

# TIPS AND TECHNIQUES



# Accuracy

Accuracy is every shooter's concern. That's obvious for competitive shooters. It's obvious, too, for anyone going on an expensive hunt. It's even obvious for the plinker. No one wants to shoot a firearm that can't hit the broadside of a barn, whatever the range. But accuracy is not a simple issue, and accuracy problems can often be extremely difficult to diagnose because they involve many factors. Let's begin this discussion by identifying several critical accuracy factors.

**BARREL QUALITY:** Barrels may differ from firearm to firearm in a manufacturing lot. Some can be inherently more accurate than others, better rifled, better finished, made with superior barrel steel. And barrels can obviously deteriorate over time with "barrel burner" loads or mistreatment.

**BARREL AND ACTION BEDDING:** How barrel and action are fitted to the stock can have important accuracy consequences. Stock binding, twisting, or variable pressure on barrel and action can produce shot-to-shot inconsistencies. Many barrels work best when they are "free floating," that is, not touched by the stock except immediately in front of the action. Incorrectly bedded actions may be pressured by high spots inside the stock or other interior wood constrictions. Removal of portions of the stock causing the binding can often correct the problem easily.

**BULLET QUALITY:** Hornady Manufacturing Company has accumulated thousands of person-years of experience on this single accuracy factor. Yes, some bullets are more accurate than others, generally as a consequence of manufacturing process and precision. Our company's goal from its beginning over 60 years ago has been to make bullets that are "accurate, deadly, and dependable." You might usefully review the essay, "Reloading and Bullet Accuracy" which appears earlier in this volume for more discussion of the topic.

**TRIGGER QUALITY:** This accuracy factor often requires a gunsmith (or new trigger or trigger parts) to correct. If a firearm's trigger will not function consistently, the shooter will be unable to squeeze off rounds consistently, either.

**LOAD:** Powder brand and powder charge can greatly influence attainable accuracy. In the new *Hornady Handbook* we have attempted with every cartridge/bullet combination to use only powders that are generally appropriate. As you will observe from time to time throughout the loading data, we have found particular combinations of powder, charge weight, and bullets to be especially accurate. Accuracy produced by this factor is a function of burn rate consistency in the cartridge/firearm combination used.

**SIGHT QUALITY/SIGHT ADJUSTMENT:** You can't hit what you don't see. You can't hit what you're not pointing at. Just as there are quality variations in barrels and triggers, so there can be quality variations in sights. Or there can be sights which simply aren't adjusted to give the shooter a correct aiming point.

**BARREL CLEANLINESS:** The barrel manufacturer is always responsible for initial barrel quality. The shooter is always responsible for keeping that barrel clean. Fouled barrels will never be as accurate as clean barrels. Both powder residue and metal fouling are cleanliness culprits, and once they get a good start, the rate of fouling increases. There are a host of commercial solvents, rods, brushes, and cleaning pads to clean barrels. Start with a brush and solvent (we'll name Shooter's Choice as an example). Apply solvent with the brush and remove metal residue with a pad. Leaving a solvent-wetted barrel to soak overnight is not too long a wait before getting on with the cleaning task. Shooters who are also impatient about cleaning often prefer Sweets 7.62 Solvent, an ammonia-based chemical. With extreme fouling, the full cleaning process may take several days for solvents to do their best work. Accuracy improvements will be well worth the effort.

**TWIST RATE:** It is possible to load a bullet in a firearm whose twist cannot stabilize it, that is, rotate it fast enough to keep it from yawing in flight. Longer bullets need faster barrel twist rates to stabilize them. You can determine the twist rate of your firearm by making a mark on a rod with a tight cleaning brush and noting how many inches it takes to revolve once.

**BARREL TEMPERATURE:** Barrels, especially those firing high intensity magnum loads, can be sensitive to heat. Even slight heat-induced barrel flexing can produce shot-to-shot inconsistencies. This is an accuracy factor easily remedied by allowing some barrel cooling between rounds.

## Accuracy and Reloading Technique

We are not finished with diagnosis of accuracy problems. Assume all of the factors listed above are non-issues for your firearm but that accuracy still is not up to your standard. There are a number of reloading-specific accuracy factors that may cause problems.

**CASES:** Uniformity is critical to accuracy. Many reloaders segregate cartridge cases by manufacturer (and even by production lot), weigh them, deburr flash holes, discard cases with outsized flash holes, turn case necks to identical diameters, and invariably clean primer pockets. Your own handling of cartridge cases will depend on your accuracy requirements. The average hunter or casual shooter will not gain much by case neck turning or individual case weighing. All reloaders, however, will benefit by primer pocket cleaning and by using cases of the same manufacturer. Bench rest shooters may take all of these steps and more to assure the ultimate accuracy.

**PRIMERS:** As we stress often in the *Hornady Handbook*, when you have developed a suitable load with one set of components, you need to develop it again when changing any single component. This is as true of primers as it is of cases. Many reloaders find that one primer works best in their firearm and simply stick with it. Never, under any circumstances, substitute a magnum primer for a load developed with standard primers.

**BULLETS:** Bullet performance can vary between firearms, whether because of their weight, shape, amount of bearing surface, or length. This is true of bullets of the finest jacket uniformity and overall concentricity. The variability in accuracy of bullets results from their use in your firearm. There are thousands of Hornady Bullet users who have found the absolutely best combination of bullet and powder charge for their firearms and wouldn't think of changing a thing. So, if you want more accuracy than you're getting with one combination, try another bullet. Experimentation can help.

**SEATING DEPTH:** A bullet may not appear accurate simply because it is not seated to the depth most suited to the firearm in use. If bullets are seated too deeply, they have a longer distance to travel unsupported to reach the bore, and may enter it off-center. In general, the less distance to the bore, the greater the accuracy. The reloader has entire control over seating depth up to the physical limitations of action, magazine, or barrel. Experimentation with seating depths can help you achieve the best. In our loading data pages we list the maximum Cartridge

Overall Length (C.O.L.) according to SAAMI specifications. Differences in manufacturing tolerances mean that your most accurate C.O.L. may differ from those published here. Closely allied with the subject of seating depth is the subject of crimping. Recoil can jar bullets loose from their original seating if they are not correctly and sufficiently crimped in place to resist such movement. In large magnum cases, crimping can assure the proper pressure build up of slow burning powders for more consistent combustion and accuracy.

**ADJUSTING FOR HEADSPACE:** Headspace adjustments involve both accuracy and safety concerns. The Illustrated Glossary at the end of the *Hornady Handbook* does an excellent job describing headspace schemes.

