisters (if you don't believe me, ask Hodgdon, which sells both these days). Yet many manuals list different charges of 414 and 760 for the same bullet in the same cartridge. The numbers won't be vastly different, but they will vary some, and the differences are totally due to variances in manufacturing lots. When a bullet company orders powder for testing, it would be unusual to get 760 and 414 from the same lot. In fact, I believe the only loading data that lists exactly the same data for both powders is Hodgdon's.

Image 2: Smokeless powders will vary slightly from lot to lot, resulting in different pressures and velocities.

Primers and brass also make a difference. Many handloaders only differentiate between standard and magnum rifle primers, but even among "standard" primers, there is enough variation to result in a 5% difference in pressure, resulting in about a 2.5% difference in velocity. Yes, there are even differences in primers from lot to lot.

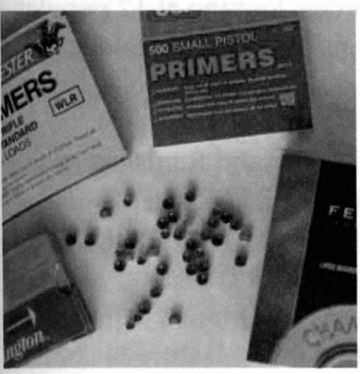


Image 3: Even changing the particular brand of primer in a handload can make a big difference in results.

Brass varies in weight, with heavier brass producing more pressure and velocity. Even the precise size of the flash-hole in the brass has some effect.

Your barrel is different than the test barrel. It doesn't matter whether barrels are factory or custom, they all vary slightly in bore dimensions. The test barrels used in pressure labs even vary somewhat.

Image 4: Pressure laboratories use precisely made barrels that are likely to differ from the average factory barrel, resulting in different velocities with the same load.

They're required to match Small Arms and Ammunition Manufacturers Institute (SAAMI) dimensions, but those dimensions are not exact, just within a certain range.

One lab technician told me that each .0001" (one ten-thousandth of an inch) of bore diameter changes pressure about 1000 psi, about 2% in a typical modern rifle load, for about a 1% change in velocity. One old ballistic rule is that any change in pressure also changes velocity about half as much. The variation differs slightly with the powder type, but the rule is still generally valid. This means that if your .270's bore measures .2773" instead of the test company's .2770" test barrel, it will produce about 3% less velocity - about 90 fps in a typical 130 grain load. Bore diameters CANNOT be held to tolerances of .0001", thus, even test barrels produce different pressures and velocities with the same load.

Let's look at some numbers from those anti-conspiracy sources of loading data. I went through five popular sources, looking at 12 popular cartridges, picking the most popular bullet weight for each round and recording the highest velocity.

The sources were Alliant, Barnes, Hodgdon, Nosler and Ramshot; with cartridge/bullet combinations of .223 Rem./50, .22-250 Rem./50, .243 Win./85, .25-06 Rem./120, .270 Win./130, 7mm Rem. Magnum/160, .30-06/180, .300 Win. Magnum/180, .338 Win. Mag./225, .375 H&H/300 and .416 Rem. Magnum/400. The 85's were picked in the .243, rather than 100, because the heaviest 6mm bullet Barnes makes is the 85 grain TSX.

The test rifles predominantly had 24" barrels, but for the rare exceptions I adjusted the top velocity by 25 fps per inch. Finally, I added all of the top velocities into a grand total. In order, from fastest to slowest, here are the results:

Nosler	36,959
Alliant	36,681
Barnes	36,642
Ramshot	36,571
Hodgdon	36,491

The difference between the highest and lowest velocity totals is 1.3% -- 40 fps in a typical 3100 fps 130 grain .270 load.

Naturally, there are anomalies in data from different companies, especially if we pick out a certain bullet weight and powder. The anomalies are the same kind of minor glitches that occur in any major collection of test data, but overall there's a remarkable agreement between the different companies.

Despite glitches in the data, I couldn't find any evidence that any single company dominated in "fastest velocity for a cartridge/bullet combination." Every company listed the highest velocity for at least one combination, just as every company listed the slowest velocity for at least one combo.

Just for fun, after going through all those numbers, I also gathered a few of my old loading manuals from back in the day when almost all bullets were cup-and-cores. A majority of the manuals lumped all bullets of a certain weight together, because there wasn't the wide variety we have today.

The manuals chosen were the Speer No. 6 (my very first loading manual, published in 1964), the Hornady Vol. II (1973) and the 2nd printing of Hodgdon's 25th (1987). One of the most interesting things turned out to be the barrel lengths in the test rifles (many were rifles, not just pressure barrels). Hornady used barrels from 20" to 28" just in the rounds selected for the data-gathering. Speer's varied less, from 22-25", while Hodgdon's were almost all 26". Muzzle velocities were adjusted for different barrel lengths in the same way, at 25 fps per inch.

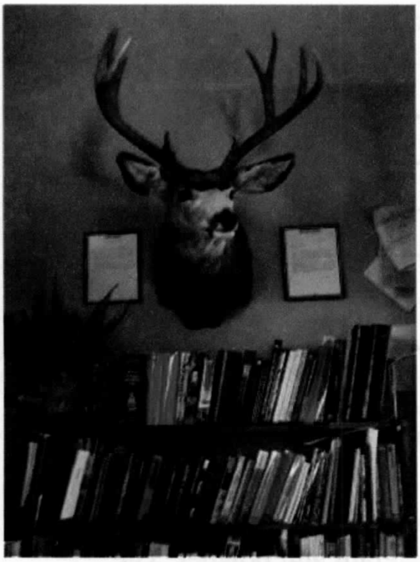


Image 5: Many handloaders expect the reloading data from various manuals to match exactly, but that's impossible.

Hodgdon listed data not only for their powders but also IMR and Winchester powders; even though Hodgdon didn't own those brands at that time, as they do today. Additionally, the fastest velocity listed almost always came from Hodgdon powders. This manual, by the way, only lists bullet weights, not make, and sometimes lists a range of weights, such as 154-162 grains in 7mm.

Not all cartridge/bullet combinations from today's list were available from the older manuals. The .416 Remington Magnum didn't exist when they were printed, and the .223 Remington wasn't listed in the Speer manual, even though it was introduced in 1964. Speer also didn't make a 225 grain .338 or 300 grain .375 (and still doesn't make a 300 .375), resulting in a seven load comparison instead of twelve.

Even though only three manuals and seven cartridge/bullet combinations were included in the data, overall muzzle velocities varied 3%, as compared to 1.3% in the modern manuals. This indicates that modern data is significantly more consistent, even though bullets vary more today.

The primary reason is that pressures were often estimated in the past using the same methods as some rather backward handloaders today. Loads were "worked up" by judging bolt-lift, seeing if primer pockets stayed tight or other "seat-of-the-pants" methods that have since been proven erratic, to say the least. This helps explain the very high velocities listed for 130 grain bullets in the .270 Winchester: 3200 from Hornady (24" barrel), 3180 from Speer (24") and 3213 from Hodgdon (26").

Contrary to popular belief, there is a lot of agreement in modern loading data, mostly due to the standardization of SAAMI and more accurate methods of testing pressure. No, the data will never totally agree across the board, just as your F250 will never get exactly the same highway mileage as your neighbor's, even if they're supposedly identical pickups made the same year. However, if we pay attention to details, today's handloading data really can help us produce more consistent and safer handloads.

Basic Statistics for Handloading

By: Bryan Litz

After learning the basic steps of handloading your own ammunition, it's natural to try and assess quality and improve your methods to produce *better*, more *accurate and precise* ammunition. The basic measures of merit for the quality of ammunition are group size and velocity variation.

The importance of group size is obvious. The smaller the group is, the easier it is to hit smaller targets from greater distances. Centering a group or shot is a matter of sight adjustment and accounting for trajectory, but making the group small is an equipment and ammunition challenge.

Minimizing velocity variation is important for long range shooting where differences in muzzle velocity translate into differences in drop (vertical dispersion).

The basic ideas stated above are rather common knowledge, and easy to grasp. However, many shooters lack the mathematical tools to assess performance in a quantitative way. This is the role of statistics, and is the subject of this chapter.

The most common statistical measure is the one that's easiest to measure: Extreme Spread, abbreviated ES. ES of muzzle velocity is the spread between the fastest and slowest shots in a group, and is easy to determine from chronograph results. The ES of a group of shots is measured from the two most distant shots.

ES is a common and easy way to assess the performance of your handloaded ammunition, and it's quite useful, especially early in the process where you're testing many different combinations and you're trying to narrow down the options.

There is another statistical measure of merit that has greater utility than ES; Standard Deviation; abbreviated SD.

Standard deviation is a measure of the variation within a sample of data. Calculating SD by hand is difficult, but fortunately there are a number of electronic tools (chronographs, calculators, PC spreadsheets, etc.) that can easily calculate the SD for you. When you know the SD for your data, you can characterize the performance of your handloads in several ways.

To be clear, using SD to characterize variations in muzzle velocity or group sizes is a better way than using ES. It's not a matter of opinion, but a matter of statistical fact. SD uses every single data point to characterize variation rather than just using the two most distant points. You can gain a more accurate understanding of variation by considering SD than ES. The following are some ways you can apply SD results to draw meaningful conclusions about your data.

One powerful way for a handloader to use SD is through the use of 'confidence intervals'. SD can be used to make predictions about your data, and to assign a confidence to the prediction. Specifically, you can say that:

68% of shots should be within +/- 1 SD of the average.
95% of shots should be within +/- 2 SD of the average.
99.7% of shots should be within +/-3 SD of the average.

In other words, the SD gives you a likelihood of how your data (velocity in this case) will be distributed around the average. The properties of the distribution are determined by the classic 'bell shaped curve', assuming a normal distribution of data. Figure 1 shows the bell shaped curve, also known as a *frequency distribution.*

Let's consider a few practical examples of how you can use SD to assess the performance of your handloads.

Consider muzzle velocity. Let's say you fire 10 shots and measure the average muzzle velocity to be 3000 fps, and the SD to be 10 fps. From the given information, you can say that 68% of the shots are likely to be between 2990 fps and 3010 fps (average +/- one SD), and 95% of the shots are likely to be between 2980 fps and 3020 fps (average +/- two SD's).

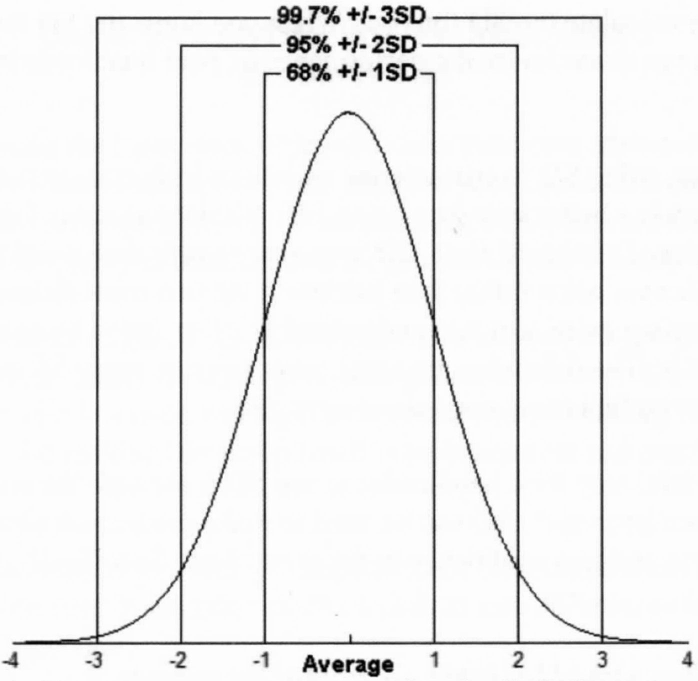


Figure 1: Frequency distribution showing the 'bell shaped curve' of normally distributed data. 68% of the area in the bell shaped curve is between +/- 1 SD, 95% of the area is between +/-2 SD's, and 99.7% is between +/- 3 SD's.

How can you use this information? Well, if you're developing ammunition for use at long range, it's important to minimize the velocity variation so the trajectories of all the bullets are as close as possible to each other, minimizing dispersion at long range. If you know that 95% of the rounds (19 out of 20 shots) will be within a given velocity band, you can use a ballistics program to estimate how much difference there'll be between the highest impacting (fastest) shot and the lowest (slowest) shot.

Using SD to assess velocity consistency is relatively common, but most shooters only record the number to compare it with other loads. Comparison is a valid use of SD, but it's important to understand the limits and meaning of a comparison.

The first thing to consider is how many shots are needed to get a meaningful SD. Contrary to common belief, an SD that's comprised of 5 shots isn't very reliable. By 'reliable', I mean it's not likely to be repeated very closely from 5 more shots of the same ammo. 10 shots is a better number to use for establishing a meaningful SD. Even after you have an SD based on 10 shots, it still could change a little bit without indicating a real difference in performance. For example, if the SD is 9.0 fps for 10 shots of load 'A', and the SD is 9.8 fps for 10 shots of load 'B,' does that mean that load A is necessarily better than load B? NO! The difference is too small. If load A has an SD of 8.0 fps and load B has an SD of 12.0 fps, then there probably is a real difference in the consistency of the ammo.

