4.2 Historical use of projectile shapes

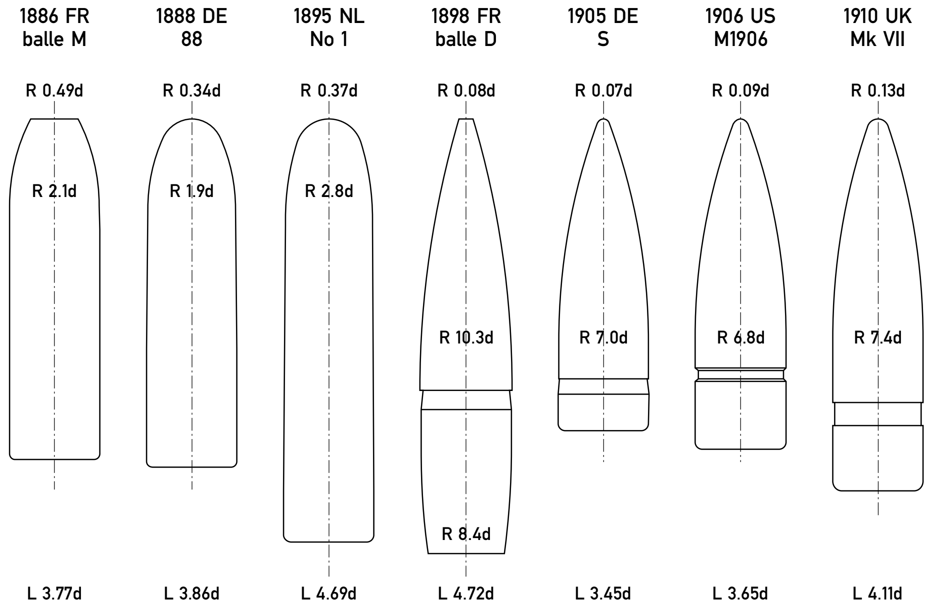

Figure 8: Historical use of projectile shapes - part 1

This section will describe historically important projectile shapes, starting with the first military rifle cartridge utilizing smokeless propellant and ending with the current 5.56 mm NATO, which was introduced about three decades ago.

Air drag is dominated by projectile *shape*[1]. To make comparisons easier, all drawings are scaled to the same diameter. The dimensions are expressed in multiples of diameter.

Each drawing is accompanied by several numbers: the one in front of the **tip** gives the **tip radius**, which is the radius of the ball shaped rounding or the flat surface (*meplat*) at the tip.

The number **inside** the projectile outline, close to the base line of the nose, describes the **ogive radius**.

In case the projectile does not have a straight base, the number at its **rear** gives the boattail angle, which is half the included angle of the cone. For balle D, which has an ogive shaped rear, the ogive radius is given.

The number *below* the rear of the projectile is its length.

[1] Stability is also very important. It will be discussed later.

The data shown is not set in stone, because bullets are manufactured with tolerances. Even sources considered reliable may contain different values.

To put bullet development into perspective beyond the naked numbers, on the following pages I attempt to describe shortly the historical path that led to the current NATO bullet.

1886

France was the first country with a militarily usable propellant made of nitrocellulose. It was developed by *Paul Vieille* (1854-1934). The rifle bullet of 8 mm calibre used in the new cartridge had a large meplat. At the time, this was not considered as a noticeable disadvantage in terms of air drag. The first jacketed bullet developed by Swiss mechanical engineer *Hebler* also had such a large meplat. [189, Tafel I] Hebler even disputed any disadvantage based on his trials. [189, p. 25]

1888

Germany followed with a 7.9 mm cartridge, after professor *Carl Scheibler* (1827-1899] had been able, based on specimens of the French propellant, to find out how the French did it. [344, p. 547, 597] It may be surprising that a scientist specializing in sugar chemistry was able to unveil the French secret. But cellulose is chemically a kind of sugar. This, by the way, is the *real* origin of German military smokeless propellant. The often cited R.C.P (*Rottweiler Chemisches Pulver*; partly nitrated wood) by *Max Duttenhofer* (1843-1903) was a dead end and not usable for the new German cartridge. The entire R.C.P. production line at Rottweil had to be dismantled and a new one for nitrocellulose propellant erected.