Essentially, headspace is the distance from the base of the cartridge case to that portion of the case that stops its forward movement when the round is fired. Straight-walled pistol cartridges, for example the 45 ACP, headspace on the mouth of the case. Excessive crimping (as in roll crimping) may lead to both pressure and accuracy problems. (Crimps for semi-automatic cartridges are most often taper crimps to facilitate proper functioning.) Belted cases headspace on the front edge of the belt. Rimmed cases headspace on the front of the rim. Each design has its particular advantages in particular applications. Accuracy and safety are concerns when case dimensions and headspace requirements are out of synch. Excessively short cases that headspace on the shoulder of the case may fire, but eventually may separate at the head. Many reloaders of rimless cases prefer to resize the case neck only, a technique that is fine for strong bolt actions but not useful for pumps, semi-autos, and lever-actions because they lack equally strong camming action.

**RESIZING PROBLEMS:** Many resizing problems result from improper or inadequate lubrication. We covered case lubrication in the illustrated Step-by-Step guide earlier in this volume and noted there that excessive lubrication could cause its own set of problems. We didn't mention the need for lube inside the necks of some cases (dry lubricant, powdered graphite, or Hornady One-Shot all work fine for the task). Remember, just a little and just inside the neck; you don't want to contaminate powder or primers. But suppose you manage to get a case stuck in your reloading die. What do you do? Buy a new die? Return the die with the stuck case to the factory for case removal? Or buy a stuck case remover? We make a 3-part remover consisting of a #7 drill bit, a 1/4"-20 tap, and a remover body that fits over the stuck case and on the base of the die. With this apparatus

1. Remove the resizing die (with stuck case) from the press.
2. Back the deprime spindle out as far as it will go.
3. Drill into the flash hole with the drill bit, then thread it with the tap.
4. Place the cap over the stuck case and thread the hex screw into the case.
5. Continue to tighten the screw until the stuck case comes out of the die.

The case is ruined, of course, but the lubrication lesson is undoubtedly learned.

**CASE REFORMING:** From time to time a reloader may wish to form one cartridge case from another. The typical steps in reforming, as you will read in the descriptions of many wildcat cartridges covered in the *Hornady Handbook*, are necking up, necking down, and fire-forming. (Case trimming will be involved in many situations as well.) Some case reforming is quite simple. You can run a 30-06 case through a 270 full length resizing die and have a new case. Other cases may require a few additional steps to reform without crumpling necks and folding shoulders. Making a 243 Winchester case directly from a 308 Winchester generally results in a very low yield. Inserting the intermediate step of running the 308 case through a 7mm-08 full length resizing die will greatly improve the yield. Necking cartridge cases down may produce some neck thickness problems not so troublesome in necking up operations when tapered expanders are employed. All reformed cases need to be checked for proper case length and trimmed. "Fireforming" involves firing the appropriate initial cartridge in the chamber of the firearm of the new caliber. Using the 7-30 Waters cartridge as an example, it is a simple matter to neck down the 30-30 to 7mm, but the reformed case will not have the dimensions of the 7-30. Fired in a 7-30 Waters chamber with a light load (never a strong one!) with the bullet seated out close to the rifling will produce the desired results.

**CASE ANNEALING:** Frequent "working" of brass cartridge case necks through firing and resizing causes the metal to become brittle and eventually split. By heating then cooling the necks of the cases, a process called annealing, this brittleness can be eliminated and the life of the cases prolonged. (Annealing is also useful when necking up cases.) Annealing is simple and safe. Re-annealing is generally not necessary for another 8 to 10 reloads.

**PRIMING PROBLEMS:** Priming was treated in some detail in our Step-by-Step reloading section, but the subject is worth a quick review. Most problems encountered in the priming process involve off-center flash holes (just discard the cases), oversized flash holes (throw them out, too, to avoid pressure problems), undersized flash holes (you can correct this problem with a drill), Berdan primers, and crimped primers. Military ammunition generally features crimped primers to assure they stay in place. They do make it more difficult to remove. After decapping, crimped primer pockets need to be reamed to remove the crimp. (We also make a primer pocket reamer, a great tool to acquire if you're going to reload a lot of military brass.) Berdan primers present so many problems that many reloaders just don't want to deal with them, period. There are Berdan decappers available, though carefully directed ice picks have been known to work in a pinch. While the repriming process is straightforward, Berdan primers come in sizes different from their Boxer primer counterparts and will not precisely fit Boxer-oriented equipment.

**CASE TRIMMING:** In the Step-by-Step section we showed a Hornady case trimmer in action, along with the dial caliper used to measure case length. Trimming can actually be accomplished in three different ways, with the trimmer device just noted or with the Hornady Case Prep Center and also with a file trim die, hacksaw, and finishing file. If you were forming 30 Herrett cases from 30-30 Winchester cases, you would be left after the first pass with a case 3/8" longer than needed. This is an ideal situation in which to use a file trim die to remove a large amount of metal at once. With whatever trimming method used, case mouths will be rough after the process and need to be chamfered and deburred before further steps in the reloading process.

**BULLET PULLING:** Suppose you make a mistake. Wrong bullet, uncertain powder, whatever problem has created an unshootable load, there is a way to correct it, generally while saving the case and bullet, too. There are three devices for doing this: an inertia bullet puller (which resembles a hammer); pliers type pullers; and collet type pullers. Inertia pullers require you to hold the cartridge case against the rim or extractor groove and hitting the inertial device against something solid. This will dislodge the bullet without damage, but it is slow and tedious if many bullets need to be pulled. Pliers type pullers grasp the bullet when the cartridge is loaded in a loading press and extract the bullet when the ram is lowered. Bullets with this system will generally be scored, and the system works best in fairly long cartridges with bullets extending far beyond the case. Collet type pullers consist of a die with a collet insert that can be tightened when the case is positioned in a reloading press

and raised into the die. The collet tightens and when the ram is lowered the bullet remains in the collet. Bullets may remain in good shape, but the process is slow—and wadcutter bullets can't be pulled.

## Pressure Signs

Powder combustion sets off the chain of events that propel a bullet out the barrel of a firearm and into its trajectory. Gases—the products of combustion—expand rapidly within the cartridge case, pushing it against the breech and chamber walls and pushing the bullet forward. Pressure, measured in terms of force per unit area, accomplishes the work.

Pressure develops every time a round of ammunition is fired. The reloader must take care to develop loads that yield acceptable pressures for the firearm and cartridge to be used. Firearms are tested to maximum allowable pressures by their manufacturers, and these allowable pressures may vary greatly, depending on the design of the firearm and the specifications of the cartridge. Older firearms, such as the 45-70, may operate at a maximum of 15,000 pounds per square inch (psi). Modern cartridges, such as the 257 Weatherby Magnum, may operate safely at a level of 60,000 psi.

