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## **TECHNICAL NOTE 110: PROJECTILE WEIGHT VERSUS RIFLING TWIST**

### **I. BACKGROUND:**

Our Marketing Department often receives calls asking what bullet weights we recommend in specific ArmaLite® firearms. Our Marketing Department responds to such requests with general guidelines.

However, in reality, projectile weight is only indirectly related to rifling twist rate. It is really the projectile's length and diameter that determine the rate of rifling twist needed to stabilize that projectile. And, the twist rate needed is affected by other factors including muzzle velocity and environmental conditions.

This Tech Note is intended to provide technically-minded shooters with more precise information regarding twist rate versus projectile stability.

### **II. FACTS FOR THE TECHNICALLY INCLINED:**

In 1879, George Greenhill, a professor at the British Royal Military Academy developed a rule of thumb formula to determine the minimum twist rate needed to stabilize any projectile. The formula, appropriately named the Greenhill Formula, has been found to be accurate enough that it is still used today. (For historical and background information on the formula, merely Google "Greenhill Formula." In the interest of time and space, I won't reiterate that background information here.)

His formula (simplified for lead core projectiles) is:

$$\text{Twist Rate} = C \times D^2 / L$$

Where:

--Twist rate is the slowest acceptable twist in inches per turn. ( Remember, a 12" twist is SLOWER than a 10" twist. The larger the number, the slower the twist.)

-- **C is a dimensionless constant (For muzzle velocities less than 1500 feet per second, we recommend 125 be used. For muzzle velocities between 1500 fps and 2800 fps, use 150. For muzzle velocities above 2800, use 180.)**

-- **D is the projectile diameter in inches**

-- **L is the projectile length in inches**

**(NOTE: Twist Rate, D and L can be expressed in any unit of measure as long as the same units are used for all.)**

Notice that the formula does not include projectile weight. Twist rate does not depend on projectile weight. It only depends on projectile length and diameter. Two projectiles with identical weight can require different twist rates. For example, a 150 grain pointed nose boattail projectile is longer than a 150 grain round nose flat base projectile. So, the pointed boattail projectile will require a faster twist than the round nose flat base projectile.

If you have a projectile, you can measure the length and diameter. You can use those dimensions to calculate the slowest twist that will stabilize the projectile.

However, it will probably be much more common that you will already own a rifle and you want to know the longest projectile that will stabilize in your rifle. In that case, you can merely restructure the formula as follows:

$$L = C \times D^2 / \text{Twist Rate}$$

Just to make certain that we understand, let's do a sample calculation. If you own a 7.62mm AR-10 with an 11.25" twist, the Greenville formula says that the longest projectile you could stabilize at 2600 fps muzzle velocity would be:

$$L = 150 \times (0.308^2) / 11.25 = 1.26"$$

It is important to note that Greenhill's formula is, in fact, only an approximate "rule of thumb". As such, it should not be taken to mean that any 1.26" long projectile will always be stable while every 1.27" long projectile will always be unstable. In fact, the formula is considered to be somewhat conservative. So, slightly longer projectiles will probably be stable under most conditions.

Likewise, the constant "C" in Greenhill's formula is only an approximation. Although we say that the constant changes from 150 to 180 at 2800 fps, it certainly makes sense that changing muzzle velocity from 2799 fps to 2801 fps would not mean that you could stabilize much longer projectiles. So, a little common sense is called for.

But, as long as we're talking about the constant "C", let's see how changing muzzle velocity can change the twist rate needed to stabilize a given projectile. As an example, let's use a 0.308" diameter, 1.3" long projectile fired at muzzle velocities of 1200 fps, 2500 fps, and 3000 fps. Greenhill's formula gives the following results.

@ 1200 fps, Twist Rate (min) = 9.1" per turn

@ 2500 fps, Twist Rate (min) = 10.9” per turn

@ 3000 fps, Twist Rate (min) = 13.1” per turn

So, for any given projectile, the higher its muzzle velocity, the slower the twist that will stabilize it. Lower muzzle velocities require faster twists.

It is also important to understand that projectile stability is affected by environmental conditions. It is air resistance that attempts to destabilize the projectile. Cold, dense air will require higher twist rates than warm, less dense air. Using Greenhill’s conservative formula should assure that your projectiles are stable in any environment.

So, you ask, why don’t we just build all rifles with a twist fast enough to stabilize any projectile regardless of its length? We don’t because, as my Harley-riding friend, Dr. Demento, used to say, “There Aint No Free Rides”. There are always tradeoffs. In this case, there are three significant tradeoffs.

--First, if you spin a projectile LOTS faster than is necessary to stabilize it, you actually overstabilize it, causing it to be somewhat less accurate than it could be with the proper twist. Certainly overstabilization is better than understabilization. But, for the very best in accuracy, the projectile should be adequately stabilized, not significantly overstabilized.

--Second, spinning the projectile places great stress on the rifling. The faster the twist, the more the stress. So, barrels with faster twists tend to wear out more quickly than barrels with slower twists.

--Third, some projectiles have relatively fragile jackets (notably varmint bullets). Spinning these projectiles too fast can cause the jackets to rupture in flight.

### **III. FACTS FOR THE TECHNICALLY DECLINED:**

If you’re easily bored or simply don’t care about the mathematical aspects of projectile stability, you may have skipped over Section II. If you did, there are still several things you need to know. Those things are:

1. Projectile stability is determined by the length and diameter of the projectile, not by projectile weight. Twist rate does not depend on projectile weight. It only depends on projectile length and diameter. Two projectiles with identical weight can require different twist rates if they have different overall lengths.
2. For any given projectile, the higher its muzzle velocity, the slower the rifling twist that will stabilize it.
3. It is the density of the air that attempts to destabilize a projectile. Cold, dense air requires a faster twist than does warm, less dense air.

For those of you who really only want to know the “bottom line”, here are four tables of twist rate versus bullet weight. These tables are based on pointed nose boattail projectiles because they are a “worst case” for projectile length to weight ratio. So any other

projectile shape of that same weight should easily stabilize. And the table assumes a muzzle velocity less than 2800 fps. And the table assumes cold, dense air.

The tables tend to be conservative. Heavier projectiles may stabilize in your rifle. If you really want to try heavier projectiles, don't let the tables stop you from testing them. If, on the other hand, you are satisfied with projectiles in the weight ranges listed below, you can be completely assured that they will be stable, even in worst case conditions.

Remember, heavier projectiles will stabilize if:

- they are flat base, and/or
- they are round nose, and/or
- they are driven at muzzle velocities above 2800 fps, and/or
- they are fired in temperate environmental conditions.

**TABLE I 5.56MM / 223 REMINGTON BULLET WEIGHTS**

- 1 Turn in 7" ----- 77 grains Max
- 1 Turn in 8" ----- 69 grains Max
- 1 Turn in 9" ----- 65 grains Max

**TABLE II 7.62MM / 308 WINCHESTER BULLET WEIGHTS**

- 1 Turn in 10" ----- 200 grain Max
- 1 Turn in 11.25" ----- 180 grain Max

**TABLE III 300 WINCHESTER MAGNUM BULLET WEIGHTS**

- 1 Turn in 10" ----- 200 grain Max

**TABLE IV .338 LAPUA BULLET WEIGHTS**

- 1 Turn in 10" ----- 300 grain Max

NOTE: In some cases, the tables above reflect the heaviest commercially available projectile. Heavier projectiles would also probably stabilize. But, without knowing their designs, we couldn't speculate.

