A Brief Synopsis of Metallic Cartridge Reloading Principals

By: C. Guenther

Reloading cartridges is something that requires a solid attention to detail and a limited use of “extrapolation”, meaning we try to reduce the amount of guesswork necessary when producing safe-to-use cartridges. That said, reloading cartridges yourself lends itself to a variability which is never encountered in factory loaded ammunition and allows for some experimentation.

However, in general, we try to limit experimentation where the most dangerous attribute of hand loaded ammunition is concerned, mainly pressure. Pressure within a cartridge is affected by a multitude of factors and can go from well within safety limits to massively overpressure and dangerous with a few seemingly inconsequential changes to a recipe

A brief synopsis of how pressure works within a gun barrel might seem a little elementary, but it is necessary to understand in order to properly apply the load data and understand what it is doing.

But in general, the attributes most associated with raising or lowering pressure are:

- Powder (quantity and burn rate)
- Primer
- Seating Depth (case capacity)
- Bullet construction
- Bullet bearing surface

POWDER

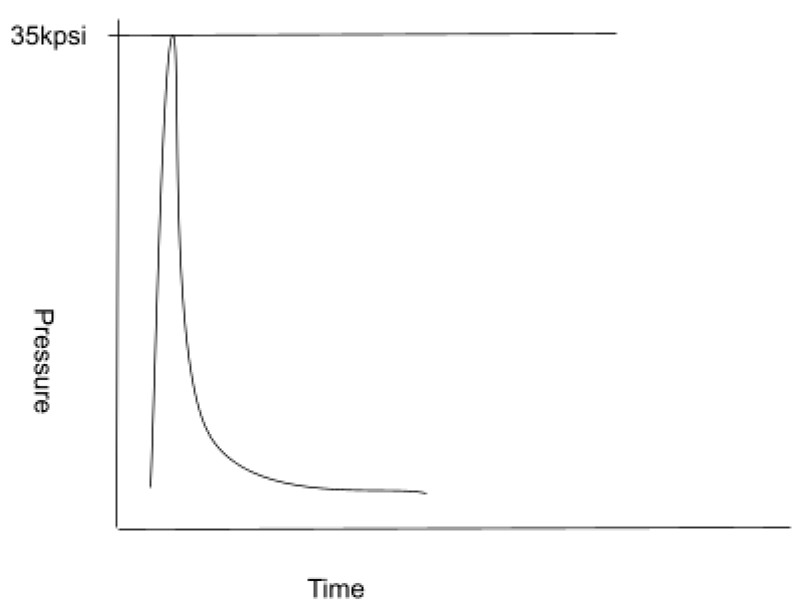
Very broadly, powder burns (it does not explode if we can help it), generates pressures (sometimes of the magnitude of up to 70,000psi), which forces a projectile into the barrel and continues generating pressure until all the powder is consumed or the bullet has left the barrel. In practice, even the slowest powders are completely consumed within the first few inches of barrel. (A fact that would be disputed by most, but is evident when studying muzzle flash, see: Hiemerl, Joseph.*The Muzzle Flash of Guns and Rockets*)

There are only two broad powder types available to consumer reloaders: Black Powder (and it’s substitutes), and smokeless powder.