Although most people are concerned with the dangers of exceeding maximum pressure, excessively low pressures can cause their own set of problems. Low pressure symptoms may range from bullets stuck in the bore to backed out primers to sooty cases. (If a bullet sticks in the barrel, lubricate the barrel and, using a long wooden dowel or rod, gently tap the bullet out. Never fire another cartridge behind a stuck bullet as serious damage and injury can occur.) Fortunately, low pressure loads can usually be corrected by gradually increasing the powder charge.

Higher than normal or acceptable pressures can cause a variety of problems, even serious damage, injury, and at the extreme, death. The firearm chamber, cartridge, bullet, and barrel form a balanced “pressure vessel system.” Excessive pressures may wreck that system by blowing up the action, exploding the barrel, or sending hot gases (and even rifle bolts) back into the shooter's face. Throughout this handbook we caution again and again to “start loads low and work up.”

We never advise starting with maximum loads. You'll always be safe if you begin to load at the lowest load listed in the Hornady data and gradually work up (increase) your load. As you increase the powder

charge, you increase the pressures in the chamber and increase the bullet's velocity. As the pressure increases, there will be noticeable signs of this increase. You must stop with loads at, but not exceeding, maximum allowable charges.

***These are signs that loads have become excessive:***

1. An increase in case head expansion as measured by a very accurate micrometer.
2. Hard or sticky extraction from the chamber of the firearm.
3. Flattened primers (the rounded edges of the primer are now flattened, filling the gap between primer and case head.)
4. Cratered primers (primer cup material flowing into the firing pin hole.)
5. Ejector marks on the case head.
6. Sooty gas leakage around the primer.
7. Enlarged primer pockets — in the worst cases with the primer blown loose.

Should any of these signs show up, stop immediately and begin to look for the cause of these high pressure symptoms. Some common causes and solutions are:

1. You are using too much powder (check your scale and powder measure; reduce the powder charge.)
2. You have changed components (i.e., different cases, different primer) from a previously acceptable load. Reduce your load and re-establish a new maximum.
3. You are using the wrong data (check your reloading data).
4. You are using the wrong powder (check your reloading data).
5. You are using a heavier bullet than called for in the data (check your reloading data and weigh your bullets).
6. Your cases are too long (trim cases).
7. Your firearm has become overheated due to hot weather or repeated firing (allow firearm to cool or re-establish a new load for hot weather)

Occasionally, some of these symptoms may have other causes. Rarely, cratered primers can be caused by a firing pin hole that is too large, or a weak firing pin spring. These problems can be handled by a good gunsmith. Excessive case expansion, hard extraction, and loose primer pockets are occasionally due to soft brass. These cases should be discarded.

Pressure signs can sometimes be accurately estimated by appearance and physical measurements. Visual inspection can determine the difference between normal pressure (primers with rounded indentations from the firing pin), high pressure (flattened primers), and excessive pressures (enlarged primer pockets). Cases subjected to excessive pressures, certainly as in the last example, are candidates for the trash bin. The abuse to which they have been subjected may lead to head separation or cartridge wall rupturing. Excessively high pressures are not only bad for the firearm where they occur, they are bad for cartridge cases—and ultimately bad for the reloader, too.

An accurate blade micrometer can be a useful instrument for detecting excessive pressures. By measuring new case dimensions before and after firing, you will be able to note signs of excess pressure. On belted magnum cases you should measure the case belt. Careful measurement of this dimension of new cases before and after firing reflects chamber pressure. Measure rimless cases just in front of the extractor groove or rimmed cases immediately in front of the rim will reveal symptoms of excessive pressure in these cartridges. When these results are compared to similar measurements on factory rounds, a reloader can approximate a safe upper pressure limit.

## Keep it Safe!

Reloading is so safe it doesn't show up on any national accident tabulations. We think there are two reasons for this.

- You need to work very hard to get into trouble reloading.

And

- Almost all reloaders are safe, cautious, sensible people to start with.

That said, let's review safety pointers for reloading. We'd be remiss if we didn't review safety procedures. One or two times though this checklist and it should become second nature to you.

**BE NEAT.** Don't start off in a clutter of open bullet boxes and powder containers. Or anything else for that matter. Your work will go faster and safer if you get out only the components you'll need for the job.

**STAY ALERT.** Reloading is safe and easy, but it still isn't a great idea to be tired, distracted, or mentally sluggish while doing it.

**KEEP COMPONENTS FROM KIDS.** Extend gun safety rules one more step. Bullets, powder, and primers are not playthings for children.

**DON'T SMOKE.** You shouldn't do it while filling up at the gas station, and you shouldn't do it while reloading, either. Keep matches and flames away from the bench.

**READ THIS BOOK.** Follow instructions. Loads are not recipes you can adjust at will. Adding a little more powder is not like adding a little more salt to the stockpot. Know the steps of reloading and follow the process carefully.

**USE PROTECTIVE EYE WEAR.** Safety-conscious shooters increasingly use protective eye wear while shooting. Do the same while reloading. The odds are very long that an accident will occur, but they're still not worth risking your eyes on.

**HANDLE PRIMERS CAREFULLY.** Primers are the most active, potentially dangerous component employed in reloading. You can get into trouble with them one of two ways: (a) by crushing, heating, or handling in such a way as to discharge them; or (b) by contaminating them with moisture, lubricant, or other material so they will misfire.

**DON'T USE MYSTERY COMPONENTS.** Unidentified powder or primers should not be used. If you put away components carefully after a reloading session, you'll never have to discard unmarked powder or primers.

**DON'T START WITH MAXIMUM LOADS.** Powder charges we label as maximum were safe in our test firearms and with our components. These loads may be more than maximum in your firearm. Start with loads, say, 10% below the maximum listed and work up. You're courting danger if you don't exercise care in load development.

**REDEVELOP LOADS WHEN YOU CHANGE COMPONENTS.** Change a primer? Change a cartridge case? Don't automatically assume an old load will work well with new components. Start low again and work up.

**DON'T USE REDUCED LOADS OF SLOW BURNING POWDERS.** Reduced loads can produce both high pressures and unpredictable results. Don't test your luck on the subject.

**EAT AND DRINK AFTER RELOADING.** Who needs load contamination or component contamination? Keep food and drink away from the reloading bench. Never ingest lead.

**SWEEP UP SPILLED POWDER WITH A BROOM.** Not a Dust Buster, not a Hoover, not a Shop-Vac. Use no machine with a danger of sparking. Sweeping is safest.