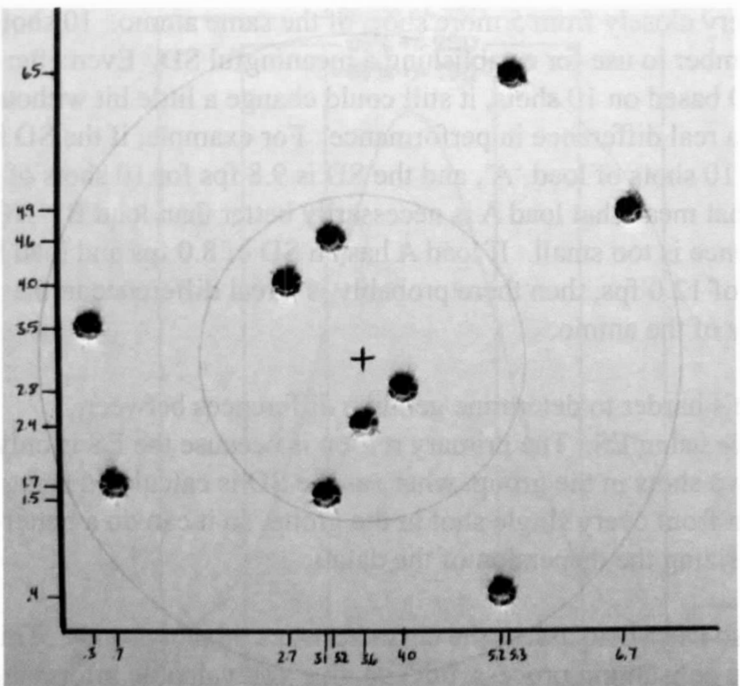
Note that it's harder to determine genuine differences between performance using ES. The primary reason is because the ES is only based on two shots in the group, where as the SD is calculated using information from every single shot in the group, so it can do a better job of characterizing the dispersion of the data.

You can also use SD to assess the characteristics of shot groups. This is a more time consuming process, but can give you valuable information about the precision of your ammo, and the probability of hitting targets of known size.

In order to collect data that will allow you to apply statistics to shot groups, you need to test at a range that produces a group big enough to distinguish individual bullet holes. When you have your group on paper, draw a vertical and horizontal line to 'frame' the group. Now measure the distance from each shot to the horizontal line, and from each shot to the vertical line (the x and y coordinates of each shot). Now average the horizontal and vertical impact points to calculate the center of the group (see Figure 2).

Finally, you can calculate the SD of the vertical and horizontal data. See Figure 2 for an example. The target in Figure 2 shows a 10 shot group with the X and Y coordinates of each shot. The average of the X and Y coordinates is the center of the group, and is indicated by the + symbol on the target.

The average SD of the vertical and horizontal dispersion is 1.9". The circles that are drawn on the group have diameters of 3.8" (+/- 1 SD) and 7.6" (+/- 2 SD). The circles are centered at the calculated center of the group.



Shot	X coordinate	Y coordinate
1	0.3"	3.5"
2	0.7"	1.7"
3	2.7"	4.0"
4	3.1"	1.5"
5	3.2"	4.6"
6	3.6"	2.4"
7	4"	2.8"
8	5.2"	0.4"
9	5.3"	6.5"
10	6.7"	4.9"
Average	3.5"	3.2"
SD	2.0"	1.8"

Figure 2. The average of the X and Y coordinates is the center of the group indicated by the + symbol. The circles indicate the confidence intervals; +/- 1 SD (68%) and +/- 2 SD (95%).

Figure 2: The average of the X and Y coordinates is the center of the group indicated by the + symbol. The circles indicate the confidence intervals; +/- 1 SD (68%) and +/- 2 SD (95%).

Note that if the vertical SD and horizontal SD are significantly different from each other, you could choose to apply them independently, which would result in ellipses instead of circles.

The meaning of the circles goes back to the bell shaped curve, standard deviation, and the assumption of normally distributed data. If you shot many groups at this distance, you could expect 68% of the shots to land within the smaller circle because it represents +/- 1 SD of dispersion. In this 10 shot example, you can see that 5 shots (50%) fell within this circle. The larger circle is +/- 2 SD in diameter, and we should expect 95% of shots to land within it over the long run. In this case, all 10 shots landed within the circle, but one is right on the line.

The usefulness of this information can be extended even farther. Suppose the target in Figure 2 was shot from *400 yards*. You can convert the measured dispersion from inches to Minutes Of Angle (MOA) and apply it to other ranges. For example, the average SD is 1.9" at 400 yards, which is 1.9"/(4*1.047) = .45 MOA. So how big is the 95% confidence area at *600 yards*? To answer this, calculate how large .45 MOA is at 600 yards: .45*6*1.047 = 2.8". Now multiply that by 4 (+/- 2 SD). 2.8" times 4 is 11.2". So at 600 yards, you should be able to hit an 11.2" circle 95% of the time with the same rifle that shot the group in Figure 2 at 400 yards. Of course this assumes the trajectory is centered and corrected properly for drop and wind drift.

You can use the technique described above to make assessments about your chances of hitting targets of various sizes at various ranges.

Load Development

The previous discussion about measuring the standard deviation of a group is useful after you've optimized the performance of your handloads and want to make some assessments about their capability. However, how do you optimize the loads in the first place? What are the variables that you can adjust in order to get the most precision from your handloads?

The loading data available for each cartridge shows many different powders that are suitable. One common misconception is that a handloader has to try all the different powders to find the best one. In reality, most of the powders on the list are capable of producing very good precision. Some may burn dirtier or cleaner than others, some may be more or less available in your local stores etc., but the powders from different makers in the same basic burn rate will not be terribly different from each other. If you're loading more than one cartridge, it's a good idea to see if there's one powder that's suitable for all the cartridges you're loading for, and stock up on large supplies of that one powder. That prevents you from having many different types of powder to manage. You can buy in large quantities, and not have to worry about changing lots too often.

Primers usually aren't a critical factor in precision, except if you get a bad lot. Any brand can make bad lots of primers. If you can't get your velocity variation down, it's a good idea to try another primer. Otherwise, it's typically not worth trying every single brand of primers to find the one that's better than the rest. In my experience, there can be as much (or more) variations between lots of primers of the same brand as there is between different brands.

The brass you use depends on your objective in handloading. If you're handloading to save money, you'll probably re-use brass that you and your friends have saved up from factory loads, maybe picked up off the range. However, if you're handloading for precision, you'll want to start with quality brass that's either new (unfired) or at least has all been fired from the same rife. Some brands of brass are more consistent than others, and some cartridges are more sensitive to quality brass than others. This is something that each shooter/handloader will decide on for themselves.

The selection of what bullet to use should be made according to the application and shooting objectives. If you're handloads are going to be used for long range hunting, you'll want a bullet that has a high BC and proven lethal performance on game. If your shooting objective is short range targets, the terminal performance of the bullet is irrelevant, and you'll just want the most precise option you can find for your rifle.

Once you've settled on the components that you're going to use for your handloads (powder, primer, brass and bullet) the strongest variables that you have control over are powder charge and bullet seating depth. There are a lot of factors related to interior ballistics that are affected by these two variables, and you will find that different rifles respond differently to changes.

Finding the best combination of powder charge and seating depth isn't always an easy process. You might find the best seating depth for a particular powder charge, but find out that a different powder charge is even better, and it might require a different seating depth for best precision. In general, the seating depth of a particular bullet in a particular rifle tends to be more static than what powder charge will work best. In other words, it's probably best to start with a low to medium powder charge and find the best seating depth. Then, using that established seating depth, start working on changes in powder charge.

One common test that's used to determine the best powder charge is called a ladder test. A ladder test is best done at long range. You load rounds having increasing powder charge, usually 0.1 to 0.3 grain increments. Then fire them consecutively on a target, noting the impact of each shot. Typically, some of the shots will cluster together, despite the range of powder charge. This powder charge and the corresponding velocity are known as a 'node', and is a good thing to identify for accuracy. Loading at a node is a way to insure that the sensitivity of your handloads will be minimized in relation to changes in velocity. The node for a particular rifle is mostly governed by the barrel's harmonics, which are determined by its length and contour.

Heavy barrels tend to dampen vibrations better than lighter barrels, and are not as sensitive to harmonics. As a result, the nodes tend to be less well defined for heavy barrels, but there can still be a slight benefit to ladder testing for heavy barrels.

Remember when working up a powder charge that all powders are sensitive to ambient temperature, some more than others. It's unwise to work up a max load in the winter when the temperature might be close to 30 degrees, and shoot that same load in the summer when it's 50 or 60 degrees hotter. You could find that your loads that were acceptable in the winter are over pressure, higher in velocity and out of tune in the summer.

After establishing an acceptable powder charge for your handloads, it's important to test for the best seating depth. Bullets with secant ogives (like the Berger VLD) are known to be more sensitive to seating depth than tangent ogive bullets (a tangent ogive blends smoothly into the bearing surface). The sensitivity of the VLD bullets to seating depth is so well-known that Berger Bullets Vice President, Eric Stecker, has written an article to help people find the most precise seating depth for any given rifle. This article can be found on page 100 in the Berger Bullets Products section.

Effects of Cartridge Over All Length (COAL) and Cartridge Base To Ogive (CBTO)

By: Bryan Litz

Many shooters are not aware of the dramatic effects that bullet seating depth can have on the pressure and velocity generated by a rifle cartridge. COAL is also a variable that can be used to fine tune accuracy. It's also an important consideration for rifles that need to feed rounds through a magazine. In this chapter, we'll explore the various effects of COAL, and what choices a shooter can make to maximize the effectiveness of their handloads.

Sporting Arms and Ammunition Manufacturers' Institute (SAAMI)

Most reloading manuals, including this one, present loading data according to SAAMI (Sporting Arms and Ammunition Manufacturers' Institute) standards. SAAMI provides max pressure, COAL and many other specifications for commercial cartridges so that rifle makers, ammo makers and handloaders can standardize their products to all work together. As we'll see later in this chapter, these SAAMI standards are in many cases outdated and can dramatically restrict the performance potential of a cartridge.

Bullet seating depth is an important variable in the accuracy equation. In many cases, the SAAMI specified COAL is shorter than what a handloader wants to load their rounds to for accuracy purposes. ***In the case where a handloader seats the bullets longer than SAAMI specified COAL, there are some internal ballistic effects that take place which are important to understand.***

Effects of Seating Depth / COAL on Pressure and Velocity

The primary effect of loading a cartridge long is that it leaves more internal volume inside the cartridge. This extra internal volume has a well-known effect; for a given powder charge, there will be less pressure and less velocity produced because of the extra empty space. Another way to look at this is you have to use more powder to achieve the same pressure and velocity when the bullet is seated out long. ***In fact, the extra powder you can add to a cartridge with the bullet seated long will allow you to achieve <u>greater velocity at the same pressure</u> than a***

cartridge with a bullet seated short.

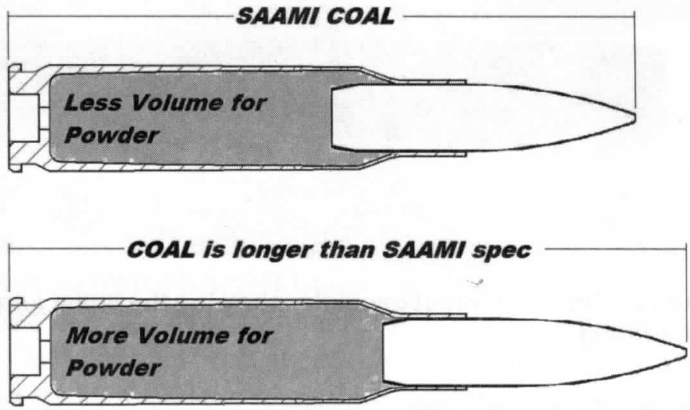


Figure 1: When the bullet is seated farther out of the case, there is more volume available for powder. This enables the cartridge to generate higher muzzle velocity with the same pressure.

When you think about it, this makes good sense. After all, when you seat the bullet out longer and leave more internal case volume for powder, you're effectively making the cartridge into a *bigger* cartridge by increasing the size of the combustion chamber. Figure 1 illustrates the extra volume that's available for powder when the bullet is seated out long.

Before concluding that it's a good idea to start seating your bullets longer than SAAMI spec length, there are a few things to consider.

Geometry of a Chamber Throat

The chamber in a rifle will have a certain throat length which will dictate how long a bullet can be loaded. The throat is the forward portion of the chamber that has no rifling. The portion of the bullet's bearing surface that projects out of the case occupies the throat (see Figure 2).

The length of the throat determines how much of the bullet can stick out of the case. When a cartridge is chambered and the bullet encounters the beginning of the rifling, known as the *lands*, it's met with hard resistance. This COAL marks the maximum length that a bullet can be seated. When a bullet is seated out to contact the lands, its initial forward motion during ignition is immediately resisted by an engraving force.

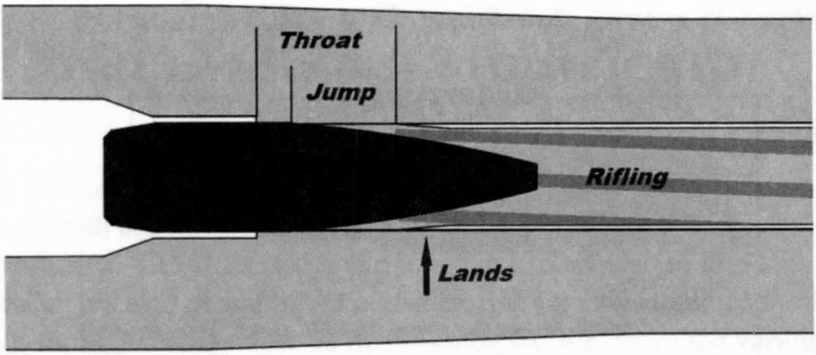


Figure 2: Chamber throat geometry showing the bullet *jump* to the rifling.

Seating a bullet against the rifling causes pressures to be elevated noticeably higher than if the bullet were seated just a few thousandths of an inch off the rifling.

A very common practice in precision reloading is to establish the COAL for a bullet that's seated to *touch the rifling*. This is a reference length that the handloader works from when searching for the optimal seating depth for precision. Many times the best seating depth is with the bullet touching or very near the rifling. However in some rifles, the best seating depth might be 0.100" or more off the rifling. This is simply a variable the handloader uses to tune the precision of a rifle.