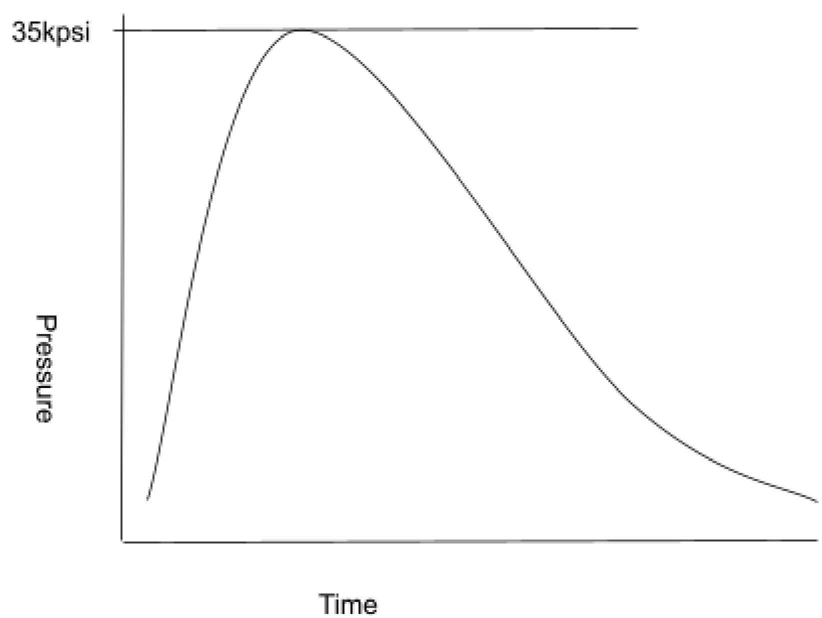
- **Black Powder:** The original gunpowder. Composed of Sulfur, Potassium Nitrate and Charcoal, it is sometimes referred to as a “low explosive”. It burns very rapidly in both open air and when confined in a gun barrel. In fact its burn rate doesn’t change much when confined. So using Black powder, a limited maximum velocity can be obtained no matter the bore size, bullet weight or barrel length and is generally assumed to be about 2,000 fps. Due to this burn characteristic, black powder rarely exceeds 20,000-25,000psi even when heavy charges are used with heavy bullets. Black powder is used in muzzleloaders and black powder cartridge loading. It is highly corrosive to gun metal due to the presence of salts in the residue. Metallic reloading with it, while similar to smokeless powder, is different enough to need another discussion which is beyond the scope of this paper on modern metallic reloading.

- **Smokeless Powder**: This is what modern cartridges use as propellant and the term “powder” from here on out will be assuming smokeless powder. Smokeless has two broad categories, from there, they further diversify. They are known as single base or double base. There are triple base powders but for all intents and purposes they are similar to double base powders with additives to affect burn rate. With smokeless, the more pressure that is generated, the faster the powder burns, to a point, beyond a pressure threshold, it begins detonating like a high explosive (not a good thing)
    - *Single base:* Powder produced using only Nitrocellulose. This is the original “cordite” and is seen mainly in slow burning rifle powder.
    - *Double Base:* Powder produced using a combination of Nitrocellulose and Nitroglycerin. These are usually seen as pistol powders but are used in rifle powders as well. The Nitroglycerin makes the powder more energetic so that a smaller amount of it yields a higher muzzle velocity.

A mention of powder burn rate seems pertinent at this point. The faster a powder burns, the less of it you can safely use and correspondingly low muzzle velocities are the usual result as less powder is less chemical potential energy that can be transferred to the bullet. This can be visualized in a graph of cartridge pressure over time, with peak pressure limited, in this example, to 35,000psi. The area under the pressure curves represent the energy that is available to be transferred to the bullet. More gradual curves yield more energy and higher velocities than sharp, abrupt changes in pressure.



A cartridge burning very fast powder has a rapid spike in pressure and a correspondingly sharp drop as the powder is consumed quickly and has very little time to push the bullet to a high velocity with the limit of 35,000psi. This is common in pistol cartridges where a long barrel isn't possible so a fast spike is necessary to get the bullet moving quickly.



A cartridge burning slower powder has more safety margin to build pressure and use more powder because the bullet can get moving and relieve the pressure as more pressure is generated. Thereby keeping chamber pressure low as the powder continues to burn. This would be typical of a bottlenecked, high velocity, high energy rifle round.

Of course, this is painting with a broad brush. At last count, there were over 100 different varieties of smokeless powder, each with different burn characteristics, to give the loader the ability to tailor a load to a particular purpose, velocity, burn rate, flash reduction, recoil… etc.