**PUT COMPONENTS BACK IN THEIR ORIGINAL CONTAINERS.** Make your reloading bench neat and safe for your next reloading session.

**IDENTIFY YOUR LOADS.** Record details of your loads before you finish and label the ammunition you've produced. Save yourself later puzzlement by noting powder charge, bullet weight, primer, and reloading session date before you finish up.

We note in conclusion that the firearm for which reloads are intended should be safe, reliable, and sufficiently strong to handle them. You will see cautions at many places in the text of this volume about matching loads to the actions they'll be fired in. Know the strength of your firearm and load accordingly is the final rule here.

## Hornady Reloading Research

We have in general selected components that are readily available through commercial reloading supply dealers and firearms retailers. Cases are Hornady cases whenever possible. In calibers where we do not manufacture cases we have used Winchester, Remington, Federal, Weatherby or Norma factory brass. Some specialty calibers are restricted to proprietary cases, and still others have been formed from other cartridge cases as the wildcat cartridge originator specified.

Standard primers were used for most calibers with most powders. In larger cases with slower powders, magnum primers were used. They generally produce a hotter flame of longer duration and are useful for consistently igniting large charges of slow powders. Powders were selected using several criteria. One important criterion is burning rate. Although there can be several charges of certain powders that will work, we have chosen the most appropriate, as well as the most commonly available powders for each caliber. The powders listed are available to most reloaders all over the U.S. We have tried to be inclusive in powder

selection, using a powder from each major manufacturer. Where particular powders gave consistently superior performance in terms of both velocity and accuracy we have so noted.

Bullets, of course, are Hornady. We have chosen the most useful and optimum for each caliber. For instance, the 300 Savage could fire a 220 grain bullet. The usefulness of such a load, however, is limited. The velocity would be so slow that there would be little, if any expansion. To be safe, rifles with tubular magazines require flat nose, round nose or FTX® (Flex Tip) bullets, because a regular pointed bullet behind another cartridge could, during recoil, act as a firing pin causing the cartridge in front of it to discharge, resulting in damage or injury. Flat or round nose bullets have such a broad surface that an accidental discharge won't occur.

Bullets are seated to a depth to meet standard overall length as established by SAAMI, the Sporting Arms and Ammunition Manufacturers Institute. Bullets of different design, but the same weight, can generally be substituted for one another. Nevertheless, if a load is developed for one style of bullet in a particular weight, it is wise, and we recommend, reducing the powder charge slightly with a different style of bullet of the same weight. For example, if a maximum charge is developed with a 30 caliber 180 grain (.308" diameter) Boat Tail Spire Point bullet, it should be reduced 5-10% when using a 180 round nose flat base. The 180 round nose bullet has more jacket surface area touching the barrel, and therefore, slightly more friction which could cause higher pressures. It is always prudent to reduce an established charge, and gradually work to a new load with the new bullet.

When possible, loading data was fired in a special firearm designed to measure pressure. There is a description of a pressure gun in the Illustrated Glossary in of the *Hornady Handbook*. The barrel and chamber dimensions are carefully produced to exact SAAMI specifications. Data is generated until a maximum pressure, determined by SAAMI, is reached. These various loads are then test fired in commercially available firearms for velocity. The powder charge and velocity chart in the *Hornady Handbook* were derived from these test firings.

In some calibers and for some cartridges, pressure barrels were not available. We developed and tested loads in these situations by employing a factory or custom firearm and by examining the brass case and the fired case extracted from the chamber. The brass case will show several indications of increasing pressures. One is case head expansion as measured by a good micrometer and compared to a fired, factory loaded cartridge. Other pressure signs of significance were cratered or

flattened primers, brass flow into ejector slots, case head separations, as well as difficult case extraction.

We employed the procedures above only when we had no other options. The vast majority of the data in this book was derived from the use of strain gauges.

All testing of this reloading data was done at 70 degrees Fahrenheit. Higher temperatures usually increase pressure and velocity. Lower temperatures generally lower pressures and velocity.

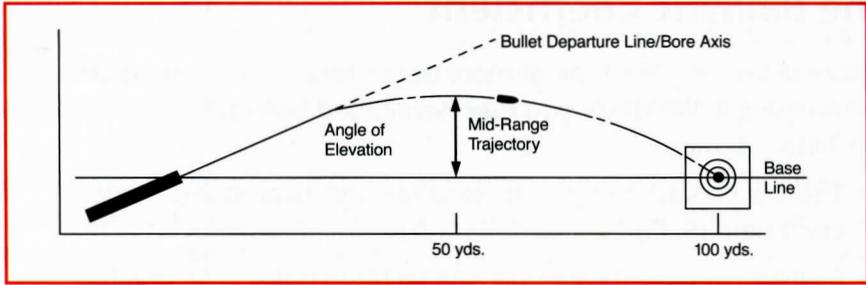
## Trajectory

Exterior ballistics deals with performance of Hornady bullets from the moment they exit the barrel until the moment that they arrive at the target. We are not concerned with internal ballistics, the province of the firearms engineer or powder chemist, nor with terminal ballistics, the province of the forensic pathologist or other scientific specialists.

Terminal ballistics is a very important concern to the military, to police, and to hunters. While there is no way to model the terminal behavior of all projectiles in all media at all velocities, we'll mention the subject briefly in the section entitled *An Aside on Energy*. For now we'll focus on exterior ballistics.

A trajectory is a description of the flight path of a projectile relative to some known and fixed points. Trajectories for BBs, field artillery projectiles, naval gun shells, mortar rounds, and small arms bullets are all parabolic in shape. In a barrel or mortar the motion of a projectile is both directed and entirely determined by the pressures of the gases behind it. But once the projectile leaves a barrel, two other forces begin to influence its flight. The first is air resistance. The second is gravity. Whatever its angle of departure and whatever its muzzle velocity, a shell or bullet will lose velocity from air resistance and lose height because of gravity. The parabolic shape of a trajectory is the result.

Narrowing our discussion to bullets only, we can provide illustrations of the parabolic curve of a trajectory and concepts related to it. In Figure A (exaggerated for purposes of illustration) we show a muzzle (left) and target (right) assumed to be horizontal on the same base line (for practical purposes the base line is equivalent to the line of sight). The firearm's barrel is elevated. The axis of the bore becomes the line of departure for a bullet leaving its muzzle. So rapidly do gravity and air resistance come into play that the bullet departure line is tangent to the trajectory only at the muzzle.