Considerations for Magazine Feeding

When a handloader is working to establish a seating depth to use with a particular bullet, he must decide if he needs the cartridges to feed through a magazine or not. If the shooting application is hunting or tactical shooting, then the shooter probably needs the rounds to cycle through the magazine so the rifle can be used as a *repeater*. However, in many slow fire target shooting applications, it's not

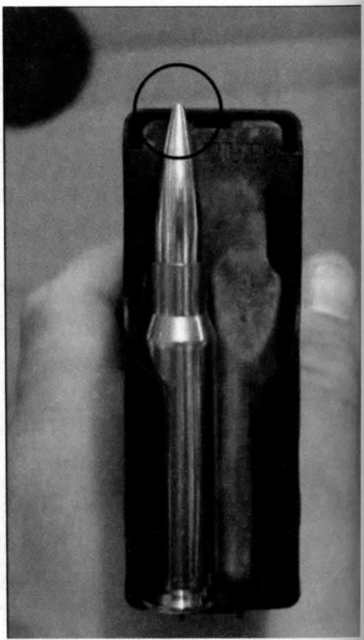


Figure 3: Illustration of a bullet being seated out of the case too far to feed through a magazine.

necessary to magazine feed the cartridges.

Often times when a shooter doesn't need to feed rounds through a magazine, the shooter can take advantage of substantial performance improvements by loading the bullets out long. This brings up an important reality of seating depth and COAL.

SAAMI COAL Limits Ballistic Performance

It is a fact that the ballistic performance of modern ammunition is directly limited by the SAAMI COAL standards that are currently in place and that rifle manufacturers build to. Even when a shooter understands the implications of cartridge case volume and has a chamber that allows them to load the rounds out long, the rifle itself (having been built to feed SAAMI length cartridges) won't allow the shooter to do so. This fact is one reason for the popularity of custom rifle builders who understand the importance of feeding longer than SAAMI length rounds and building rifles with long enough actions and magazines to cycle the rounds. The first commercial rifle manufacturers who figure this out and start building rifles capable of feeding longer rounds will lead the way into modern times. There have been many improvements to several key components of modern rifle ammunition, specifically bullets and powder. It's unfortunate that many rifle makers continue to adhere to the antiquated SAAMI limitations that were put in place so long ago when components were so different, standards which limit the performance of modern potential.

Summary of COAL discussion

To recap the important considerations regarding bullet seating depth as it relates to COAL, we can say:

- Seating a long bullet to the restrictive SAAMI COAL can severely decrease the internal volume of the cartridge, which will limit the max velocity the cartridge can achieve.
- If magazine feeding is not a requirement (or if you have a longer than standard magazine) you can load your bullets long, which increases the volume for powder and allows you to use more powder and achieve faster MV for the same pressure.
- If you load the bullet too long and it encounters the lands, this can elevate pressure due to the engraving force resisting the bullet's initial forward motion.

Cartridge Base To Ogive (CBTO)

The previous section focused on the importance of COAL in terms of SAAMI standards, magazine lengths, etc. There is another measure of length for loaded ammunition which is highly important to precision. Refer back to Figure 2. Suppose the bullet was seated out of the case to the point where the base of the bullet's nose (ogive) just contacted the beginning of the riflings (the *lands*) when the bolt was closed. This bullet seating configuration is *referred to as touching the lands,* or *touching the riflings* and is a very important measurement to understand for precision handloading. Due to the complex dynamics of internal ballistics which happen in the blink of an eye, the ***distance a bullet moves out of the case before it engages the riflings is highly critical to precision potential.*** Therefore, in order to systematically optimize the precision of his handloads, it's critically important that the precision handloader understands how to alter bullet seating depth in relation to the riflings.

Part of the required knowledge is understanding how to accurately and repeatably measure the Cartridge Base To Ogive (CBTO) dimension, and furthermore how to communicate this dimension to other shooters. The following material will shed some light on the subtleties and pitfalls of the various methods available for measuring CBTO.

Why not use CBTO as a SAAMI standard?

If CBTO is so important to the precision capability of rifles, you might ask, "why is it not listed as the SAAMI spec standard in addition to COAL?" There is one primary reason why it is not listed in the standard. This is the lack of uniformity in bullet nose shapes and measuring devices used to determine CBTO.

Let's start by acknowledging the diversity of bullet nose shapes. All noses are essentially a curve that is part of a larger circle. You would think this would make nose shapes fairly consistent. The problem is that the circular arc geometries are different for each bullet design. Even for a given bullet design, tool making is not a precise enough process to make these shapes precisely the same from tool to tool. Add to this the challenge of putting this curve on a surface that is round (like a bullet). Doing this means that the size and location of the curve is influenced by the diameter of the bullet.

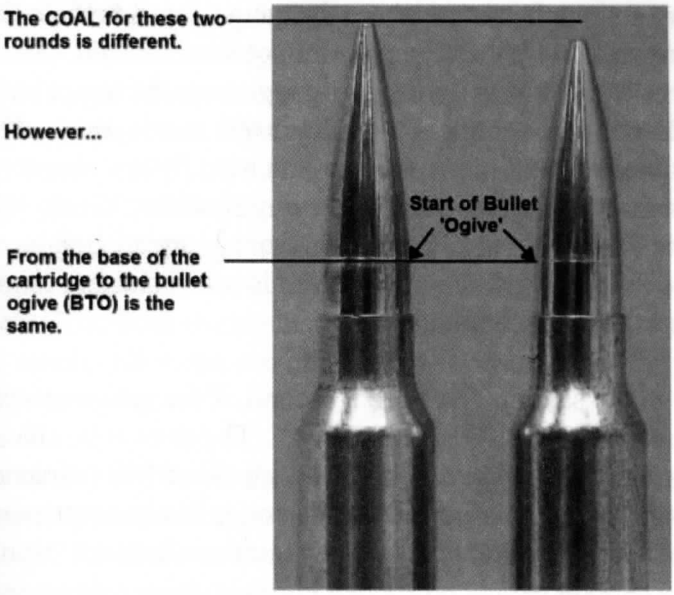


Figure 4: Two different bullet shapes, seated to the same CBTO length, but different COAL. Note the shiny scratches on the bullets made by the comparator tool, which indicates a point on the bullet ogive near where the ogive will engage the riflings.

When your bullet seater touches the tip of one bullet, the distance to the point on the nose that engages the rifling is fixed. If your bullets have precisely the same nose curve and the same diameter, then your CBTO will be very uniform and should easily be able to maintain a +/- .001 tolerance. This is achieved when using good bullets, properly chamfered case mouths, and a seater die that does not allow the bullet to bottom out (within the seater die cone) on the tip of the bullet.

Measuring, Recording and Communicating CBTO

There is a vast lack of uniformity in comparators and measuring devices used to determine CBTO. This is a critical point to understand. To measure from the base of the cartridge to where the bearing surface ends on the bullet, you must use a gauge that will attach to your calipers and which also goes over the nose of the bullet to touch the point where the bearing surface transitions into the nose curve. We already sorted out that bullets can and will vary in this area (at least from type to type if not lot to lot). This makes it impossible for gauge manufacturers to use one given diameter and shape in their gauges. So there is no standard shape and diameter for gauges. Said differently, gauges can and will vary in both inside diameter and the shape where the gauge contacts the bullet. There is another reason why these gauges are not standardized. Since bullet nose shapes and diameters will vary, gauge manufacturers know that gauge standardization is impossible. Since this is true, the end result is that this measurement becomes a comparison used by one shooter rather than a consistent dimension used by many shooters. Given this fact, they are free to open their tolerances up from gauge to gauge. Anyone who understands tooling knows that it is much cheaper to make a tool with a larger tolerance window.

Some of you might be saying, "Hold on a second, if the gauge can vary, then how can anyone use CBTO successfully?" The answer is, since this dimension cannot (or is not) standardized, the specific CBTO dimension used by one shooter is critical; but this dimension is likely not to match the specific dimensions of a cartridge shot by another shooter. "Huh?" you say? Let me explain.

If you have one gauge and you are shooting one lot of bullets, you have the ability to measure and adjust CBTO to get the most performance out of your rifle. All of the dimensions using your gauge and bullets are meaningful to your rifle. Testing to find the best CBTO is a key part of getting the most precision from your rifle and handloads.

For example, suppose that your CBTO using a 308 Winchester is 2.110". You take this to the range and it shoots like a "house a fire" (shoots great). If you call your buddy up and tell him that he should try a CBTO of 2.110" in his rifle, he will be grateful until he goes to the range. When your buddy, who has a different rifle/chamber, is using a different bullet (type or lot) and different gauge sets up his cartridge to have a CBTO of 2.110", he will expect the same level of performance. But his rifle doesn't shoot well at this CBTO dimension. You both are puzzled until you try something.

You take your gauge and your bullets over to his house to find out what he has done wrong. The first thing you do is you measure the CBTO of his ammo. This is when you find the first problem. His CBTO is 2.074". Just as you start to give him a hard time for getting it wrong, he pulls out his gauge and measures his ammo again. When he does it with his gauge he gets 2.110". ***In this scenario, the difference is due to the fact that your gauges are not the same.***

Trying to sort it out further, you decide to load some of your bullets into his cases with his seating die set up exactly the same. Then you should be able to get the same measurement, right? You load one round and take a measurement. With your bullet at his seater die setting, your CBTO is at 2.093". When he measures this cartridge with his gauge he gets 2.057". What the heck? Now you both are all over the place. This second attempt to get things sorted out is thwarted by the fact that the nose shape of your bullets is different than the nose shape of his bullets. You both decide that this is a waste of time since the variation is so much. How can something that varies so much be important to performance?

This simple answer is that you have to apply it correctly and to your rifle using your own gauge and your own bullets. The first step is to establish the distance from the bolt face to the rifling. How is this done? There are two most common ways, and neither is without difficulties. The most consistent and accurate way is to load a cartridge purposefully long using medium to light neck tension. This must be a dummy cartridge with no powder or primer. Also, to achieve the proper neck tension, you must use a sizing die with interchangeable neck bushings. This won't work if you use only an expander ball to size your necks. When you chamber the round and close the bolt, the bullet gets pushed into the case. If you slowly open the bolt and remove the cartridge, it should be a representation of the distance from your bolt face to where the bearing surface of the bullet engages the rifling. The bullet may pull back out of the neck if it is wedged too tightly into the lead angle of the rifling. If you do this several times and come up with the same dimension (within .005), you can call it good.

There are a few things you need to be aware of when using this method. It is important that you use exactly the same bullet each time. Not the same type of bullet or same lot, but the ***exact same bullet***. If the neck tension is light enough, you should not change the shape when you pull it for another measurement. You also need to measure the COAL to make sure the bullet moved in the first place. You may seat it long thinking that your throat couldn't be longer than this COAL but find out that when you do this check, the bullet doesn't move at all. This indicates that either the bullet pulled back out when you opened the bolt or the bullet was not out far enough to touch the rifling. Another aspect of this method is that neck tension on the bullet will push the bullet into

Figure 5: Hornady 'Lock-n-load', formally known as the 'Stony Point Guage'.

the rifling. The resulting dimension is not "just touching" the rifling, but will already be a slight jam.

The other common way to get this dimension is to use the Stoney Point (or Hornady) Overall Length Gauge. This is a device that allows you to push a case into a chamber that holds a bullet in the neck loosely. After the case is inside the chamber, you push the bullet forward with a rod until it stops at the rifling.

You then tighten a screw into the rod to set the dimension. You remove the device and get either a cleaning rod or small brass rod to put into your muzzle to knock the bullet out of the rifling (since there is no neck tension to pull the bullet out).

After you get the bullet out, you put it on top of the case with the rod fixed into the locked position. This also gives you a representation of the distance from your bolt face to where the rifling begins. However, this method is not typically accurate for two reasons. The first is because *the case you use is not fire formed to precisely match your chamber.* This means that the end of the case is not likely in the precise location as your bolt face. You can get one of your fired cases fitted to go in the device but this is only good for that barrel/chamber and it doesn't overcome the other problem with this method.

The other problem is that you can't fit your calipers directly over the bullet nose and under the middle of the base of the case. Your calipers must be at a slight angle when using this device. This will make the dimension different from when you check a cartridge. Both methods are better than nothing; but won't be precisely accurate; so you will need to understand and make compensations for these shortcomings.

So now you know a close approximate dimension from your bolt face to where your bullet touches the rifling using your bullets and gauge. It is from this starting point that you can tune your rifle very effectively (see page 100 for Berger's recommended process to optimize seating depth for precision). Whatever amount you make this dimension longer than this starting measurement is a jam. If the starting dimension was 2.110" and you change it to 2.120", you are using a .010" jam. If you change your dimension to 2.090", you are using a .020" jump (as an example). **The key to this process is that you find which CBTO shoots best in your rifle using your bullets and your gauge.** It will take a bit of effort to get this sorted out (especially if you haven't done it before); but I can assure you that once you know and control this dimension accurately, you will be able to obtain better performance from your load in your rifle. It is important to remember that you can't ignore COAL, especially if you want to feed through a magazine. However, if you know your CBTO and then find out your COAL is 0.050" too long to feed through a magazine, then you are equipped to decide what to do next. If you must feed through the magazine, you will know for sure that you will have to add 0.050" more jump (make the CBTO 0.050" shorter) to get the cartridge into your magazine. This may or may not affect the rifle's performance but at least you will have hard and reliable data from which to make decisions.

Figure 6: Zooming in on a bullet's meplat reveals irregularities, which are normal and prevent consistent COAL measurements.

Benefits of having a uniform CBTO

There is another aspect to knowing your CBTO when checking your COAL as it pertains to performance. With good bullets, tooling and carefully prepared cases, you can easily achieve a CBTO that varies less than +/- .001"; but your COAL can vary as much as .025" extreme spread (or more with other brands). This is not necessarily bad and it is much better than the other way around. If you have a CBTO dimension that varies but your COAL dimension is tight (within +/- .002), then it is most likely that your bullet is bottoming out inside the seater cone on the bullet tip. This is very bad and is to be avoided. It is normal for bullets to have precisely the same nose shape, and it is also normal for these same bullets to have nose lengths that can vary as much as .025".

This variation in nose length typically does not negatively affect performance. The reason this is true is because as long as the nose shape is the same from bullet to bullet, the only way a nose length variation will negatively affect performance is if this variation in length has a significant impact on the outside diameter of the meplat (pronounced MEE-plah) or tip of the bullet. When it comes to Berger bullets, we purposefully set our dies so that a variation in nose length has essentially no impact on meplat diameter. The way we do this is proprietary, but it is effective and makes normal nose length variation essentially irrelevant.