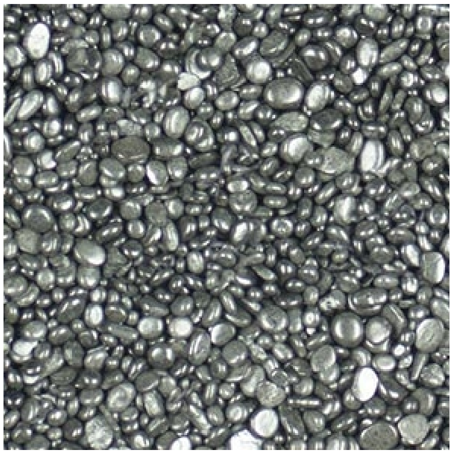
Powders can be broken down into three major appearances, with each having variations within it. But the three are:

Extruded or Tubular:

This is typical of slower burning powders such as rifle powders or magnum handgun powders. These tend to meter decently well in powder measures.

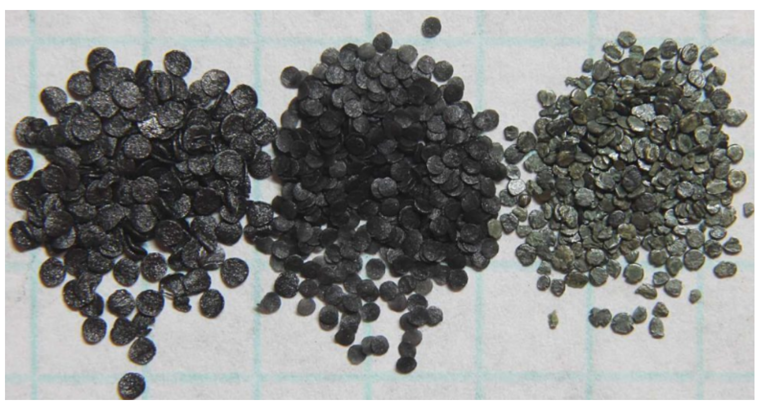
Spherical

(magnified many times. This usually has an appearance like fine black sand):



These can be both slow burning rifle powders and medium to slow rate pistol powders. These are the best metering powders for ease of loading.

Flake



These are small, flat flakes of powder and are the most difficult to get to meter well. They are almost exclusively pistol or shotgun powders and vary from fast-medium burn rate to the very quickest burning smokeless powders available. They are commonly used in 12, 16 and 20 gauge shotgun loads and pistol ammunition.

PRIMERS

Primers come in a large variance of make, size and power, but for most commercially available rifles and pistols, they can be categorized as:

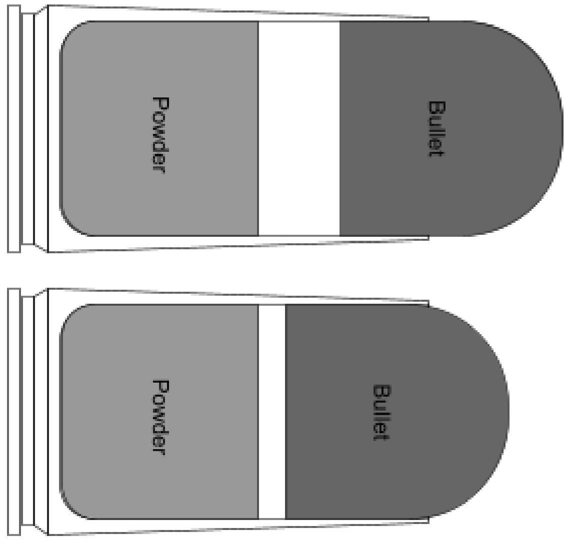
- ➢ *Large Pistol*: Used in cartridges with large powder charges or large diameter bullets (over .40). E.g. .45ACP, .41 Magnum, .44 Magnum, etc
- ➢ *Small Pistol:* Used in cartridges with smaller powder charges or small diameter bullets. E.g. .25ACP, .32 ACP, 9mm, .38/.357, .40S&, etc.
- ➢ *Large Rifle:* used in most large capacity big game, bottlenecked rifle cartridges. E.g. .243, .270, .308, .30-06, .300 Win Mag., etc.
- ➢ *Small Rifle*: Usually relegated to small capacity cartridges, mainly varmint or cartridges designed from vermin cartridges. E.g. .17 Hornet, .17 Remington, .22 Hornet, .222 Rem, .223 Rem, .330 Blackout, etc.
- ➢ *Large Rifle Magnum:* Reserved for very large capacity Magnum rifle rounds. E.g. .300 Weatherby, .338 Win Mag, .375 H&H/Ruger, .416's and .458 magnums.