1895

As an example of the round nosed bullets of the time, the Dutch projectile is shown. Due to its smaller calibre of 6.5 mm, it is relatively longer to keep up the sectional density. Especially the armies in northern and southern Europe chose this calibre, as did Japan.

The European central powers France, Austria-Hungary and Germany chose bullet diameters above 8 mm. Their neighbours in the west (United Kingdom, Belgium) and the east (Russia) selected bullet diameters around 7.9 mm (calibre designations .303 inch or 7.7, 7.65, and 7.62 mm). Spain and Serbia adopted 7.2 mm bullet diameter (calibre 7 mm). The economically important but militarily insignificant United States chose calibre .30 with a bullet diameter of 7.8 mm. All cartridges had round nose bullets.

1898

France's second breakthrough after the new propellant was the introduction of a revolutionary projectile design based on aerodynamic considerations. As in Paul Vieilles approach to internal ballistics, it was the systematic planning and execution of experiments, this time by captain *Georges Desaleux* (1851-1937), that led to success. Triggered by reports about a boattailed artillery projectile by *Whitworth* and another

with a slender nose by *de Bange*, Desaleux embarked from 1894 to 1896 on systematic shooting trials at Versailles.

It turned out that best results were obtained with noses as slender as possible and a boattail that was a truncated ogive. The meplat at the tip should be kept as small as possible. As the very close tolerances on the drawings for balle D prove, great emphasis was put on its shape. [104] For us today it is most interesting that it was already recognized by the French that the transition between the truncated ogive (or boattail) and the rear surface should be a sharp edge ("arètes vives"). Looking at modern designs, this nearly 120 years old insight seems all but forgotten.

Analysis of the trials led to a design with a nose length of 2.5*d*, a shank spanning 25 percent of the entire length and an ogival shaped boattail. *Atelier de Puteaux* then produced five different bullet types, designated A through E, which had an identical shape but were made from different materials, resulting in different masses.

Design D, with a mass of 13.2 g, turned out to be the best combination of ballistic properties, compatibility with well used barrels, and suitability for mass production.

Following an initiative by captain *Arthus*, experiments with a longer nose of 3.0*d* were made. After solving some problems, the French in January 1898 arrived at the final balle D of 12.8 g with an enlarged diameter of 8.3 mm (Figure 8).

The origin of balle D as described here is taken from [74, p. 366-369], published in 1935. Keeping everything secret was so effective that even in France no more details are known today[2].

The new smokeless powder made a much faster velocity possible compared to gun powder. As we know today, at high velocities the wave drag becomes dominant. The slender nose of balle D in this situation has much less drag than the round nosed bullets of the time. The boattail reduces base drag, which especially at lower velocities is the dominating factor of total drag.

Because nose as well as base of balle D have an ogival outline, boattailed bullets are called *bi-ogival* in France and in Russia. This name is still in use, even for modern designs which have a truncated *cone* boattail.

Balle D is not made of a jacket and a lead core (*full metal jacket*, FMJ) like its predecessor, but entirely of gilding (brass with 90 percent copper). The steps of manufacture, as described in [170], are very different from the conventional drawing process for a typical FMJ. In Germany, traditionally short on copper, the generous consumption of this metal created much astonishment.

1905

Around the time French balle D went into production in 1901, apparently Germany got wind of it earlier than other countries. Instead of plainly copying it, a different approach was chosen. While balle D was significantly lighter (12.8 g) than its predecessor (15 g), the Gewehr-Prüfungskommission decided to use a bullet that

[2] In France it is suspected that the Germans after 1940 removed all documents to Germany, where they perished later in the war.

was another third lighter (10 g). This allowed an extremely high muzzle velocity[3] for the time. The nose was not quite as slender as that of balle D. Because of the small mass, there was no room for a boattail.