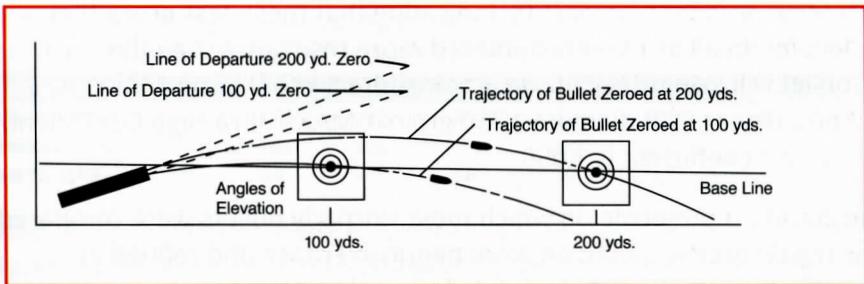


**FIGURE A**

The trajectory immediately begins to drop below the bore axis. The angle of departure (for small arms generally very small) is formed by the intersection of the line of departure and the base line. The midrange trajectory is the bullet's height above the base line halfway between the muzzle and the point of impact (here, the target).

Figure B uses the same firearm, bullet, and muzzle velocity to compare two different trajectories (the barrel is represented for simplicity in only one position). The difference between trajectories results from different angles of departure required to zero the firearm (change its point of impact) at two ranges; 100 yards and 200 yards. Trajectories fall below the base line (line of sight) in Figure B at zeros of 100 and 200 yards respectively. Bullet trajectories beyond their point of impact are described in terms of inches of drop.

While it makes sense to calculate trajectories for naval shells in terms of angles of departure and while one could do this for small arms trajectories as well, the shooter's primary reference in the field is the line of sight.



**FIGURE B**

## The Ballistic Coefficient

Before discussing this topic in more detail, let's dispel some myths surrounding it. Whatever you may have heard before, these are the facts.

- There is no such thing as an absolute and invariable ballistic coefficient (B. C.)
- Ballistic coefficients are only one factor in bullet selection for different kinds of shooting.
- A ballistic coefficient can change with reference to (1) altitude, (2) temperature, (3) atmospheric pressure, and (4) relative humidity.
- Ballistic coefficients are measures of a bullet's relative efficiency.
- Ballistic coefficients are not measures of a bullet's "goodness."
- Higher B.C.s do not necessarily make a bullet "better."
- Lower B.C.s do not necessarily make a bullet "worse."

A ballistic coefficient is the measure of a bullet's relative ability to overcome air resistance. Each bullet can be assigned a numerical value expressing this efficiency. The basis of this value is a ratio comparing the performance characteristics of a particular bullet against the known trajectory characteristics of a standard projectile. The ratio compares the drag of a bullet (loss of velocity caused by air resistance encountered in flight) to the drag of the standard projectile. Expressed as a formula,

$$\text{B.C.} = \frac{\text{Drag of standard projectile}}{\text{Drag of test projectile}}$$

Observe that ballistic coefficients in this book are, with only one exception, less than unity [1.0], indicating that these test projectiles—bullets for small arms—encountered more resistance than the standard. The single exception in the entire line of Hornady bullets is our 50 caliber (.510" diameter) 750 grain A-MAX® Ultra High Coefficient. Its ballistic coefficient is 1.050.

The standard projectile on which most Hornady bullets were compared was the G1 Model, based on work begun in France and refined at the U. S. Army Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland. Ballistic coefficients for most Hornady bullets were determined by computer calculations using data from test firing research performed in our 200 yard underground test range. New ELD-X® and ELD® Match bullets are measured with Doppler radar at extended distances.

Ballistic coefficient calculations combine both shape and sectional density factors. As a practical matter, most shooters understand that bullets with a pointed shape more easily retain their velocity than round nose or flat point bullets. This can be directly observed in the amount of drop bullets of the same weight but different shapes produce at the same target range. Expressed another way, round nose and pointed bullets will require different sight adjustments to attain the same zero over the same range. If more streamlined bullets maintain their velocity better, heavier streamlined bullets of the same shape will outperform lighter bullets at the same muzzle velocity.

The following examples quickly demonstrate the importance of shape to velocity retention and flat trajectory. We have chosen to compare in this example two bullets of identical caliber, weight, and sectional density fired at identical 3000 fps muzzle velocities. Shape is the only variable in this example; all other factors have been held constant. Observe the marked difference in bullet behavior over the ranges shown. The round nose bullet sheds its initial velocity faster than the spire point. Because energy is the product of mass x velocity squared, the round nose bullet's more rapid velocity loss produces an even faster loss of energy. Most dramatically, as the less efficient round nose shape loses its velocity, the effects of gravity show up in terms of greater bullet drop relative to the spire point bullet.

### 30 CAL. (.308" DIA.) 180 GRAIN SPIRE POINT

SECTIONAL DENSITY: 0.271 BALLISTIC COEFFICIENT: 0.425

RANGE (YARDS)	MUZZLE	50	100	200	300	400	500
VELOCITY (fps)	3000	2887	2777	2565	2362	2169	1985
ENERGY (ft.-lb.)	3597	3331	3082	2629	2230	1880	1574
100 YD. ZERO	-1.5"	-0.2"	0.0"	-3.0"	-11.3"	-25.9"	-47.8"

### 30 CAL. (.308" DIA.) 180 GRAIN ROUND NOSE

SECTIONAL DENSITY: 0.271 BALLISTIC COEFFICIENT: 0.241

RANGE (YARDS)	MUZZLE	50	100	200	300	400	500
VELOCITY (fps)	3000	2803	2614	2259	1933	1639	1385
ENERGY (ft.-lb.)	3597	3139	2731	2040	1493	1073	767
100 YD. ZERO	-1.5"	-0.2"	0.0"	-3.6"	-14.1"	-34.0"	-67.0"

Does this comparison argue entirely against using round nose bullets? By no means; over the 100 to 200 yard ranges typical of a great deal of hunting, the round nose holds its own. Moreover, many who hunt with them regard them as utterly reliable over their intended distances. Confidence counts more than a lower ballistic coefficient to these folk.

# Correction Factors

Ballistic coefficients are calculated not only with reference to a standard projectile, but with reference to standard test conditions as well. All ballistic coefficients and ballistics tables in this book have been adjusted to standard conditions. Altitude=sea level. Temperature=59 degrees Fahrenheit. Atmospheric pressure=29.53" of Hg. Relative humidity=78%. These are standard conditions for the Aberdeen test site. What happens when the conditions are not standard? These four test examples will demonstrate changes in a calculated ballistic coefficient resulting from varying different test factors in turn.

## TEST NO. 1: STANDARD CONDITIONS

CONDITIONS: Sea Level, Temperature = 59°F, Barometric Pressure 29.53", Relative Humidity 78%.