There are really only two sizes, Large and Small. But each primer has different burn characteristics, different quantities of explosive and different applications. Using the wrong primer can push pressure beyond safe limits. It is best to stick with the primer size recommended in the recipe. I.e. don't put a large rifle primer in an automatic pistol case and then fill the case to its max rated charge. Modern firearms are massively overbuilt to keep shooters safe, but constantly pushing the ragged edge of pressure is inducing significant wear and tear on a firearm.

SEATING DEPTH

As mentioned above, the more pressure builds, the faster smokeless powder burns, which creates a vicious cycle. The faster it burns, the faster it creates more pressure and the faster it burns. Something will have to give. Usually it is the bullet, which begins to move down the barrel, creating more space for the powder to expand into and keeping pressure safe. But if the bullet cannot move fast enough, the steel of the barrel and the action will give. This is colloquially known as a "kaboom".

One of the major contributing factors to how quickly pressure builds, is how much space is in the cartridge case to begin with. In loading manuals, there will be a dimension, typically measured in inches, though occasionally it will be in millimeters, known as "C.O.A.L." or "O.A.L" This stands for Cartridge OverAll Length and is the dimension from the base of the case to the tip of the very explicitly described bullet (we will get into why this is important when we discuss bullets). This measurement is a way of describing how deeply seated into the case a bullet is. Every thousandth of an inch a bullet encroaches on the powder space, increases ignition pressures a little more and boosts overall chamber pressure. Encroach too much on it and you run the risk of damaging the gun. This is why COAL is given as part of the recipe. It is not a suggestion. Going longer than COAL is fine to a point. But butting the bullet up against the rifling in the throat of the chamber will increase pressure as well as the bullet cannot get a "running start" to engage the rifling. It must be forced to do so by pressure alone. So COAL is a crucial piece of information. Obviously there is give and take. If you cannot seat to COAL, for instance, if the throat is too short, then reduce the powder charge accordingly then work your way back up looking for pressure signs (see section on "pressure signs").



The round on the top will generate less pressure than the one on the bottom given the same powder charge.

BULLET CONSTRUCTION AND BEARING LENGTH

When looking at load data, many times there is a specific bullet that is used for the data. In some instances, it is possible to choose a bullet of a similar profile and similar weight (no more than 5% heavier), and use that load data. Other times, it will vastly change the chamber pressure generated. A good example of this is to compare a 125 grain .357 lead bullet and a .357 125 grain Barnes XPB bullet.

Lead on the left. The red band on the lead bullet is a groove filled with bullet lubricant. The red lines indicate bearing surface on the bullets. Notice the lead bullet has significantly less bearing surface than the solid copper barnes on the right. On top of this, lead is a natural lubricant and is very soft whereas the copper bullet is much harder to compress, has no relieving grooves or lubricative properties and has much more of the bullet's shank that must be forced into the rifling. Copper is also much less dense than lead, so a 125 grain .357 bullet made of copper is about the same length as a 158 grain bullet. So seated to the same COAL, the copper bullet would encroach more into the powder space. So what would be a safe maximum load for the lead bullet would be very unsafe for the copper bullet.