The light, fast German *Spitzgeschoss* (S bullet) had a flatter trajectory than balle D up to about 800 m. Beyond this range, the small mass took its toll and balle D was superior. The German military expected the decisive actions in battle at distances below 800 m and decided in favor of the S bullet. [127, p. 204]

In figure 8 the S bullet is shown with the crimp groove that it got during World War 1. Its purpose was to make the seating of the bullet in the case more robust.

Thanks to French secretiveness, international observers gave the S bullet the credits of innovation that really should have gone to balle D.

1906

The German approach of using a light bullet with a tangent ogive of about $7d$ was followed by a number of armies. The U.S. Army for example threw its brand new round nose cartridge (known as .30-03) for the M1903 rifle over board and adopted a light pointed bullet designated M1906. This cartridge, known worldwide by its civilian designation .30-06, is still popular today. Russia adopted a very similar bullet in 1908 (called L bullet).

When France in the mid-twenties decided to find a successor to its 8 mm cartridge, the new 7.5 mm cartridge (bullet diameter 7.8 mm) was also given a light pointed bullet. [210]

It is remarkable that those armies which used calibre 6.5 mm *stayed* with the round nose bullet shape mostly as long as they used this calibre. Notable exceptions are Japan (already 1905!) and Sweden (as late as 1941).

1910

The British Army made the switch to a light pointed bullet in 1910. A difference from the designs mentioned so far was the use of an aluminium core that filled the front half of the jacket. This moved the center of gravity back, making the bullet less stable once it entered the body of an enemy. The bullet mass was 10.4 g. When first adopted, this design showed accuracy problems. [245] To correct this, the aluminium core was made smaller, increasing the mass to 11.3 g. This was the Mark 7 cartridge[4] as used in both World Wars.

1911

The Swiss did not follow the popular approach of the time, but instead went along the lines of the balle D. The new cartridge *Gewehrpatrone 11* (GP11) was introduced in 1911 together with a new rifle and the first Swiss machine gun.

Unlike balle D the Swiss GP11 bullet was a conventional design of lead core and jacket. Instead of an ogive shaped boattail it has a truncated cone as is usual today. [371]

[3] 895 m/s according to official firing tables, [123, 185] but in reality about 870 m/s. [92, 94, 423]

[4] Before 1945 Roman mark numbers were used: Mark VII.

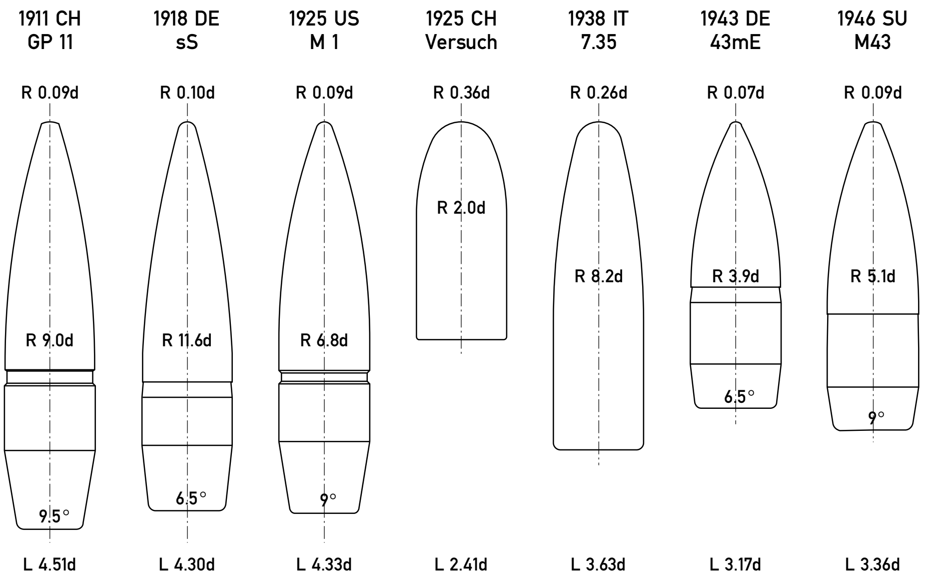

Figure 9: Historical use of projectile shapes - part 2

1918

The First World War brought about the rise of the machine gun. With the development of trench warfare, machine guns were used at ever increasing ranges. Eventually highly specialized troops were trained to use machine guns in artillery fashion for indirect fire at extreme ranges from defilade positions. This required highly trained operators.