Summary of Cartridge Base To Ogive (CBTO)

To recap the important considerations regarding bullet seating depth as it relates to CBTO, we can say:

- CBTO is a critical measurement to understand for handloaders because it's directly related to precision potential, and you control it by simply setting bullet seating depth.
- Tools and methods for measuring CBTO vary, most have pitfalls that you should think carefully about.
- A CBTO that produces the best precision in your rifle may not produce the best precision in someone else's rifle. Even if you have the same rifle, same bullets, same model of comparator gauges, etc., it's possible that the gauges are not actually the same; and measurements from one don't translate to the same dimension for another.
- Once you find the CBTO that produces the best precision in your rifle, it's important to allow minimal variation in that dimension when producing quality handloads. This is achieved by using quality bullets, tooling and properly preparing case mouths and necks for consistent seating.

G1 vs G7 Ballistic Coefficients (BC)

By: Bryan Litz

Science has been helping us gain a more accurate understanding of our world for centuries, and the branch of science we care about as shooters is known as ballistics. The science of ballistics is well developed and understood by those who study it, but the tools and information being used by average shooters is not necessarily optimal for the shooter's applications. There is a better, more accurate way for shooters to use ballistics to help them predict trajectories and hit targets. ***The purpose of this chapter is to present a better way for shooters to calculate ballistics.***

What is a Ballistic Coefficient?

Most long range rifle shooters are familiar with the Ballistic Coefficient (BC). Without getting into the math, I'll define the ballistic coefficient in words as: ***The ability of the bullet to maintain velocity, in comparison to a 'standard projectile'.*** A high BC bullet can maintain velocity better than a low BC bullet under the same conditions. Measurements for ballistic performance, including drop and wind deflection, relate to the bullet's ability to maintain velocity. In short; *the higher the BC, the better the all-around ballistic performance of the bullet will be.*

How a Ballistic Coefficient is used

Details of ballistic trajectories can be predicted with computer programs using all the relevant variables, including BC. As with all prediction programs; the accuracy of the outputs depends on the accuracy of the inputs. This is why we have to examine the real meaning and implications of using a Ballistic Coefficient to characterize the bullet's ability to maintain velocity.

A relatively well-known fact is that the BC of a bullet is different at different velocities, but not many shooters know why it changes, or what the consequences are. To understand why a BC changes at different speeds, we have to go back to the definition of BC, which is: *The ability of the bullet to maintain velocity, in comparison to a 'standard projectile'.* It's the 'standard projectile' part of the definition that we need to key in on. What is the 'standard projectile'? What does it look like?

Traditionally, the 'standard projectile' used to define BCs for the entire sporting arms industry has been the G1 standard projectile. The G1 standard projectile shown below has a short nose, flat base and bears more resemblance to a pistol bullet or an old unjacketed lead black powder cartridge rifle bullet than to a modern high velocity long range rifle bullet.

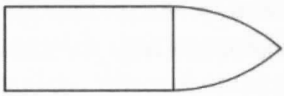


Figure 1: The G1 standard projectile

The reason the BC of a modern long range bullet changes so much at different velocities is because modern bullets are significantly different in shape in comparison to the G1 standard the BC is based on. Meaning, the drag of a modern long range bullet changes differently than the G1 standard projectile, so the coefficient relating the two (the ballistic coefficient) changes with velocity as well.

There are a couple ways to manage the problems caused by the dependence of BC on velocity. One is to use a G1 BC that's averaged for the speed range you're interested in. This will get you close, but what if the BC of the bullet is defined for a speed range that's different than what you're interested in? It's not easy to adjust the BC for different average velocities. Second, give the BC in several velocity 'bands'. This can be an accurate approach, but leaves room for misinterpretation. For example, a shooter could misunderstand why there are different BCs and choose the wrong one. Furthermore, not all ballistics programs allow you to input multiple BCs. In short; ***the use of the non-representative G1 standard to define BC is responsible for the velocity dependence and associated problems with BCs.***

A better standard for long range bullets

Looking at the G1 standard projectile again, you might think; "it's too bad there isn't a standard that's more representative for modern long range bullets". In fact, there are several standard projectiles, all with different shapes, that are more representative of modern long range bullets than the G1 standard. The standard that bears the closest resemblance to most modern long range bullets is the G7 standard, shown in Figure 2.

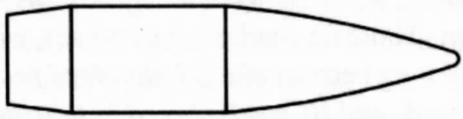


Figure 2: The G7 standard projectile

Clearly, the G7 standard projectile, with its long boat tail and pointed ogive bears a much stronger resemblance to a modern long range bullet than the G1 standard projectile. As a result, ***the BC of a modern long range bullet that is <u>referenced to the G7 standard</u> is constant for all velocities.*** In other words, a trajectory that's calculated with a G7 BC doesn't suffer the same velocity dependence problems and inaccuracies as calculations made with a G1 BC.

Another benefit of using G7 BC's is that it provides a more fair comparison between bullets. For example, consider two .30 caliber 168 grain match bullets from different manufacturers. Even if both projectiles are identical in shape and weight, it's possible for them to have different advertised G1 BCs if the BCs are calculated for different velocities. For example, if one of the bullet's BC is calculated for a 3000 fps (muzzle velocity) and the other is calculated for an average velocity between 3000 fps and 1500 fps, then the BC that's based only on muzzle velocity will be higher, but less relevant for long range shooting than the average BC. In other words, the two bullets actually have the same performance, but the 'smoke and mirrors' that results from the velocity dependence of G1 BC creates the illusion that one bullet is better than the other. If you considered the G7 BC of the two bullets, it would be the same for all speeds.

You may observe that not all bullets look like the G7 standard, and for short, flat based, blunt nosed bullets, the G1 standard is actually more representative. For that reason, BCs for flat based bullets should continue to reference the G1 standard, and boat tailed bullets should reference the G7 standard.

Why were we stuck with G1 referenced BCs for so long?

Obviously, the difference between G1 BCs and G7 BCs is that the numeric value of the G7 BC is lower than the numeric value of the G1 BC. For example, if a bullet has a G1 BC of .550, the G7 BC will be close to .282 (same bullet). Even though the G7 BC of .282 is a more accurate representation of the bullet at all speeds, ***the numeric value of the G7 BC is lower.*** Thus, for marketing purposes, we've been stuck with G1 BCs for so long because ***the G1 standard projectile is the highest drag standard, and BCs referenced to that standard will be higher than BCs referenced to any other standard.*** Would you rather compare the performance of your Camaro to a Mustang or a Pinto? The Mustang is a more meaningful comparison, but the Pinto allows you to boast higher relative performance. Bullet makers have known for many years that the G1 standard is a poor standard for long range bullets, but continue to use it. Why? One reason is that it is believed the first company to advertise G7 BCs will 'confuse' people, and the lower numeric value of the G7 BC will push people away from their product.

It's easy to understand the fear of being the first to do something new. That's ok, at Berger Bullets we are committed to the success of shooters. That commitment means making the best bullets available, but also includes providing shooters with the most suitable and accurate information to use those bullets most effectively. Berger's commitment to the shooter is why we are making the shift to G7 referenced BCs. The change will take time to get used to; however, shooters will be empowered to make better informed decisions about their equipment and will be able to calculate more accurate trajectories. Consequently, the other bullet companies will follow by providing G7 BCs for their long range bullets because it's the right thing to do. ***In the end, this change will mean greater success for shooters.***

Using the G7 BC: Calculating trajectories

Most modern ballistics programs are being created with the ability to use BCs that are referenced to different standards (G1, G5, G7, etc). Calculating a trajectory with a G7 BC is as simple as selecting "G7 BC" in the program, and giving the program a G7 BC instead of a G1 BC. The other inputs are handled the same, regardless of which G standard is used. There are many free ballistics programs that can calculate trajectories using G7 BCs, including the program that's available on the Berger Bullets webpage. Trajectories calculated with the Berger Ballistics program using the G7 BCs provided for Berger Bullets are extremely accurate.

Using the G7 BC: Comparing bullets

One way that BC is used by shooters is to compare the relative performance of bullets. Comparing bullets by BC is only possible if the BCs are referenced to the same standard. For example, if you know the G1 BC of one bullet is .500, and the G7 BC for another bullet is .230, it's impossible to tell which is better just from the BCs. Since other bullet companies don't yet advertise G7 BCs, how is it possible to compare the other brands' G1 BC bullets to Berger's G7 BC? *Applied Ballistics for Long Range Shooting* by Bryan Litz is a book that contains measured G7 BC's for many long range bullets. This resource can be used to make fair apples-to-apples comparisons for many bullets of various brands. The same test procedure (repeatable within +/- 1%) was used to measure the G1 and G7 BCs for bullets in the above book so meaningful comparisons can be made between brands.

Conclusion

Ballistics is the science of shooting, and like all sciences, must evolve as technologies improve. The use of the G1 standard for modern long range bullets is dated, and it is time to catch the science of shooting up with the technology of shooting. As part of our commitment to the success of shooters, Berger Bullets is matching the application of small arms ballistics with the small arms bullets technology by offering accurate and *properly referenced* G7 BCs for our long range bullets.

All of the pieces are now in place for shooters to take full advantage of this more accurate BC.

- Berger now provides G7 BCs for our bullets.
- The book: *Applied Ballistics for Long Range Shooting* provides G7 BCs for all other brands of bullets.
- Ballistics programs are available that can calculate trajectories using the G7 BCs.

In conclusion, everything is now available for shooters to take immediate advantage of this new type of BC, and do everything that was possible with the G1 BCs, only with more accuracy.

FORM FACTORS: A USEFUL ANALYSIS TOOL

BY: BRYAN LITZ

Background

In 2009, Berger Bullets introduced G7 BC's for boat tail bullets. For those who are unfamiliar with G7 BCs, it's simply a Ballistic Coefficient referenced to the G7 standard projectile instead of the G1 standard projectile. The G7 standard is a better match for modern long range bullets, so the G7 BC will be more constant over a wide range of velocities compared to a G1 BC. Please refer to the previous section for a complete explanation of the benefits of using G7 BC's.
Since 2009, many shooters have realized the benefits of G7 BC's through more accurate trajectory predictions. The objective of this chapter is to highlight another empowering analysis feature of the G7 paradigm: form factors.

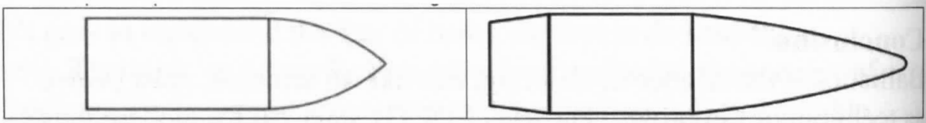


Figure 1: G1 (left) compared to the G7 (right) standard projectiles.

How sectional density and form factor comprise BC

In words, the Ballistic Coefficient of a bullet describes how well the bullet can maintain velocity while penetrating the air. Mathematically, BC is sectional density divided by form factor. Sectional density is easy to calculate because it simply depends on the bullet's caliber and weight. For example, the sectional density of a 175 grain .308 caliber bullet is: $175/7000/.308^2 = 0.264$ (the bullet weight is divided by 7000 to convert from grains to pounds). Anyone with a pocket calculator can easily figure out the sectional density of any bullet, given its caliber and weight.

Form factor is the tricky part because it requires a measurement of the bullets drag, which is related to the bullets profile. In particular, the form factor is the bullets drag divided by the drag of a standard bullet. When working with G7 BCs, you divide the drag of a particular bullet by the drag of the G7 standard projectile.

As an example, consider the 30 caliber 175 grain VLD shown in Figure 2 next to the G7 standard projectile.

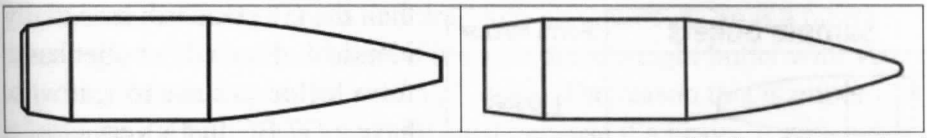


Figure 2: Berger 30 caliber 175 grain VLD (left) compared to the G7 standard projectile (right).

Looking at the two bullet profiles, not considering the caliber or weight, how would you expect the drag of the Berger VLD (on the left) to compare with the drag of the G7 standard (on the right)? Well, the VLD has a shorter boat tail, and a blunter nose than the G7 standard projectile, so it ought to have more drag. In fact, the measured G7 form factor of this VLD is 1.035. That means the drag of the VLD is 1.035 times the drag of the G7 standard (in other words, 3.5% more drag).

To calculate the G7 BC of this bullet, simply divide its sectional density, .264, by the form factor of 1.035: .264/1.035 = .255.

I apologize for the math involved in this explanation, but please stick with me. I promise it will be worth it!

Getting a feel for form factor

The following table will broaden the application of form factor to several other bullets that have different profiles with different amounts of drag.

The first bullet "a" appears at the top of the chart has a very short boat tail, and a short ogive with a wide blunt tip. This bullet has a form factor 1.286, or 28.6% more drag than the G7 standard shown in the middle of the chart.

The next bullet "b" has a longer nose (which lowers drag), with a smaller diameter tip (also lowers drag), but still has a relatively short boat tail. This bullet has a form factor of 1.036, or 3.6% more drag than the G7 standard.