ESTABLISHING A SAFE LOAD

While many experienced reloaders can extrapolate known data and develop loads that will work with a few unknowns, an inexperienced reloader who doesn't have a full grasp on "what is too much" because they have no frame of reference should stick to established loading practices and recipes. There are a few rules that guide any reloader, and will help to gauge where the safety zone is.

1. **NEVER** exceed the maximum listed load for a cartridge/bullet combination. Doing so is playing with fire and may end up damaging your firearm or worse. There are experienced reloaders who will tell you it is possible, and some may be right, for THEIR gun. But without at least a strain gauge, it is only a "best guess" type of scenario.

2. Along with number one, only use load data from established sources (Powder and bullet companies). Internet forums aren't great data sources unless they include a picture from the loading manual they are referencing. Same goes for Youtube videos.

3. If no starting load is given, then assume that the load given is the max and start powder charges 10% below this number. Do NOT reduce powder charges more than 10% until you are familiar with your powders characteristics. This can be as dangerous as over charging with some powders. Hodgdon H110 is a good example of this.

4. Lead bullets are softer and slipperier than copper jacketed bullets. You can use load data for an equivalent weight jacketed bullet of similar profile if you cannot find data for the lead bullet assuming the lead bullet is not more than 0.001" larger in diameter than the jacketed.

5. Loading longer than COAL is fine as long as the round will fit into the chamber without the bullet shank hitting the rifling and the round will still fit in the magazine.

6. Visually inspect your cartridge powder levels before you seat your bullets to ensure that they are all roughly the same. The .38 special is a huge case that was designed for black powder. Some charges for this max out at 3.5 grains, which is a very small amount. Putting 7 grains in will not necessarily be noticeable due to the size of the case, but will likely blow the gun to pieces and parts of your hand with it. If you aren't sure, dump the case into the scale and weigh it again.
   This can be avoided by choosing powders that fill a case more than halfway, where a double charge would overflow the case. Doing this also confirms that

you will not be seating a bullet on an empty case. A primer has sufficient force to jam a bullet an inch or two into the barrel and getting it out usually requires a mallet.

7. If you have a round go off with heavy recoil or is really loud. Or you see pressure signs, **STOP** and pull those bullets.
8.

PRESSURE SIGNS

Reading pressure signs only comes with lots of reloading experience. The methods usually given are not gospel. More often than not, they are a false positive or they lull one into a false sense of security.. The thing most people will not mention is this: **IF YOU ARE LOADING HANDGUN ROUNDS AND ARE SEEING PRESSURE SIGNS, YOU ARE ALREADY WAYYYY OVER PRESSURE.** I will give the example of the .45ACP. This cartridge has a maximum allowable pressure of 21,000psi according to SAAMI who sets these standards. Brass cases don't even start to flow (or irreversibly change shape or swage the metal) until they are over 70,000 psi (hence the upper limit of conventional brass cased cartridges). If people are saying "Oh I can keep going higher because I don't see any pressure signs' ', it's because you won't see them until you are almost 4x the maximum allowable pressure of the cartridge.

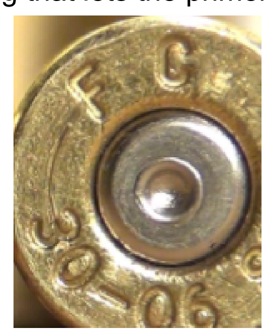
This isn't to discredit signs, but for most cartridges (those that don't operate at 60-70kpsi, if you see pressure signs, you are already way out of the safety margin. That said, there are things to look for. Very much like trying to identify an illness however, many of these have alternative explanations and only experience will tell the handloader which ones are benign and which ones are not.

