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

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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 As we'll see later in this chapter, these SAAMI standards are in many cases outdated and can dramatically restrict the performance potential of a cartridge.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.

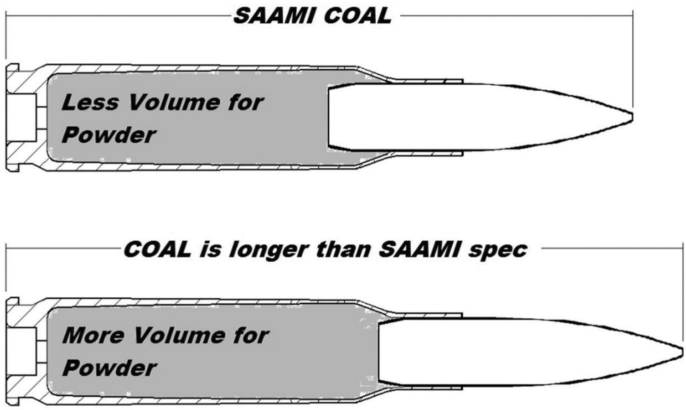

Figure 1: When the bullet is seated farther out of the case, there is more volume available for powder. This enables the cartridge to generate higher muzzle velocity with the same pressure.

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.

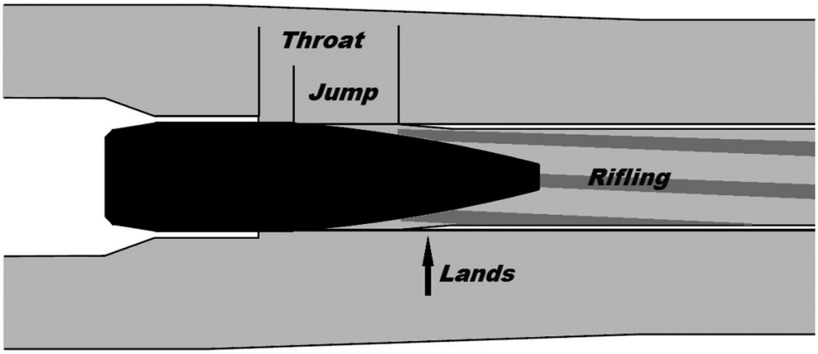

Figure 2: Chamber throat geometry showing the bullet *jump* to the rifling.

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.

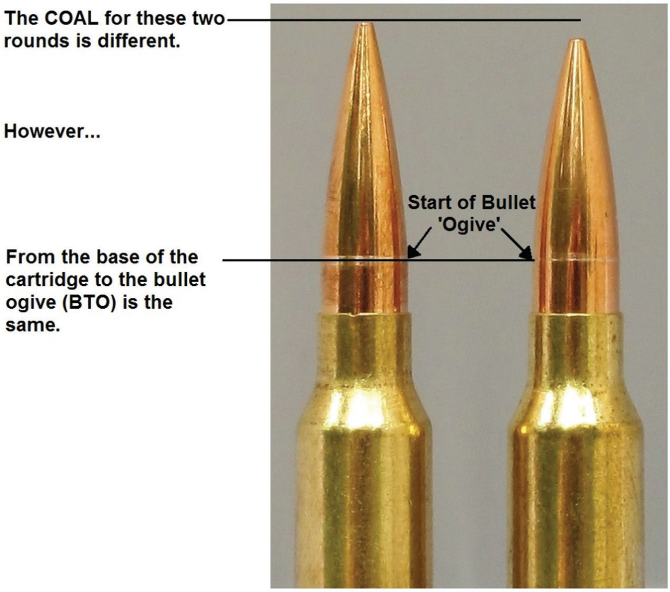

Figure 4: Two different bullet shapes, seated to the same CBTO length, but different COAL. Note the shiny scratches on the bullets made by the comparator tool, which indicates a point on the bullet ogive near where the ogive will engage the riflings.

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.