RANGE (YARDS)	MUZZLE	100	200	300	400	500
VELOCITY (fps)	2900	2627	2371	2129	1901	1690
TRAJECTORY-100 yd zero	-1.5"	0.0"	-3.6"	-13.3"	-30.8"	-57.9"

Results: Calculated ballistic coefficient = .338

## TEST NO. 2: HIGHER TEMPERATURE

CONDITIONS: Sea Level, Temperature = 89°F, Barometric Pressure 29.53", Relative Humidity 78%.

RANGE (YARDS)	MUZZLE	100	200	300	400	500
VELOCITY (fps)	2900	2640	2395	2162	1943	1739
TRAJECTORY-100 yd zero	-1.5"	0.0"	-3.5"	-13.1"	-30.1"	-56.4"

Results: Due to less dense air (warmer temperatures) the calculated B.C. is .355.

## TEST NO. 3: HIGHER BAROMETRIC PRESSURE

CONDITIONS: Sea Level, Temperature = 59°F, Barometric Pressure 31.00", Relative Humidity 78%.

RANGE (YARDS)	MUZZLE	100	200	300	400	500
VELOCITY (fps)	2900	2614	2346	2094	1858	1641
TRAJECTORY-100 yd zero	-1.5"	0.0"	-3.6"	-13.6"	-31.5"	-59.5"

Results: Due to denser air (higher barometric pressure) the calculated B.C. is .322.

## TEST NO. 4: HIGHER ALTITUDE

CONDITIONS: 10,000', Temperature = 29°F, Barometric Pressure 21.00", Relative Humidity 78%.

RANGE (YARDS)	MUZZLE	100	200	300	400	500
VELOCITY (fps)	2900	2693	2495	2306	2124	1952
TRAJECTORY-100 yd zero	-1.5"	0.0"	-3.3"	-12.2"	-27.6"	-50.8"

Results: Due to less dense air (higher altitude) the calculated B.C. is .448.

The .338 calculated ballistic coefficient has ranged from .322 to .448 as conditions have varied. Common sense suggests that a bullet might perform better in higher temperatures (less dense air), at lower barometric pressures (less air pressure), and at higher altitudes (much lighter air). When there is less air to resist a bullet's flight, it will become more efficient—and conversely. How can you account for significantly non-standard conditions in preparing, say, for a major hunt? Assuming

that you know the temperature, barometric pressure, and ballistic coefficient of the bullet you will be shooting in non-standard conditions, you can calculate the apparent ballistic coefficient of the bullet and otherwise find the trajectory for your non-standard condition site.

The drag on a bullet is largely produced by the density of the air through which it travels. The first conversion factor to correct for changes in air density is the ratio of:

$$\frac{\text{Standard Pressure}}{\text{Shooting Site Pressure}}$$

which is used as a multiplier in the correction calculation. The correction factor for temperature is another ratio, but with a twist:

$$\frac{\text{Shooting Site Temperature} + 459.4}{\text{Standard Temperature} + 459.4}$$

The 459.4° addition to the site temperature and standard temperature is to place both in the absolute Rankine Scale. (Absolute zero is -459.4° Fahrenheit or 0° Rankine.) The resulting ratio is also a multiplier in the correction process.

Corrections can be made as well for relative humidity, but the correction process is tedious and the precision gained is negligible. At any rate, while we've seen barometers in camp and thermometers on the trail, we can't recall seeing hunters lugging hygrometers. Besides, we have already captured the primary factors requiring adjustment.

Assume that we encounter the following conditions on a hunt. The temperature is a chilly 29° Fahrenheit, the barometric pressure 21.00"Hg., and the relative humidity 85%. Think about this a minute and it seems we're on a mountain hunt in some very raw conditions. Relative humidity is very close to the standard 78%, so we'll not worry about adjustments there. But the temperature and atmospheric pressure are far from standard. What effect will they have on the ammunition we've loaded with a standard condition ballistic coefficient of .338?

The temperature correction factor =  $\frac{29 + 459.4}{59 + 459.4} = .942$

The barometric pressure correction factor =  $\frac{29.53}{21.00} = 1.406$

The Apparent Ballistic Coefficient = Temperature correction factor x Barometric pressure correction factor x Present ballistic coefficient = .942 x 1.406 x .338 = .448.

As a practical matter, the lower temperature alone would reduce the apparent ballistic coefficient, but in combination with the low barometric pressure correction the overall result will be flatter trajectories for the ammunition brought on this hunt.

Shooters who go from low altitudes to high altitudes or vice versa should bring along enough ammunition to sight in their firearms at the new location. The flat trajectories obtained with reloads in Fort Collins, Colorado may not be so flat on a hunt in the woods of Maine. Aiming higher over common ranges is the answer here. Conversely, taking tested loads from Mobile, Alabama to the mountains of British Columbia may require aiming lower than one might have back home.

For ranges up to and including 300 yards, ballistic coefficient corrections may not, practically speaking, be required. Steadiness of the shooting position and the aiming skills of the shooter may account for more difference between planned and actual trajectory than correction factors might require. If actual shooting conditions are going to be dramatically different from those at home, it's sound advice to take enough ammunition to re-zero your firearm at the shooting site.

## **An Aside on Energy**

Over the years many writers have spent considerable time pursuing the concept of bullet performance. In match competition or target shooting, performance standards are simple and direct. Bullets for target shooting should be highly efficient (streamlined, possessing a high ballistic coefficient) in order to shoot as flat as possible and buck the effects of wind drift. Efficiency counts for naught, however, if these bullets are not accurate as well—made so carefully and precisely that they will routinely yield sub-minute-of-angle performance on targets.

Performance for hunting bullets, however, is a far more complex matter. Some have contended that you must expect to find your splendidly mushroomed bullet under the game animal's hide opposite the entry hole. Shame on you if it doesn't weigh used 95% of what it weighed new. Others have said it's fine if the bullet enters and exits its target as long as it does deadly damage on its way. Pragmatists are pleased with bullets that strike where aimed and drop and kill the game immediately. They are hunters, they argue, not forensic pathologists.

Is performance a matter of opinion only? Of conjecture? A subject like religion and politics on which there will always be disagreement?

The experienced hunter knows that he will never be presented only with perfect shots under ideal conditions with his equipment always in superb shape and his rifle zeroed at the absolutely correct range. That's why the experienced hunter loves his sport so much. His skill is involved, his judgment is required, his intelligence is always called for—and he will face real challenges in the field. His need is to prepare for those challenges, both in his selection of equipment and his preparation for the field. Any hunter's odds are greatly improved when he chooses the right gun, the right bullet, and the right load for the task at hand. As much as a shooter needs to understand such variables as trajectories, the effects of wind drift, and bullet velocities over anticipated hunting ranges, so, too, must he give thought to the energy that the bullet will generate upon impact.