1. **Sticky extraction** - The shells don't extract easily from the gun. This is pertinent in any firearm except an autoloader. This is a decent sign of overpressure if
    a. The shells aren't known to be exceptionally soft cartridge brass. Soft brass will over-expand even at normal pressures and stick.
    b. Dirty chambers. This is self explanatory. Dirty chambers will cause the shell to stick.
2. **Case head and Primers**
    a. Overly Flattened - This is one of the most commonly quoted and is one of the least reliable on its own. There are a lot of reasons that a primer could appear very flat, even at very low pressure. However, if there is no bevel left and the primer is mashed flush with the rear of the case as seen here, this is an issue.

b. cratering/ flattening - This is one of those “you need experience” types of signs to look for as many times these are false positives. An example of true cratering is seen here:

This is a cratered primer.

However, sometimes this is caused by an overly large firing pin opening that lets the primer flow into it. Such as this:

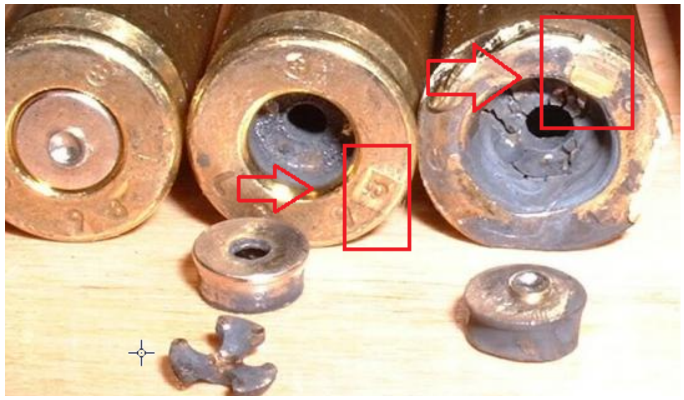


I wouldn’t call this an overpressure round. But a large firing pin opening. The differences are subtle but are present.

c. Pierced primers - When pressures get too high, the primer is driven rearward with so much force that the firing pin actually pierces it. Again, this has legitimate causes other than high pressure such as a firing pin which is too long or a very soft/wrongly chosen primer (like putting a small pistol primer in a .223 case). Or overly beveled primer pockets. This is however cause to examine your loads. If you get a pierced primer, that is a signal to stop shooting until you figure out what has caused it.

d. Blown primer - This one has fewer legitimate reasons. The only one that comes to mind is an overly beveled primer pocket. A blown primer 95% of the time is caused by serious overpressure. Before continuing anything, check the firearm and make sure it hasn't been damaged and STOP using those rounds. In the picture below we see two blown primers, the one on the right has not only blown the primer but severely enlarged the primer pocket. It would take huge amounts of pressure to do this (perhaps upwards of 100,000psi) to get brass to flow like silly putty.

e. Extractor groove/wipe - This is always a good earmark. Again, soft brass could cause this but it is a pretty solid indicator that the pressure is high enough to swage the case into the extractor groove. It shows itself as a negative of the extractor groove and, on a rotating bolt rifle, a clean brass wipe.



The last picture is a duplicate which makes a point. Very rarely do pressure signs show up by themselves. There are usually multiple pressure signs. When you see one, there is likely another to corroborate it.

A DISCUSSION ON BULLET CHOICES

One of the great things about handloading is that you are no longer stuck in a pigeon hole that a factory has loaded for you. That being said, now that you can stuff any bullet you want into a case and push it out the barrel at some speed, there is some terminology that is helpful in understanding so that you don't waste time and money trying to find a bullet that does what you want it to.

Every handloader has a favorite bullet for hunting big game, small game, varmint, plinking, etc. but the general concept is that most bullets fall into a narrow few categories