Bullet "c" has a long nose and boat tail. Note that the length of the bearing surface is unimportant to the bullet's drag and form factor. Only the nose length, nose profile, meplat diameter, boat tail angle and boat tail length dictate what the drag and form factor of the bullet will be. This bullet has a form factor of 1.006, which is only 0.6% more drag

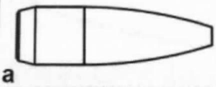
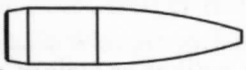
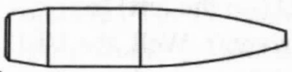
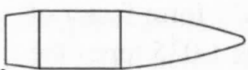
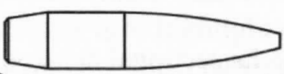
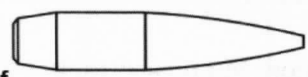
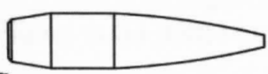
Sample Bullets	Form Factor
 a	1.286
 b	1.036
 c	1.006
 d	1.000
 e	0.993
 f	0.933
 g	0.923

Figure 3: Form factors from high to low.

than the G7 standard; essentially identical. Since this bullet has a form factor so close to 1, it will have a G7 BC that's very close to its SD (because BC = SD/ form factor).

Bullet "d" is the G7 standard. The weight and caliber of this bullet is unimportant in this analysis of form factors.

Next down is bullet "e," with a long nose and BT with G7 form factor of 0.993, again very close to 1.000, but just a little bit less drag than the G7 standard (0.7% less drag to be exact).

Bullet "f" has a very long secant nose, small meplat and long boat tail. This bullet has a G7 form factor of 0.933, which is really very low drag.

The last bullet is "g" and has a nose and boat tail very similar to the bullet just above it, but has a form factor of 0.923. That's 7.7% less drag than the G7 standard and is considered very good.

Applying the knowledge of form factors, or "What's it all mean?"
For those who've stayed with the conversation this far, thank you. Your long attention span is about to be rewarded!

We've discussed what the G7 form factor is: a factor that relates the drag of any bullet to the drag of the G7 standard projectile. So why is it so important to have an awareness and understanding of form factor? Isn't this what BCs are for; to be able to make comparisons between bullets using a single number? It's true that BC is a useful measure of merit for ballistic performance, but there's a problem with using BCs alone to assess ballistic performance. The problem with BCs is that they combine the effects of mass and drag into one number. So if a bullet has a high BC, you don't know if it's a medium weight bullet with very low drag, or a heavy bullet with high drag. The reason this is important is because if a bullet has a high BC just because it's heavy, it will suffer from having a depressed muzzle velocity, and performance will not be as good as the high BC implies.

To illustrate the importance of this, consider two .30 caliber bullets. One is 175 grains with a very low drag profile (low form factor). The other is a 190 grain bullet that is a higher drag profile. Both bullets have the same BC. What bullet would you rather shoot, and why?

In this example, the obvious choice is the 175 grain option because you will get higher muzzle velocity and still have the same BC.

Bullets will achieve different muzzle velocities depending on their weight; with lighter bullets achieving higher muzzle velocities than heavier bullets. This makes it difficult to assess ballistic performance for bullets of different weights, just based on their BC alone.

However, form factor is a more universal indicator of a bullets efficiency and performance potential. The form factor of a bullet is essentially a measure of how efficiently a bullet flies, regardless of the bullet's weight.

Looking over the line of Berger Bullets, examples of low form factor bullets are:

- The 6mm 95 grain VLD with a form factor of .923
- The 6.5 mm 140 grain VLD with a form factor of .918
- The 7mm 180 grain Hybrid with a form factor of .924
- The .338 300 grain Hybrid with a form factor of .895

At the current time, the form factors for Berger's .30 caliber line are not very good in comparison to other calibers. The lowest drag .30 caliber bullets only have form factors of around .98. Just looking at BCs, the weakness of the .30 caliber line isn't quite evident, but a form factor analysis shows that caliber to be an obvious outlier.

If you've ever heard someone make a comment to the effect of "it's a high BC bullet for its caliber and weight", what they are essentially saying is "that bullet has low drag, and a good (low) form factor". These are the bullets you want to identify because they will give the best ballistic performance, regardless of what weight or caliber the bullet is, and what MV you can achieve with it.

Bullet mass basically trades retained velocity for muzzle velocity, which is essentially a wash in terms of ballistic performance. However, low drag makes a bullet of any weight more efficient at any velocity.

If you're wondering how to figure out the G7 form factor of various bullets, it's quite simple. Just divide the sectional density by the G7 BC. For example, consider the .30 caliber 175 grain bullet used earlier in this example. It's sectional density is .264, and the G7 BC is .255. So the G7 form factor is .264/.255 = 1.035. In this way, you can calculate the form factor for any bullet you have a G7 BC for, and assess that bullet's efficiency in terms of form factor.

Currently, Berger and Lapua are the only two bullet companies that provide G7 BCs for their bullets. However, I've published a book that has experimentally measured BCs for over 235 bullets from many brands, including their G7 form factors. If you want to save yourself some time doing calculations, you can pick up the book to see a tabulated list of all measured bullets with their G7 form factors.

The following is a table that lists the G7 form factors for all boat tail Berger Bullets (the G7 standard applies best to boat tail bullets, whereas the G1 standard applies for flat base).

This table shows the basic metrics for all Berger Bullets that have G7 BC's (bullets with boat tails).

You'll notice that the sectional densities and BC's vary a great deal for all these bullets because of the different weights and calibers. It's impossible to know from the BC alone if a bullet is a good bullet for a particular caliber and weight.

However, the form factor is unrelated to the caliber and weight, so it clearly indicates the merit of the bullet's profile, as it relates to low drag and ballistic performance.

Bullet Dia.	Grain	Design Type	Sectional Density	G7 BC	G7 FF
22 CAL					
0.224	70	VLD	0.199	0.190	1.049
0.224	73	BTHP	0.208	0.176	1.181
0.224	75	VLD	0.214	0.217	0.984
0.224	77	BTHP	0.219	0.192	1.142
0.224	80	VLD	0.228	0.228	0.999
0.224	80.5	LRBTHP	0.229	0.234	0.979
0.224	82	BTHP	0.233	0.227	1.028
0.224	90	LRBTHP	0.256	0.262	0.978
0.224	90	VLD	0.256	0.281	0.912
6MM					
0.243	65	BTHP	0.157	0.138	1.140
0.243	90	BTHP	0.218	0.210	1.037
0.243	95	VLD	0.230	0.249	0.923
0.243	100	BTHP	0.242	0.246	0.983
0.243	105	BTHP	0.254	0.253	1.004
0.243	105	VLD	0.254	0.272	0.934
0.243	108	BTHP	0.261	0.262	0.997
0.243	115	VLD	0.278	0.279	0.997
25 CAL					
0.257	115	VLD	0.249	0.239	1.041
6.5 MM					
0.264	100	BTHP	0.205	0.193	1.062
0.264	120	BTHP	0.245	0.232	1.060
0.264	130	VLD	0.266	0.282	0.945
0.264	140	BTHP	0.287	0.286	1.003
0.264	140	VLD	0.287	0.313	0.917
0.264	140	LRBTHP	0.287	0.303	0.947
7 MM					
0.284	168	VLD	0.298	0.316	0.942
0.284	175	VLD	0.310	0.336	0.922
0.284	180	Hybrid	0.319	0.345	0.924
0.284	180	BTHP	0.319	0.314	1.015
0.284	180	VLD	0.319	0.337	0.946
30 CAL					
0.308	155	BTHP	0.233	0.224	1.042
0.308	155	VLD	0.233	0.225	1.037
0.308	155.5	LRBTHP	0.234	0.237	0.988
0.308	168	BTHP	0.253	0.231	1.095
0.308	168	VLD	0.253	0.242	1.045
0.308	175	LRBTHP	0.264	0.264	0.998
0.308	175	VLD	0.264	0.255	1.033
0.308	185	JUGGERNAUT	0.279	0.287	0.971
0.308	185	VLD	0.279	0.281	0.991
0.308	190	VLD	0.286	0.291	0.983
0.308	210	LRBTHP	0.316	0.320	0.988
0.308	210	VLD	0.316	0.323	0.979
.338 CAL					
0.338	300	Hybrid	0.375	0.418	0.897

The form factors are color coded according to the G7 form factor:

- Red is a form factor of 1.000 or higher (drag equal to or greater than the G7 standard projectile).
- Yellow indicates a form factor between 0.999 and 0.950 (drag that's equal to 5% less than the G7 standard projectile).
- Green indicates a form factor that's below 0.950 (drag that's 5% or more below the G7 standard).

Bullets with form factors in the green category are extremely low drag and quite rare among the many various brands of long range bullets. You can see that Berger's line has the highest concentration of 'green' in the 6.5 and 7mm calibers. That is one reason why these calibers are so successful at long range, because they have bullets with relatively high BC's for their caliber and weight; which is a direct effect of the low form factor (low drag).

You'll also note that 'green' form factors are totally absent from the .30 caliber line at the current time. This deficiency of low drag bullets in .30 caliber has been identified and current designs are in progress that will elevate the performance of this caliber with lower form factor designs. By the time this information is printed, Berger will have introduced several new low (green) form factor designs.

Conclusion

- The analysis of form factors can be very useful when considering a bullet's long range performance potential.
- Going by BC alone can be deceptive since BC includes the weight and caliber of the bullet.
- Form factor indicates how much drag the bullet has, which is a very important consideration for all bullets of all calibers.
- Unlike BC, knowledge of form factors is universal among all calibers and weights of bullets. A G7 form factor of 0.920 is excellent for any bullet, be it .22 cal, 6mm or .338 caliber.
- Form factor is not dependant on bullet weight or caliber.

Next time you're considering the performance potential of a bullet for long range shooting, be sure to ask yourself how the form factor compares to other bullets in its class. Look for more low form factor/ high BC bullets to be made available from Berger in the coming years.

High Power Silhouette

By: Matt Hetzenauer

The ram buckled slowly, almost majestically, as he fell. I'd called the shot "good" when it broke, the crosshairs settling on a solid heart shot as the gun went into recoil. With the rifle perfectly zeroed and a well executed shot, the 7mm bullet smacked into the animal precisely where I'd thought it would. A flick of the bolt ejected the fired case and I quickly chambered another; one down, four more to go. The ram in question was a life-sized steel silhouette, the object of the game of Siluettas Metallicas.

This is perhaps the ultimate form of competition for hunters. Originating in Mexico as a live animal shoot, the sport evolved to today's version with life-sized metallic silhouettes now representing the animals, standardized distances and course of fire. Since it began among Mexican hunters, it logically progressed with rifles perfectly suited to the game fields. The sport does not permit the heavy jackets and slings used in conventional High Power competition. Unlike Benchrest and their rock-solid firing position, silhouette is shot entirely offhand. The game has evolved over the years, but the basic premise is still faithful to the original intent; a reasonably light, practical hunting rifle, chambered in an adequately powerful cartridge and shot from an unsupported position typical of the game fields. It's frustrating, it's difficult, but most of all, it's fun!

Image 1: Shooters benefit greatly from a good spotter and this relationship can be critical. Silhouette (like most shooting disciplines) is a mental game. The feedback from a good spotter/coach can keep the shooter focused on his game.

A match consists of forty rounds for record, ten shots each at four different animals and four different ranges. The targets are; Chickens at 200 meters, Pigs at 300, Turkeys at 385 meters and the Rams at a full 500. Targets are arranged in banks of five animals, and the shooter has two and one half minutes to fire one shot at each. The five-round bank is

Image 2: A full array of animals can be an impressive sight. This is the NRA range at the Wittington Center, in Raton, NM. The distant rams are 500 meters down range, the turkeys at 385, the pigs at 300 and the chickens a mere 200 meters.

repeated, for a total of ten shots at each animal and distance.

The basic rules of the game couldn't be simpler; fire one shot at each of the animals within the time allowed, and knock them to the ground. Note, that I didn't say "hit". A hit on an animal that leaves it standing, is counted as a miss. This is called "ringing" an animal, and yes, you'll see it happen. In this respect, it's kind of like cross-firing in that there are only two kinds of shooters; those who have, and those who will (three kinds, if we count those who will again). As aggravating as it can be to fire a perfect shot, hear the solid impact of bullet on steel, plainly see the splash mark left on the animal and have him stand there unimpressed, it's also part of the game. Besides, it makes it so much more satisfying when they do go down.

The matches are broken down (as are most NRA matches) by shooter classification. Once you've fired a match and been classified, you will compete against shooters of similar skill based on your scores. As your scores improve, you will be reclassified and moved into the next higher bracket. The scores that make these classes will vary from the Heavy rifles to the Hunter rifles, as the light rifles are a bit harder to shoot well.

The Silhouette rifle

Silhouette rifles are basically divided into two categories; Standard or "Heavy" rifles and Hunters. The standard rifle gives the shooter more latitude in that the stock configuration is a bit more open, and the allowable weight limitation is 10 lbs, 2 oz, ready to go to the line. For this reason, the Remington 700 is a popular action choice for custom builds. It's light, and there's a wealth of aftermarket/gunsmithing options available. Trigger weight is wide open, with the only requirement that it be safe. The Hunter class guns are more tightly restricted. Here the max weight is 9 lbs, and the trigger must break at no less than 2 lbs. The stocks of these guns are much more akin to conventional hunting rifles.

While open sights are permitted, they are rarely seen on the firing line. Especially with the natural backgrounds seen at most silhouette ranges, the extra magnification of a scope is a great asset. In the early days, standard hunting scopes were the norm, albeit leaning towards the upper end of magnification, such as 10-12X. Today, a more specialized variety has evolved, dedicated target scopes with magnifications of 24X and above. One of the primary requirements for a silhouette scope is absolute repeatability. In this game, sighters are taken at the beginning of the match; everything that goes down range once the match has begun counts for record. This means the shooter needs a scope that can be zeroed at distances of 200 to 500 meters, and will come right back to that zero when it's dialed in as the shooter advances to that yard line. Unfortunately, many scopes won't reliably do this. Leupold and Weavers have proven the most popular, and both have a good track record in this game. Target knobs are preferred, as the zero will be changed repeatedly during a match. Most of these knobs give a scale to return to a given setting, which the shooter will have recorded in his data book. Dot reticules are preferred by most competitors, usually in the one half Minute Of Angle (MOA) range. The smaller 1/8 and 1/4 MOA dots used for Benchrest are just too easy to lose in the shadows.