A bullet's kinetic energy, measured in foot-pounds, is a proxy for what's generally termed "stopping power." The higher a bullet's energy at the point of impact, it has been assumed, the greater its "stopping power." There are some caveats here. A bullet completely releases its energy in the target only if it remains in the game animal. If it has more than adequate energy it may do its job and exit. This is certainly no cause for alarm. If it does not have sufficient energy to bring about a kill, whether through improper bullet choice or shots at excessive ranges, that is a cause for alarm. Responsible hunters make sure they can get the job done with the tools they have chosen. Taking shots at ranges where a bullet cannot reliably hit and kill a game animal is quite irresponsible behavior.

Hornady bullets for varminting are designed to fly fast and to release their high kinetic energy instantaneously and explosively. Should they be too powerful for a particular varmint and pass on through, the wound channel and exit hole will attest to their destructive power.

Hornady bullets for game hunting are designed for reliable, controlled expansion in all hunting bullet designs. No hunting bullet can be as effective as possible if it does not expand to a larger diameter than its caliber dimension. Expansion slows the bullet and allows it to shed kinetic energy as it does. GMX® bullets are expanding monolithic hunting bullets. Other Hornady bullets for hunting are made with the InterLock® or InterBond® features that bind jacket and core. This assures a heavier mass to penetrate the game animal and propagate shock waves within it. The higher the terminal velocity of the bullet, the higher its terminal

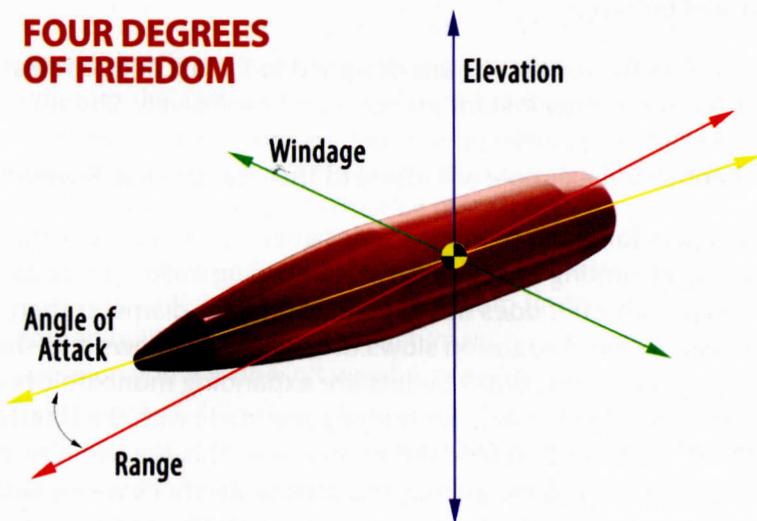
energy. Expansion and penetration insure energy release which in turn produces lethal results—and more certain kills.

This is not, nor is it intended to be, the final word on hunting bullet performance. Rather, we hope to stimulate your thinking about the subject and how important terminal bullet energies are to performance. Terminal energies and superior bullet expansion design permit the complete release of a bullet's remaining energy within the game animal. Hornady bullets are backed by over 60 years of expertise on the subject.

## Online Ballistics Calculator

Hornady offers two different ballistics calculators on their website that can assist in determining the kind of performance to expect from a specific load. These web-based calculators allow you apply certain conditions like altitude, temperature, humidity, wind speed and shooting angle to determine the amount of drop to expect. The patent pending 4DOF® Ballistic Calculator offers even more precision by applying "4 degrees of freedom" when calculating a projectile's flight.

The Hornady® 4DOF® (Four Degrees Of Freedom) Ballistic Calculator determines trajectory solutions based on projectile Drag Coefficient (not Ballistic Coefficient), combined with exact physical modeling of the projectile and its mass and aerodynamic properties. Additionally, it is the first publicly available calculator that accurately determines the correct vertical shift a bullet experiences as it encounters a crosswind; referred to as Aerodynamic Jump (AJ).



## **WHY THE NAME, "4DOF" (4 DEGREES OF FREEDOM), AND WHAT IS A "DEGREE OF FREEDOM?"**

Quite simply, "Degree or Degrees Of Freedom" is a physics term for actions or responses of an object that are independent of each other. Up to this point, all publicly offered small arms trajectory programs have treated a projectile as an inanimate lump using only three degrees of freedom to calculate trajectory (windage, elevation and range); the projectile's movement in relation to its line of flight isn't accounted for.

The trajectory solution provided by the Hornady 4DOF Calculator is calculated by incorporating the projectile's movement in the standard 3 degrees as well as its movement about its center of gravity and subsequent angle relative to its line of flight (angle of attack); aka the 4th Degree Of Freedom. A tremendous amount of the software as well as projectile properties goes into the calculation of this simple sounding angle of attack.

## **WHY DON'T WE USE A BALLISTIC COEFFICIENT (BC) FOR THIS CALCULATOR?**

The question is probably best answered with a question: why calculate a trajectory using a mathematical comparison of your bullet to a "Standard Projectile" (oversimplification of BC) when you can use an exact model of the projectile in the trajectory calculation (Drag Coefficient)?

Using Doppler radar, Hornady ballisticians have calculated the exact drag versus velocity curve for each projectile in the 4DOF bullet database. Ballistic Coefficient can change as velocity changes. A drag curve doesn't change- the curve is specific to each projectile and is directly related to its trajectory.

The Hornady 4DOF Calculator accurately calculates the mass properties, aerodynamic properties and the responses of the projectile as it flies downrange as well as the movements of the projectile due to these responses, such as spin drift, accurate Gyroscopic Stability (Sg) and Aerodynamic Jump (AJ). There is no Ballistic Coefficient (BC) needed or used in 4DOF.

## **WHICH CALCULATOR SHOULD I USE?**

The Hornady Standard Ballistics Calculator uses BCs (G1 or G7 ballistic coefficients) to calculate trajectory and is ideal for traditional hunting

and varmint bullets at close to moderate distance. For more precise long range calculations using select low-drag precision bullets, the Hornady 4DOF calculator will give you more accurate solutions.

The use of drag coefficients, projectile dynamics, aerodynamic jump and spin drift enable the Hornady® 4DOF® Ballistic Calculator to accurately measure trajectories, even at extreme ranges. It is ideal for both long range and moderate distances and is available for the low-drag precision bullets listed in the drop down menu of the calculator. For calculating trajectories of traditional hunting and varmint bullets using BCs (ballistic coefficients), the Standard Ballistics Calculator is more applicable.