- **General plinking** - cheap target ammunition for punching holes in paper and bouncing a tin can around the range. These are usually FMJ (Full metal jacket), cast lead, or any other inexpensive bullet choice that allows you to feel comfortable turning your money into a tiny hole in some paper.
- **Self Defense:** These are usually a premium, hollow point bonded bullet designed from the factory to work well in a specific caliber. See below for description of bonded bullets.
- **Hunting** - There are many, many different sizes and types of game animals so there are many types of hunting bullets. There are broad categories and narrower definitions
    - Cup and Core - Also called CnC bullets. These are jacketed rifle or pistol projectiles and are the original jacketed bullet. A copper jacket with a lead core swaged into them. Many are fine for large game and some have the jacket mechanically locked to the core (Hornady Interlock, Remington Core Lokt) Others don't and function fine for lighter large game like whitetail deer. The issue that presents itself with these, is when they are driven to a high velocity, there is the possibility that they "splash" or explode, creating a large but superficial wound because the bullet didn't penetrate and blew up on the surface. This leads to wounded game and a lost animal sometimes. As such, it is my recommendation that impact velocities are kept under 2,700fps (rifle) or 1,500 fps (pistol) otherwise

weight retention can drop quickly depending on what is hit. Varmint bullets also fall into this category. The only difference is that they are *designed* to explode on impact, as penetration isn't really an issue on small animals.

- Premium Bonded - These come in a variety of choices. They are typically a lead core bonded to the jacket so the lead cannot separate (with the notable exception of the Nosler Partition which has a mechanical expansion arrester in it). Examples would be: Nosler Accubond, Swift Scirocco, Swift A-Frame, Woodleigh Weldcore, Federal Fusion, and more. These have very high weight retention (>80% in most cases) and most will penetrate heavy bone and sinew and reach the vitals from almost any angle, given proper caliber choice for the animal. Good for any impact velocity, but best if the impact velocity is over 1,800 fps (rifle) or 900fps (pistol) to ensure expansion. These are also some of the most expensive projectiles on the market today.

- Monometal: These are expanding bullets usually made from solid copper or "Gilding metal" which is a high content copper alloy. The noses peel back into a number of sharp petals and they penetrate the best for their weight, of any bullet. In fact, a hunter can step down in bullet weight a little compared to a lead equivalent because of the high weight retention and toughness of these bullets. They have nearly 100% weight retention and routinely pass all the way through game animals. The flip side to these is that the impact velocity must be very high. Above 2,000 fps for a rifle and above 1,050-1,100fps for a pistol to ensure that they expand. This limits a standard velocity rifle to shots inside about 250 to 275 yards. Examples would be the Barnes TTSX and TSX (rifle) and PBX (Pistol) series, Hornady's GMX and Cutting Edge bullets.

Terms used in bullets

- Spt/Sptz - Spitzer, a pointed bullet, usually soft nose
- RN - Round nose
- FMJ/FMC/MC - Full metal jacket
- SP - Soft Point
- RNSP - Round nose Soft Point
- BT - Boat Tail - For higher ballistic coefficient.
- LRN - Lead Round nose
- LRNFP - Lead Round Nose Flat Point
- HP - Hollow point
- Cannelure - The indented ring around the shank of a bullet to provide space to crimp the shell in, simultaneously it also crimps the core into a CnC bullet

Cannelured bullet

- Crimp groove - Similar to above

- Relieving bands - reliefs cut into a bullet shank to reduce bearing surface and reduce pressure and fouling

A discussion of bullets wouldn't be complete without talking about the little numbers usually present as specifications on every bullet you will buy. The Ballistic Coefficient, and the Sectional density.

Ballistic coefficient - A measure of how well the bullet flies through the air. A higher ballistic coefficient bullet will carry its speed and energy farther and will be less affected by wind. This is generally abbreviated B.C. and expressed as a decimal i.e. 0.433

Sectional density - A ratio of a bullet's weight to its diameter. The heavier it is for its diameter, likely it will have a higher B.C. and will penetrate better on impact. This is often abbreviated S.D. and is also a decimal. Bullets with a S.D. over 0.300 are typically seen as being suitable for the largest game on earth and penetrate into next week. Most large game bullets are in the .190 to .280 range, while handgun bullets and varmint bullets are generally lower than rifle bullets, but not always.

Bibliography:

1. Hiemerl, Joseph. “The Muzzle Flash of Guns and Rockets”. *U.S. Army Material Command.* December 1985. https://apps.dtic.mil/sti/citations/ADA164593