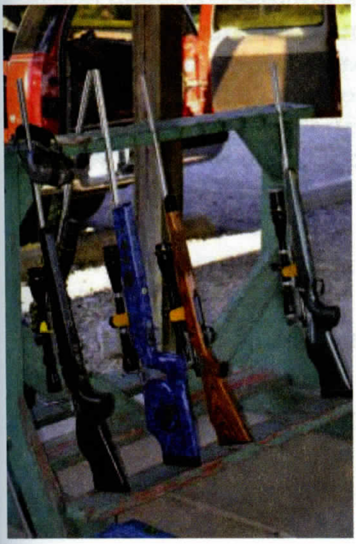


Image 3: Despite their origins as conventional hunting rifles, today's silhouette rifles are highly developed for this game. Here are some typical examples of both light and heavy rifles.

The Cartridges

Given the distances involved, accuracy is a paramount consideration. What else goes into a good silhouette cartridge? It must combine that accuracy with the ability to deliver enough power to reliably topple the heavy steel animals. The rub here is that power translates into recoil on your end of things, which makes precise shooting over long strings of fire considerably more difficult. You'll want a compromise, a cartridge that delivers sufficient momentum and energy to take the animals down, but not much more. Popular cartridges include the 7mm/08, the 260 Remington, the 7mm BR and the 6.5x47. Short action cartridges are preferred, primarily to avoid the extra weight incurred by a longer action. Remember, we're on a budget here as far as weight is concerned, and you want to be able to use that weight where it does the most good. The Remington M700 has been a longtime favorite for this sport, as it offers a near ideal combination of weight, accuracy potential, availability and cost. The wealth of aftermarket triggers and other accessories also made for this action are another solid bonus.

Image 4: Targets are reset between relays. Hits are not enough. The target must be knocked completely off the rail or pedestals (seen here at the target's feet) to count for score. A hit on the target which fails to knock it off its pedestals is called "ringing" the animal, and is counted as a miss.

The Bullets

While many bullets will prove satisfactory at the shorter yard lines, those used for the turkey and (particularly) the rams need to be of good sectional density and have a relatively high ballistic coefficient. Odd as it sounds to those who haven't experienced this, a lighter bullet may be a better choice than a much larger diameter, heavier bullet. With the 7mm's, something like the various 168's or 175's are reliable, while a lower BC 180 from a 308 will often leave rams standing. Yes, BC is a serious factor for the silhouette shooter, and should be considered. Most shooters will use at least two loads, a heavy bullet load for the rams, and possibly the turkeys, and a somewhat lighter bullet load for reduced recoil on the chickens and pigs. These aren't as hard to topple as the farther targets, and the reduction in recoil just makes it easier to stay focused and break good shots throughout a long course of fire. Remember, this game calls for precision first and foremost.

In addition to the original centerfire game, there's also a rimfire version, shot on one-fifth scale targets, at one fifth the distance. The equipment rules are virtually identical, making this a perfect training tool for the high power Silhouette shooter. The scores required of each of the respective classes are adjusted somewhat, but it's a very compatible experience. The rifle weights and profiles are virtually identical, and it's possible to build a rimfire that precisely duplicates your centerfire rig.

Aside from the sheer enjoyment of the sport itself, Silhouette shooting serves a very important purpose for the hunter; it allows a shooter to get to know his (or her) limitations. Given the similarities between the rifles used for Silhouette shooting and hunting, it's a very direct comparison. This translates into a shooter who knows their equipment better, knows their own limitations and capabilities, and can have greater confidence in taking a difficult shot in the field. Since you probably already own a hunting rifle that will get you started, what's stopping you?

See you on the range!

Introduction to Hunting

By: John Barsness

Hunting is one of the oldest human activities. In fact, some anthropologists argue that hunting made us human. It changed us from loose bands of tree-dwelling vegetarians to upright humans that cooperated when hunting, especially when pursuing larger mammals. Many of the earliest human tools were made for hunting—or at least the oldest surviving tools, because they were made from stone that exist unchanged for untold millennia, unlike tools made of plants or animal parts.

Image 1: Many game animals can be called by imitating sounds they (or their prey) make. Bull elk are sometimes called during the rut by "bugling" like another bull, but more often making the softer call of a cow elk.

Our hunting tools eventually evolved from thrown rocks and hand-held clubs to spears, and then to smaller spears propelled by atlatls (throwing sticks) or bows. These lighter, faster "spears" allowed us to kill game at much longer distances than with a hand-thrown spear. Around 1000 A.D. we invented gunpowder, and in the millennium since, the rifle has become a much longer ranged hunting tool than any Stone Age archer could have ever imagined.

In the earliest hunting, anything was "fair," because we hunted to survive. We drove animals over cliffs, or into bogs or tarpits that grabbed and held our quarry. Sometimes we used fire to push animals into lakes, where we chased them down in canoes and killed them with spears.

As our hunting tools became longer ranged, however, we could actually stalk animals, using terrain and vegetation to approach within atlatl or arrow range. Or we sat concealed near where animals came to eat and drink. We not only used our versatile human voices to communicate with each other while hunting, but to imitate the sounds of animals and draw them close enough for an arrow. We could even move very slowly through brush and woods, hoping to slip up on bedded or feeding animals and put an arrow in their ribs—or, in the case of a poisoned arrow, anywhere at all.

Image 2: Open country, in particular, lends itself to finding animals by glassing with binoculars and spotting scopes. These two hunters are glassing for mule deer in Montana.

The first firearms weren't any longer ranged than bows, and not as effective within that range, since they weren't very accurate. Plus, when they went off (if they went off) they made a loud noise and a cloud of smoke, alarming animals that could have been shot at repeatedly with a silent, quickly "reloadable" bow.

Eventually, however, our firearms became more accurate and longer ranged, mostly due to rifled barrels, first developed in the early 1500's, in what is now Germany. A couple of centuries later, a scientist named Sir Isaac Newton (yes, the Newton of the apple tree) was the first man to attach a telescope to a rifle.

In the last decade of the 1800's, smokeless powder increased the range of hunting rifles enormously. In the 20th century, smokeless-powder rifles, combined with increasingly available and sophisticated telescopic sights, made shooting a deer or elk relatively easy even at several hundred yards. By 2000, laser rangefinders made it entirely possible to kill big game at even longer distances. A good example is my custom 6.5-06. With handloaded 140 grain Berger Match Grade VLD Hunting bullets, it will put three shots into 3" at 700 yards, accuracy that would have been considered good at 300-400 yards not all that long ago. And the adjustments of its Leupold scope can be clicked to put that group right where the reticle is held.

This technology might seem to be an enormous advantage to the hunter. Certainly, if humans still hunted to survive we could certainly wipe out complete species—just as we did in the past with clubs, spears and black powder rifles. Hunting, however, ceased to be the way most humans gather their daily meals several thousand years ago. Instead we grow food and animals, and barter and trade for most of our meals. Hunting is instead a ritualized return to an earlier time, a reenactment of our early history, even if the technology has changed. We limit ourselves in the number of animals we hunt, in order to take that giant step backward for a few days a year.

Also, even hunters with long range rifles and high-magnification binoculars must still learn the same things about animals that our Stone Age ancestors did tens of thousands of years ago. Most wild animals don't wander around in the open where a 700-yard rifle is useful, so to be consistently successful we need to know where animals hide and what they eat. Both often change throughout the year, or even over a month during the traditional autumn hunting seasons, due to changing weather.

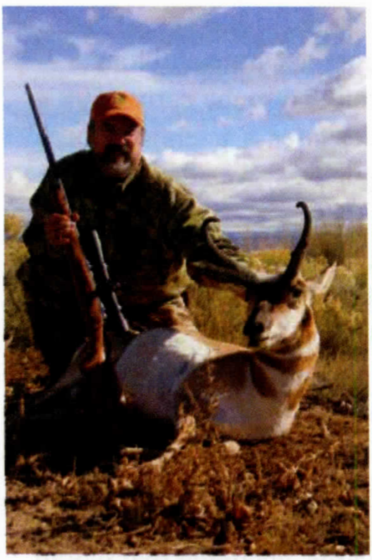


Image 3: Even though today's rifles are capable of fine accuracy at much longer ranges, the hunter still must know the habits of game animals. This pronghorn was taken with a custom 6.5-06 rifle using Berger 140 grain Match Grade VLD Hunting bullets.

Normally, modern hunters don't hunt at night, so we have to take advantage of the daylight hours when animals move between their bedding grounds and food. This often means hiking through the dark to be on a mountainside at the first gray light of dawn, or traveling back down the mountain after the sun has long since set. Yes, we have flashlights, these days often attached to our heads, but traveling through the dark in steep, wild country is still an adventure back in time.

Modern hunters still use almost all of the same techniques used by our prehistoric ancestors. A modern rifle makes it more possible, though not easy, to "still hunt" through places where animals are resting or feeding. The word "still" refers to the illusion of stillness. Like the minute hand of a clock, the good still hunter moves very

Image 4: Some game animals are most effectively hunted by sitting in a stand where they're likely to come by during their daily travels. Eileen Clarke took this big whitetail buck while sitting on a stand on a below zero day in late November.

slowly, and even stops still quite often, while looking about constantly in an attempt to see a deer or elk before it perceives his distinct bipedal silhouette.

Still hunting is one of the highest hunting skills, though not practiced nearly as much these days, primarily because our most common game, the white-tailed deer, is so abundant across much of North America. Instead, the whitetail hunter is more likely to sit on a stand (either on the ground or in a tree) where deer are likely to travel between their feeding and bedding grounds. These areas are located by reading "sign," the marks made by hooves and antlers, or by finding plants that have recently been browsed and fresh deer droppings.

Game animals are also actively tracked. This is most successfully done on damp ground, dry sand or especially snow, but can be done on even fairly hard ground by a practiced tracker. Even with snow, however, there are certain subtleties that can help enormously. Fall days often rise above freezing, even in the northern part of the continent, and then nighttime temperatures drop below freezing, creating a hard crust on snow, making walking too noisy to follow animals. When that happens (and it happens frequently) it's smarter to sleep in and hunt in the afternoon, when the crust has melted again.

With today's superb optics, glassing has become a very popular way to find game, especially in open country. Glassing is often a combination of stand-hunting and stalking. The hunter sits where a large piece of country can be seen, especially early and late in the day when game tends to move, though some animals can be found by glassing even when they're bedded down. When game is spotted, the hunter then has to stalk within rifle range, using terrain, vegetation and air currents to prevent the animal from seeing or smelling his approach.

Glassing is often referred to as spot-and-stalk, an apt term, and is most frequently practiced in the western and northern parts of North America, where open country is more common. It's my favorite form of hunting, since nothing quite matches the adrenalin rush that involuntarily courses through my blood during the last critical yards of a stalk—when I must also remain calm and balanced. That conflict of calm and adrenalin is the heart of hunting.

Driving game isn't as common as it was half a century ago, but can still be effective, especially if we and our hunting partners know a certain piece of country very well. In fact, a correctly-done drive is one of the higher arts of hunting. Instead of hooting and tromping across the landscape, the skillful driver imitates like a still-hunter who's moving just a little too fast, alarming deer or elk just enough that they move off slowly, stopping now and then to look back to make sure of the whereabouts of the hunter. In known country the animals will often move off along predictable routes, where other hunters wait.

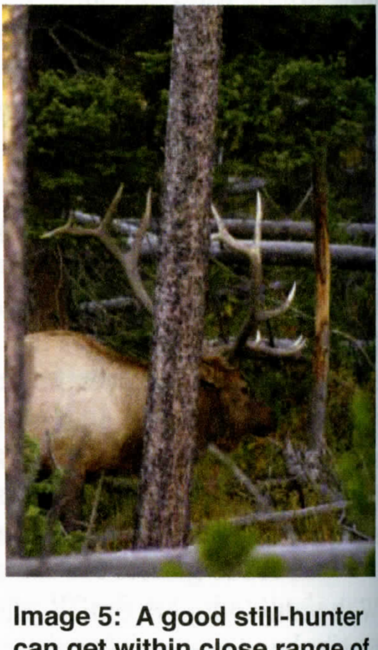


Image 5: A good still-hunter can get within close range of big elk, even in thick timber.

Animals can also be called within range, though this still means the hunter must know where they might be at any time of day. Normally, wild animals won't come more than a few hundred yards to a call, though often only a few yards is necessary, just enough to bring a buck out of his bed into a clearing. Buck whitetails and bull elk will come to calls during their annual autumn rut, when they're seeking female company, though these days so many hunters have been rattling whitetail antlers or blowing elk bugles for so many decades that a grunt call is more likely to fool a buck, or a cow call bring in a bull. In some areas calling has been overdone enough that the odds lie with other techniques, such as still hunting or driving.

Image 6: Fresh snow makes tracking game much easier, but a skilled tracker can also follow an animal on bare ground.

The experienced hunter knows all of these techniques, and continually learns from the animals themselves, because despite the wonders that can be performed with an accurate long range rifle, successful hunting is still a combination of knowing the varying habits of wild animals throughout the weeks and even months of open seasons, and some luck. Yes, luck still plays a big part in any real hunting, and even with all our modern advantages in rifles and optics, we won't succeed every time. The possibility of failure is the uncertainty that causes that balance between adrenalin and calm, just as it did tens of thousands of years ago when we became human and sat around a fire, chipping at rocks and planning the next day's hunt.

Precision Hunting

By: John Burns

Precision Hunting is a term I coined to describe a new style of hunting that combines most aspects of conventional rifle hunting with the new technology and techniques of long range shooting.

Precision Hunting requires the hunter to work harder and practice more in the off season, to carry more equipment in the field, to spend more of his hard earned dollars on optics, rifles, ammunition, rangefinders and to show more restraint in shots approaching the limit of his equipment and shooting skill.

If all the above doesn't scare you off and this idea of Precision Hunting sounds interesting, then continue on and we will try and hit the high points.

First and foremost, we must always remember to only try a shot in the field that our previous practice has proven we are capable of making. Just because the buck is huge and it is the last day of the hunt, this is not a justification for taking a shot beyond the proven capabilities of our shooting skill or our equipment. With the popularity of longer range shooting comes an increased scrutiny and we all need to behave responsibly and ethically in the hunting field.