## Free Ballistic App with 4DOF®

Our free Hornady Ballistic Calculator App includes the advanced 4DOF® calculator as well as a standard BC calculator. Providing more accurate trajectory solutions, the 4DOF® calculator incorporates the projectile's movement in the standard 3 degrees but also adds its movement about its center of gravity and subsequent angle relative to its line of flight, which is the fourth degree of freedom.

- Calculates more accurate trajectories, especially at extreme ranges
- Can be used without wireless connectivity
- Pre-populated with long range match and hunting style bullets
- Includes spin drift, aerodynamic jump, and other calculations not available on traditional ballistic calculators.

Search Apple and Android app stores

# HORNADY.COM/BALLISTICS

Standard/Metric: **Standard** Basic/Advanced: **Advanced**

Description:  
30-06 165gr SST 2850 fp

Ballistic Coefficient (0.01 - 1.2): 0.447 Velocity (100 - 4600 ft/s): 2850

Weight (8 - 1000 grains): 165 Maximum Range (100 - 2000 yds): 1000

Interval (yds): 100 Zero Range (0 - 2000 yds): 100

Sight Height (0.1 - 4 inches): 1.5

Drag Function: G1 Shooting Angle (-90 - 90 degrees): 20

Wind Speed (0 - 70 mph): 8 Wind Angle (0 - 360 degrees): 90

Altitude (0 - 15000 ft): 5800 Pressure (15 - 40 hg): 29.53

Temperature (-40 - 140 F): 59 Humidity (0 - 100 %): 78

[RESET TO DEFAULTS](#) [CALCULATE](#)

Hornady offers two different ballistics calculators on their website that can assist in determining the kind of performance to expect from a specific load. These web-based calculators allow you apply certain conditions like altitude, temperature, humidity, wind speed and shooting angle to determine the amount of drop to expect.

**RESULTS**



## BALLISTICS CALCULATOR

**Your Input Variables**

Ballistic Coefficient	0.447	Velocity (ft/s)	2850	Weight (grains)	165
Maximum Range (yds)	1000	Interval (yds)	100	Drag Function	G1
Sight Height (inches)	1.5	Shooting Angle (degrees)	20	Zero Range (yds)	100
Wind Speed (mph)	8	Wind Angle (degrees)	90	Altitude (ft)	5800
Pressure (hg)	29.53	Temperature (F)	59	Humidity (%)	0.78

**Ballistics Results - 30-06 165gr SST 2850 fps**

RANGE (YARDS)	VELOCITY (FPS)	ENERGY (FT.-LB.)	TRAJECTORY (IN)	COME UP IN MOA	COME UP IN MILS	WIND DRIFT (IN)	WIND DRIFT (MOA)	WIND DRIFT (MILS)
Muzzle	2850	2978	-1.5	0	0	0	0	0
100	2683	2637	0.1	-0.1	0	0.5	0.5	0.1
200	2522	2331	-2.8	1.3	0.4	1.9	0.9	0.3
300	2367	2053	-10.9	3.5	1	4.4	1.4	0.4
400	2217	1801	-24.8	5.9	1.7	8	1.9	0.6
500	2072	1573	-45.3	8.7	2.5	12.9	2.5	0.7
600	1933	1369	-73.5	11.7	3.4	19.2	3	0.9
700	1800	1187	-110.5	15.1	4.4	27	3.7	1.1
800	1673	1025	-157.7	18.8	5.5	36.5	4.4	1.3
900	1554	884	-218.6	23	6.7	47.9	5.1	1.5
1000	1442	762	-289.1	27.6	8	61.3	5.9	1.7

[View Full Results](#) [View Cheat Sheet](#) [Print](#) [Close](#)

Once your variables are entered, an easy-to-read reference table is available to view and print.

**RESULTS**

The following table is provided as a "cheat sheet" that you can tape to your gun.

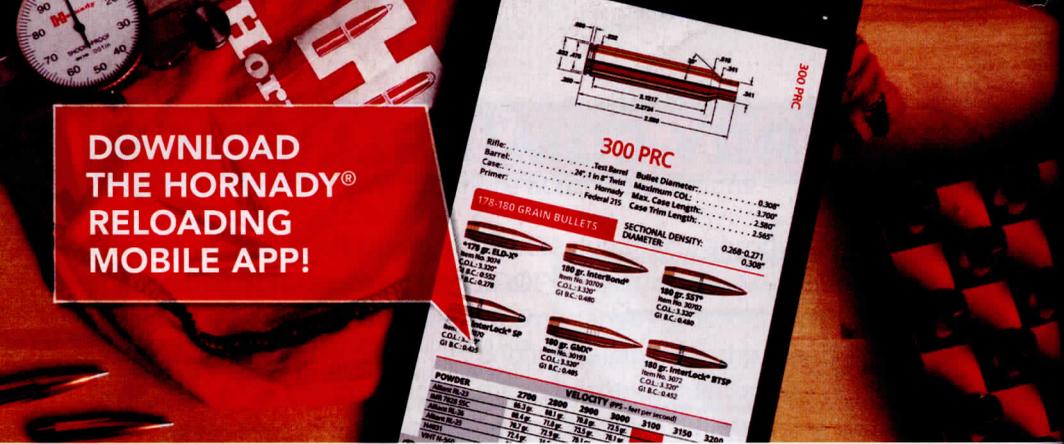
**FUELED BY Hornady**

	30-06 165GR SST 2850 FPS	165 GR.		0.447 B.C.							
Range	Muzzle	100	200	300	400	500	600	700	800	900	1000
Trajectory	-1.5	0.1	-2.8	-10.9	-24.8	-45.3	-73.5	-110.5	-157.7	-218.6	-289.1
Come UP in MOA	0	-0.1	1.3	3.5	5.9	8.7	11.7	15.1	18.8	23	27.6
Come UP in MILS	0	0	0.4	1	1.7	2.5	3.4	4.4	5.5	6.7	8
Wind Drift in MOA	0	0.5	1.9	4.4	8	12.9	19.2	27	36.5	47.9	61.3
Wind Drift in MILS	0	0.5	1.9	4.4	8	12.9	19.2	27	36.5	47.9	61.3
Wind Drift in MOA	0	0.5	0.9	1.4	1.9	2.5	3	3.7	4.4	5.1	5.9
Wind Drift in MILS	0	0.1	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7

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You can also print a "cheat sheet" to tape to your gun or reference in the field.





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