Nobody had expected this application of machine guns before the war. The light pointed bullets used by Germans, Britons, Russians and Americans were not really up to this task. For example, the Americans were taken by surpise that the M1906 bullet would have a real range of only 3.1 km instead of the predicted 4.3 km. [181, p. 19] Balle D was better suited for the purpose and the Germans adopted a similar design of the same mass (12.8 g), called *schweres Spitzgeschoss* (sS, heavy pointed bullet). It had a more slender nose than balle D. The cone angle of the boattail is even today the smallest in standard use.

I suspect that the Germans developed the sS bullet as soon as they received information about the technical details of balle D. Because, if any specimens of balle D were available, they certainly were not enough for a firing trial program. Also, the solid gilding design was out of the question for Germany. So the natural thing, in my view, would have been to develop a conventional FMJ bullet along the lines of balle D. This could be used for ballistic tests. There is no proof for this assumption,

only an indication in [127, p. 202].

1925 US

While before the First World War the machine gun had not been taken seriously by military authorities, after the war the pendulum swung fully. Requirements for machine gun fire at extreme ranges became the basis of ammunition development. Some armies dropped light pointed bullets entirely and adopted cartridges with heavy, aerodynamically better bullets along the lines of balle D, GP11, and sS. In the U.S. Army the M1 bullet shown in figure 9 replaced M1906 in 1925. Nose shape is identical for both, but the M1 has an additional boattail. Germany did the same in 1930 by adopting the sS bullet as standard for rifle and machine gun. Finland followed in 1936 by adopting the heavy D166.

The U.S. Army was not able to stick the M1 out and in 1940 decided to return to M1906, which was now called M2. So only Germany and Switzerland managed to keep a single round for rifle and long range machine gun. Finland was attacked in 1939 by the Soviet Union and had more pressing problems than its peacetime ammunition plans.

Several armies kept the shape of the cartridge case for rifle and machine gun, but used a special load for the latter. Because France was not able to complete the changeover from 8 mm to 7.5 mm between the wars, it introduced an 8 mm model 32N and a 7.5 mm model 33D. The Soviet Union in 1930 adopted a cartridge named D. The British Army in 1938 chose a cartridge named Mark 8z (the "z" hints at a propellant charge of nitrocellulose instead of cordite and has no relation to the bullet). Practically nothing is known about the Polish cartridge D (for *dalekonośnym*, far-reaching) of this kind. [164] It had a still heavier bullet (13.75 g) than the German sS cartridge utilizing the same case.

Especially armies which had 6.5 mm rifles went so far as to introduce new, powerful cartridges for machine guns. The Netherlands rebuilt its 6.5 mm Schwarzlose machine guns for a 7.9 mm rimmed cartridge. Norway, Sweden, and Italy chose entirely new cartridges in 8 mm calibre which were significantly more powerful than the German 7.9 mm (for example, Sweden 14.2 g at 760 m/s).

During the Second World War, it turned out that there had been practically no use of machine guns in an indirect fire role. Mortars took over the role as *artillery of the infantry* and were much more effective at it. Long range machine gun cartridges disappeared after 1945.

1925 CH

The next projectile in figure 9 represents a totally different conclusion from infantry combat in the First World War. The machine gun had taken over firing at mid and long range targets. As a consequence, the soldier no longer needed a rifle designed for musketry: strictly directed fire by all members of a unit at targets 1000 m away. Instead, the soldier used his rifle at ranges up to about 300 or 400 m. A less powerful cartridge, making possible a much shorter and lighter rifle, and allowing better