In addition to the standard hunting items such as binoculars, all weather clothing, boots, packs, etc. the Precision Hunter needs a few extra items:

1. Laser rangefinder.
2. An accurate rifle
3. A telescopic sight that will allow for elevation and windage correction for different ranges and atmospheric conditions
4. Accurate and terminally effective ammunition.

Laser rangefinders available to the Precision Hunter have come a long way from the old and incredibly dangerous Russian military units. In the late 80's, these non eye safe surplus rangefinders offered incredible capability at the expense of possibly blinding you or some other poor hapless fellow. I had one for a short while, but returned it to the original owner after I learned of the danger from these types of rangefinders. My

Image 1: Bull elk taken at 1102 yds with 140 grain Match Grade VLD Hunting bullets in .264 Win Mag.

first good rangefinder was eye safe and would reliably range to 1500 yds or so. It cost over $2,000 in 1990's dollars and is still useful. The same or better capability can now be purchased for less than a third of the price and a fraction of the weight and bulk.

When purchasing your rangefinder, always buy more range than you feel you will need because bright sunlight and oblique angles will degrade the performance of all lasers, and you will sooner or later get in a hunting situation where your laser won't be able to give an accurate range.

An accurate rifle is most likely the easiest "extra" item to procure for the Precision Hunter. Odds are pretty good the rifle you now own, when fed the right ammunition, is more than adequate. The world is full of good quality factory rifles that will shoot under a Minute of Angle. Such a rifle will never be the weak link for all but the most practiced and seasoned Precision Hunters.

The farthest shot I have ever attempted on an elk, 1102 yds, was successfully made using a factory barreled Remington 700. This rifle started life as a Sendero in .264 Win Mag and I did swap out the less than ideal factory stock. Loads using the 140 grain Match Grade VLD Hunting bullets shot very well when the bullets were just kissing the lands. I am not saying the custom rifles we build at Greybull Precision don't shoot better, but there are plenty of good rifles that will provide great accuracy. If a new Precision Hunter is on a limited budget then look to the rifle you already own and use the money you saved for the real game changer, the scope.

The optic we mount on our rifle has a much greater influence on performance than the rifle itself. An optic that will allow us to rapidly and precisely adjust the point of impact is where we get the biggest bang for our buck. Ammunition also plays a major role in overall performance, but there is very little difference in the cost of great ammunition verses run of the mill hunting fodder.

There is a much greater disparity in the retail price of scopes designed to be used for hunting. The Precision Hunter needs to look for an optic that will allow adjustment in the zero of the "system" to compensate for various ranges and conditions. These adjustments must be repeatable and of an intuitive nature so we can effectively use them under the pressure of real world hunting.

There are many different systems available from simple hold over reticles to sophisticated but simple to use custom drop compensating turrets. While all the different systems have their proponents, it seems that most serious Precision Hunters have gravitated to the custom drop compensating turret combined with a windage enabled reticle as the most effective solution.

We have saved the ammunition for last as this is a reloading book and ammunition is one of the few places where we essentially get the proverbial free lunch. While the ammunition suitable for Precision Hunting is not exactly your daddy's ammo, it doesn't really cost any more than other less effective types of hunting ammo.

The secret to this "wonder" ammo is the Very Low Drag or VLD bullet. The VLD is a rarity in that it really has no downside as a hunting bullet for thin skinned game. Need a bullet to break the shoulder of a big bull elk at 50yds? Need a bullet to reliably expand on the ribs of a distant antelope? The VLD in an appropriate weight answers both questions perfectly.

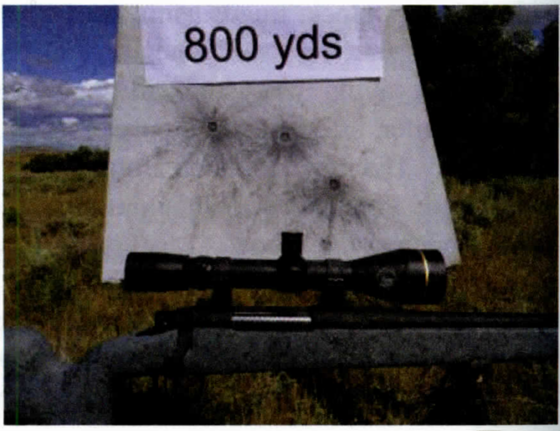


Image 2: Greybull Precision rifle in 7mm Remington Magnum shooting the 180 grain Match Grade VLD Hunting bullet.

The only real downside to the VLD is the bullets less forgiving nature in regards to throat design and concentricity. Most factory rifles will handle the VLD very well, but if you happen to have the bad luck of getting a lemon I would suggest sending that rifle down the road and trying again, the VLD is worth the hassle.

Some cartridges are particularly well suited as launch platforms for the VLD. The 7mm Remington Magnum is really the Precision Hunters gold standard. If you are in the market for a new rifle to use the VLD then the 7mm Rem Mag deserves a very hard look.

Precision Hunting is much like bow hunting in that there is a very real sense of accomplishment after a successful hunt. All the preseason work and practice pays off when you successfully make a perfect shot that other hunters have no business attempting.

The key to doing it right is to put in the time and effort and only take a shot in the field your prior practice has proven you are capable of making.

Rifle Barrel Twist Rates

Berger provides the minimum recommended barrel twist rates necessary to stabilize each of our bullets. A very common question is: "How do I know what the twist rate is in my barrel?" Often times the twist rate is stamped on the barrel itself. Other times you know because you've specified a custom rifle build and deliberately selected the barrel twist yourself.

If you don't know the twist rate of your rifle barrel, you can use the following method to measure it directly.

1) Insert a cleaning rod with a tight fitting patch into the breach end of the barrel. Push it in until the patch is fully engaged in the riflings.

2) Push the cleaning rod into the barrel until the rod makes one complete revolution and measure how far the rod traveled. You can determine the travel of the rod and the angular rotation using index marks.

3) Repeat the measurement several times. The average distance required for the cleaning rod to complete one revolution is the twist rate of the barrel in 'inches per revolution'.

Even if you know the twist rate because it's been specified or it's stamped on the barrel, it's a good idea to measure it anyway just to be sure.

The tables on the following pages are a reference for common rifle barrel twist rates.

17 CCM - 1 in 10"	Cooper
17 Remington - 1 in 9"	Remington 700, 7
17 Remington - 1 in 10"	Cooper; Sako; Thompson/Center Rifle and Carbine
17 Ackley Hornet - 1 in 10"	Cooper
17 Mach IV - 1 in 10"	Cooper
22 CCM - 1 in 14"	Cooper
22 Hornet - 1 in 12"	Thompson/Center Rifle and Carbine, NEA Handi-Rifle
22 Hornet - 1 in 14"	Kimber 82; Savage 24 - V + F, 219, 340; Cooper; Ruger M-77
22 Hornet - 1 in 16"	Winchester 70; Ruger 3; Browning A-Bolt II, 1885; Kimber; Anschutz 1432
22 K-Hornet - 1 in 12"	Thompson/Center Rifle and Carbine
22 K-Hornet - 1 in 14"	Cooper
218 Bee - 1 in 12"	Thompson/Center Carbine
218 Bee - 1 in 14"	Cooper
221 Fireball - 1 in 12"	Thompson/Center Carbine
221 Fireball - 1 in 14"	Cooper; Remington 700 Classic
219 Zipper - 1 in 14"	Marlin 336
222 Remington - 1 in 12"	Thompson/Center Carbine and Rifle
222 Remington - 1 in 14"	Browning; Remington 722, 725, 700, 600, 40-XB, 760, 788, 660; Savage 24-V, 340, 112, 2400; Sako; Winchester 70, 770; Wichita; Colt; Husqvarna; Cooper
222 Remington - 1 in 16"	J.C. Higgins 52, early Sako
22 PPC - 1 in 12"	Thompson/Center Rifle
22 PPC - 1 in 14"	Sako Benchrest-Varmint / PPC; Cooper
222 Rem. Magnum - 1 in 12"	Sako
222 Rem. Magnum - 1 in 14"	Browning; Remington 722, 700, 40-XB,Husqvarna, Sako
222 Rem. Magnum – 1 in 15.5"	Sako/1972
223 Remington - 1 in 7"	Colt; Ruger Mini-14; Eagle Arms Eagle Eye;H&K SL8
223 Remington - 1 in 8"	Eagle Arms Golden Eagle, Armalite
223 Remington - 1 in 9"	Colt; Win. 70 HBV; Savage 110, 112, 116; Steyr Aug-SA; Eagle Arms standard models; Savage; Winchester 70
223 Remington - 1 in 10"	Ruger Mini-14 & #1
223 Remington - 1 in 12"	Colt Bolt Action, AR-15; Remington 760, 700, 788, 7; H&R; Sako; Savage 340; Winchester 70; Thompson/Center Contender,

Rifle Barrel Twist Rate Chart

223 Remington - 1 in 12" cont'd	Encore and Rifle; Ruger # 1, 77; NEA Handi-Rifle, Howa; CZ
223 Remington - 1 in 14"	Remington 40-XB; Husqvarna; Savage 24-F+V, 340; Wichita; Weatherby Vanguard; Cooper
224 Weatherby Mag. - 1 in 14"	Weatherby
225 Winchester - 1 in 14"	Winchester 70, 670; Savage 340, 24-F
22-250 Remington - 1 in 12"	Sako; Savage 110, 112; Thompson/Center Rifle
22-250 Remington - 1 in 14"	Browning; Remington 700,788, 40-XB; Savage 99, 110, 112-V; H&R; Husqvarna; Ruger; Winchester 70, 770; Mossberg; Weatherby; Sako current models
220 Swift - 1 in 12"	Savage 112; Thompson/Center Rifle
220 Swift - 1 in 14"	Winchester 70; Remington 700; Ruger 77; FN; Savage 112-V
220 Weatherby Rocket - 1 in 14"	Weatherby
6 TCU - 1 in 10"	Thompson/Center Carbine and Rifle
6 x 45 - 1 in 12"	Cooper
6 PPC - 1 in 10"	Thompson/Center Rifle
6 PPC - 1 in 14"	Sako, Ruger VT
6 x 47 - 1 in 12"	Cooper
243 Winchester - 1 in 9"	Remington 660, 700, 788 (1969);
243 Winchester - 1 in 9 1/8"	Remington 700, 7400, 7600, 7
243 Winchester - 1 in 9 1/4"	Savage (present)
243 Winchester - 1 in 10"	Browning; Colt; FN; Harrington and Richardson models 300, 308, 360; Husqvarna; Mannlicher Schoenauer; Musketeer; Mossberg 800; Remington 700, 40-XB; Savage 99, 110, 111, 112-V, 116 (old); Sako Bolt and Lever Actions; Schultz and Larsen; Stevens 110; Winchester 70, 88,100,670,770; J.C. Higgins 51-L; Ruger 1, 77; Wichita;Weatherby Vanguard; Thompson/Center Rifle
243 Winchester - 1 in 12"	Steyr SSG-PII
244 Remington - 1 in 10"	Remington 700
244 Remington - 1 in 12"	Remington 722, 760, 740, 725, 40-XB; Sako
6mm Remington - 1 in 9"	Remington 600, 700, 742, 760, 660; Browning B-78; Ruger
6mm Remington - 1 in 9"	Remington 700, 4, 6, 7, 7400,7600
6mm Remington - 1 in 10"	Remington 40-XB; Schultz and Larsen; Ruger 1, 77; Browning
6mm International - 1 in 12"	Remington 40-XB

6 x 47mm - 1 in 12"	Remington 40-XB
6 x 47mm - 1 in 14"	Remington 40-XBBR
6mm Remington BR - 1 in 14"	Remington 40-XBBR
240 Weatherby - 1 in 9 1/2"	Weatherby Mark V
256 Winchester - 1 in 10"	Thompson/Center Carbine
256 Winchester - 1 in 14"	Marlin 62
25-35 Winchester - 1 in 10"	Thompson/Center Carbine, Winchester Model 94
25 TCU (25 Ugalde) - 1 in 10"	Thompson/Center Carbine and Rifle
250 Savage - 1 in 9 1/2"	Weatherby
250 Savage - 1 in 10"	Savage 99, 110; Remington 700; Ruger 77
257 Roberts - 1 in 9 1/2"	Browning A-Bolt II
257 Roberts - 1 in 10"	Remington 722, 760, 700; Winchester 70; Ruger 77; Thompson/Center Rifle
25/06 Remington - 1 in 10"	Remington 700, 40-XB; Ruger 1, 77; Browning; Sako; Winchester 70; Savage 110, 112; Thompson/Center Rifle
257 Weatherby Mag. - 1 in 9 1/2"	Weatherby (current)
257 Weatherby Mag. - 1 in 12"	Weatherby (old)
257 Weatherby Mag. - 1 in 14"	Mannlicher-Schoenauer
6.5 TCU - 1 in 8"	Thompson/Center Carbine and Rifle
6.5 M-Schoenauer - 1 in 8 1/4"	Mannlicher-Schoenauer
260 Remington – 1 in 8"	Ruger 77
260 Remington – 1 in 9"	Remington 700, Savage
260 Remington – 1 in 10"	Browning
6.5 x 55mm - 1 in 7.87"	Winchester 70
6.5 x 55mm - 1 in 8"	Husqvarna; Remington 700 (1994); Thompson/Center Rifle, Ruger 77
6.5 x 55mm - 1 in 8 1/4"	Schultz & Larsen
6.5 x 55mm - 1 in 9"	Remington 40-XB
6.5 Remington Magnum - 1 in 9"	Remington 600,660,700; Ruger 77
6.5 x 68mm - 1 in 11"	Mannlicher-Schoenauer
264 Winchester Magnum - 1 in 8"	Thompson/Center Rifle
264 Winchester Magnum - 1 in 9"	Browning; FN; Husqvarna; Musketeer; Remington 700; Savage 110; Sako; Schultz & Larsen; Winchester 70, 670, 770
264 Winchester Magnum - 1 in 10"	Colt; Mannlicher-Schoenauer
270 REN - 1 in 10"	Thompson/Center Carbine
270 Winchester - 1 in 9"	Mannlicher-Schoenauer
270 Winchester - 1 in 9 1/2"	Husqvarna
270 Winchester - 1 in 10"	Browning; FN; Harrington & Richardson 300; High-Standard; J.C. Higgins 50, 51, 51-L; Husqvarna; Musketeer; Remington

270 Winchester - 1 in 10" cont'd	700, 721, 760, 725, 7400, 7600, 4, 6; Savage 110, 114, 116; Sako; Schultz & Larsen; Winchester 70, 670, 770; Ruger 1, 77; Mossberg; Marlin 455; Wichita;Weatherby Mark V, Vanguard; Magnum Research Mountain Eagle, (Sako-Krieger-Bell and Carson); Thompson/Center Rifle
270 WSM - 1 in 10"	Winchester 70, Browning
270 Weatherby Mag. - 1 in 9 1/2"	Weatherby Mark V
270 Weatherby Mag. - 1 in 10"	Weatherby Vanguard; Browning BAR Mark II; Winchester
270 Weatherby Mag. - 1 in 12"	Weatherby (old)
7 TCU - 1 in 9"	Thompson/Center Rifle and Carbine
7 x 30 Waters - 1 in 9"	Thompson/Center Carbine
7 x 30 Waters - 1 in 9 1/2"	Winchester 94
7mm-08 Remington - 1 in 9"	Thompson/Center Rifle
7mm-08 Remington - 1 in 9 1/2"	Browning 81, BLR, A-Bolt II; Sako; Savage (present)
7mm-08 Remington - 1 in 10"	Remington 7, 788, 700; Winchester 70; Savage 110
7 x 64mm Brenneke - 1 in 9"	Thompson/Center Rifle
7 x 57mm - 1 in 8"	Ruger (present)
7 x 57mm - 1 in 8 1/2"	Winchester 70 (post 64)
7 x 57mm - 1 in 8.7"	FN
7 x 57mm - 1 in 8 3/4"	Winchester 54, 70 (pre '64); Ruger 77
7 x 57mm - 1 in 9"	Mannlicher-Schoenauer; Thompson/Center Rifle
7 x 57mm - 1 in 9 1/4"	Remington 700
7 x 57mm - 1 in 9 1/2"	Ruger 1, 77 (old); Savage 110
7 x 57mm - 1 in 10"	Winchester 70
7mm Express - 1 in 9 1/4"	Remington 700, 4, 7400
280 Remington - 1 in 9"	Magnum Research Mountain Eagle; Thompson/Center Rifle
280 Remington - 1 in 9 1/4"	Remington 760, 740, 742, 700, 721, 725, 7400,7600
280 Remington - 1 in 9 1/2"	Ruger 77 (old); Savage 110; Ruger (present)
280 Remington - 1 in 10"	Winchester 70; Browning A-Bolt II; Sako
284 Winchester – 1 in 8 3/4"	Ruger 77
284 Winchester - 1 in 10"	Browning A-Bolt, 81 BLR; Savage 99; Winchester 88, 100
7mm SAUM - 1 in 9 1/4"	Remington Model Seven
7mm WSM - 1 in 9 1/2"	Winchester 70, Browning
7mm RUM - 1 in 9 1/4"	Remington 700
7 x 61 Sharpe & Hart - 1 in 10"	Schultz & Larsen
7mm Dakota - 1x10"	Dakota Arms

RIFLE BARREL TWIST RATE CHART

7mm Remington Magnum - 1 in 9"	Husqvarna; Remington 40-XB, 700 (1969); Magnum Research Mountain Eagle; Thompson/Center Rifle
7mm Remington Mag. - 1 in 9 1/4"	Remington 700; Savage 110, 111, 112, 114, 116; Sako; Winchester 70, 770; Ruger 1, 77 (old); Mossberg; Browning A-Bolt II, 81 BLR; Weatherby Mark V
7mm Remington Mag. - 1 in 9 1/2"	Ruger (present); Savage (present)
7mm Remington Mag. - 1 in 10"	Browning; FN; Harrington & Richardson 300; Musketeer; Schultz & Larsen; Browning BAR Mark II;Weatherby Vanguard
7mm Weatherby Mag. - 1 in 9 1/4"	Remington 700
7mm Weatherby Mag. - 1 in 9 1/2"	Weatherby Mark V (present)
7mm Weatherby Mag. - 1 in 10"	Weatherby (1965)
7mm Weatherby Mag. - 1 in 12"	Weatherby (old)
7mm STW – 1 in 9"	Remington 700, Winchester 70
7mm STW – 1 in 9 1/2"	Ruger 1; Savage
30 M1 Carbine - 1 in 10"	Thompson/Center Carbine
30 M1 Carbine - 1 in 16"	30 U.S. Govt. Carbine; Universal
30 M1 Carbine - 1 in 20"	Marlin 62; Ruger
7.62 x 39mm - 1 in 10"	Thompson/Center Rifle
7.62 x 39mm - 1 in 12"	Colt; Ruger
30 Herrett - 1 in 10"	Thompson/Center Carbine
30 Remington - 1 in 12"	Remington 81, 141
30-30 Winchester - 1 in 10"	Marlin 336; Remington 788; Thompson/Center Carbine
30-30 Winchester - 1 in 12"	Savage 24, 170, 340, 219; Winchester 64, 94, 66; Mossberg 479, 679
300 Savage - 1 in 10"	Remington 81, 722, 760; Savage 110
300 Savage - 1 in 12"	Savage 99
30-40 Krag - 1 in 10"	Ruger 3, Winchester 95
307 Winchester - 1 in 12"	Winchester 94
308 Winchester - 1 in 10"	Colt; J.C. Higgins 51-L; Mannlicher Schoenauer; Marlin 455; Musketeer; Remington 722, 740, 742, 760, 700, 40-XB, 788, 660, 600, 7400, 7600, Four, Six, Seven; Schultz & Larsen; Ruger 77; Wichita. Savage 99, 110, 112, 116 (present);Weatherby Vanguard; Steyr SSG-PIV; Thompson/Center Rifle
308 Winchester - 1 in 12"	Browning 81 BLR, BAR Mark II, A-Bolt II; Colt; FN; High Standard; J.C. Higgins 50, 51, 51-L; Harrington & Richardson 300, 308;

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308 Winchester - 1 in 12" cont'd	Husqvarna; Mossberg 800; Savage 99, 100, 110, 2400; Sako Bolt Action and Lever Action; Winchester 70, 88, 670, 770; Steyr SSG-PI, PII, PIII; Stevens 110; 100, Remington 700, 40-XC.; Springfield Armory M1A
30-06 - 1 in 10"	Browning 81 BLR, BAR Mark II, A-Bolt II; Colt, FN; High Standard; J.C. Higgins 50, 51, 51-L; Harrington & Richardson 300; Mannlicher Schoenauer; Marlin; Musketeer; Remington 721, 760, 740, 742, 725, 700, 40-XB, 7400, 7600; Savage 110, 114, 116 (present); Sako; Schultz & Larsen; Stevens 110; Winchester 70, 670, 770;Weatherby Vanguard, Mark V; Ruger 1, 77: Wichita; Mossberg; Magnum Research Mountain Eagle; Thompson/Center Rifle
30-06 - 1 in 12"	Husqvarna; Remington 700 Varmint (old); Browning 78
300 H & H Magnum - 1 in 10"	Browning; Remington 721; Sako; Winchester 70
300 WSM - 1 in 10"	Winchester 70, Browning; Savage
300 SAUM -1 in 10"	Remington Model Seven
308 Norma Magnum - 1 in 10"	Musketeer; Schultz & Larsen
308 Norma Magnum - 1 in 12"	Browning; Husqvarna
30-338 - 1 in 10"	Remington 40-XB
300 Winchester Mag. - 1 in 10"	Browning BAR Mark II, A-Bolt II; FN; Harrington & Richardson 300; Musketeer; Remington 700, 40-XB; Savage 110, 112, 114, 116; Sako; Winchester 70, 670, 770; Ruger 1,77; Magnum Research Mountain Eagle; Wichita; Weatherby Mark V, Vanguard (new); Thompson/Center Rifle
300 Winchester Magnum - 1 in 12"	Husqvarna
300 Weatherby Mag. - 1 in 9 1/2"	Weatherby Mark V (current)
300 Weatherby Mag. - 1 in 10"	Weatherby Vanguard (current); Sako; Winchester 70; Remington 700
300 Weatherby Mag. - 1 in 12"	Weatherby (old); Remington 700 (current)
300 RUM - 1 in 10"	Remington 700; Savage
30-378 Weatherby – 1 in 10"	Weatherby Mark V
300 Dakota - 1 in 10"	Dakota Arms

Rifle Barrel Twist Rate Chart

32 H&R Magnum - 1 in 10"	Thompson/Center Carbine
32-20 Winchester - 1 in 10"	Thompson/Center Carbine
32-40 Winchester - 1 in 16"	Thompson/Center Rifle
32 Remington - 1 in 14"	Remington 81, 141
32 Winchester Special - 1 in 16"	Marlin 336; Winchester 64, 94
8 x 68S - 1 in 11"	Mannlicher-Schoenauer
8mm Remington Magnum – 1:10"	Remington 700
330 Dakota - 1 in 10"	Dakota Arms
338 Winchester Magnum - 1 in 10"	Weatherby Mark V; Mannlicher-Schoenauer; Savage 110, 116; Winchester 70; Ruger 77; Sako (current), Mossberg; Remington 700; Weatherby; Vanguard; Browning A-Bolt II; Magnum; Research Mountain Eagle; Thompson/Center; Rifle
338 Winchester Magnum - 1 in 12"	Browning BAR Mark II; Sako (old)
340 Weatherby Magnum - 1 in 10"	Weatherby Mark V
338 Lapua Magnum – 1 x 10"	Sako TRGS
338 Lapua Magnum – 1 x 12"	Sako TRG42
338-378 Weatherby – 1 x 10"	Weatherby Mark V
338-06 A-Square – 1 x 10"	Weatherby Mark V
338 RUM - 1 in 10"	Remington 700
348 Winchester - 1 in 12"	Winchester 71
9mm Luger - 1 in 10"	Colt; Marlin 9; Uzi Carbine
9mm Luger - 1 in 14"	Thompson/Center Carbine
357 Magnum - 1 in 14"	Thompson/Center Carbine
357 Magnum - 1 in 16"	Marlin 1894; Navy Arms RB
357 Rem. Maximum - 1 in 14"	Thompson/Center Carbine
35 Herrett - 1 in 14"	Thompson/Center Carbine
35 Remington - 1 in 12"	Savage 170
35 Remington - 1 in 14"	Thompson/Center Carbine
35 Remington - 1 in 16"	Marlin 336; Remington 81, 141, 600, 760
38-55 Winchester - 1 in 12"	Thompson/Center Carbine and Rifle
38-55 Winchester - 1 in 18"	Ruger; Marlin 336 Cowboy
356 Winchester - 1 in 12"	Winchester 94
358 Winchester - 1 in 10"	Mannlicher-Schoenauer
358 Winchester - 1 in 12"	Savage 99; Schultz & Larsen; Winchester 70, 88, 100
358 Winchester - 1 in 16"	Ruger
35 Whelen - 1 in 14"	Thompson/Center Rifle
35 Whelen - 1 in 16"	Remington 700, 7400, 7600; Ruger
350 Remington Magnum - 1 in 16"	Remington 600, 660, 700; Ruger 77
358 Norma Magnum - 1 in 12"	Husqvarna; Schultz & Larsen
375 Winchester - 1 in 12"	Winchester 94; Marlin 375; Savage 99; Ruger; Thompson/Center Carbine and Rifle

375 H&H Magnum - 1 in 12"	Remington 700; Winchester 70; Ruger; Sako; Browning A-Bolt II;Weatherby Mark V; Remington 700 Custom; Thompson/Center Rifle; Savage
375 H&H Magnum - 1 in 14"	Browning (old)
375 Weatherby Magnum - 1 in 12"	Weatherby
375 RUM - 1 in 12"	Remington 700
375 Dakota - 1 in 12"	Dakota Arms
378 Weatherby Magnum - 1 in 12"	Weatherby Mark V
40 Smith & Wesson - 1 in 16"	Thompson/Center Carbine
10mm Auto - 1 in 16"	Thompson/Center Carbine
404 Dakota - 1 in 14"	Dakota Arms
41 Magnum - 1 in 18 1/2"	Marlin 1894
416 Remington Magnum - 1 in 14"	Remington 700; Winchester 70; Sako;Thompson/Center Rifle
416 Remington Mag. - 1 in 16 1/2"	Ruger
416 Dakota - 1- 14"	Dakota Arms
425 Express - 1 in 10"	Savage 116 SE
44 Magnum - 1 in 20"	Thompson/Center Carbine
44 Magnum - 1 in 38"	Ruger Carbine; Marlin 336, 1894; Remington788; Winchester 94; Browning 92
444 Marlin - 1 in 38"	Marlin 336; 444S
450 Marlin – 1 x 20"	Marlin 1895M
45 ACP - 1 in 16"	Marlin 45
45 Long Colt - 1 in 16"	Thompson/Center Carbine
45 Long Colt - 1 in 38"	Winchester 94
45 Winchester Mag. - 1 in 16"	Thompson/Center Carbine
45-70 - 1 in 14"	Thompson/Center Carbine
45-70 - 1 in 20"	Ruger 1, 3; Marlin 1895S; Browning B-7, 1885; Thompson/Center Rifle
45-70 - 1 in 22"	Navy Arms
450 Dakota - 1 in 14"	Dakota Arms
458 Winchester Magnum - 1 in 14"	Remington 700; Winchester 70; Ruger 1; Savage
458 Winchester Magnum - 1 in 15"	Mannlicher-Schoenauer
458 Winchester Mag. - 1 in 16 1/2"	Browning; Savage 116SE
458 Winchester Magnum - 1 in 18"	Sako
460 Weatherby Magnum - 1 in 16"	Weatherby Mark V