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Density Characterization of Armor Piercing Ammunition

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ABSTRACT: A 1986 Federal law regulates the manufacture, importation, and sale of armor piercing ammunition. The external appearance of various types of armor piercing ammunition are described, along with a method of density determination that will assist in distinguishing armor piercing ammunition from conventional ammunition.

KEYWORDS: criminalistics, armor piercing, projectile, density, ammunition

In the Fall of 1986, Public Law 99-408 was signed into effect by the President. This law regulates the manufacture, importation and sale, (but not mere possession), of armor piercing ammunition, and was enacted because of the purported proliferation of the use of this type of ammunition during the commission of crimes. The act also amends the United States Code, chapter 44 of title 18 by defining the term "armor piercing ammunition" as "a projectile or projectile core which may be used in a handgun (*sic*) and which is constructed entirely (excluding the presence of traces of other substances) from one or a combination of tungsten alloys, steel, iron, brass, bronze, beryllium copper, or depleted uranium" [*1*].

Although the tone of this statute is more regulatory than penal, the enforcement of the statute will necessarily call upon the expertise of someone within the forensic science community to determine whether a particular projectile falls under the purview of the law. Firearms examiners in particular may wish to be familiar with the various armor piercing projectiles that may be encountered and that may be covered by this statute. As of the time of the passage of this law, no fewer than eight types of armor piercing projectiles of various calibers were available. In response to the anticipated demands that will be placed on forensic scientists to identify armor piercing projectiles, we have compiled information describing these projectiles and various methods that can be used to determine whether an evidence cartridge may be classified as "armor-piercing." It should be clearly recognized that not all armor piercing ammunition is covered by Public Law 99-408; ammunition for which no handgun is manufactured would be excluded under the wording of the statute.

In the initial implementation of Public Law 99-408, the Bureau of Alcohol, Tobacco, and Firearms (BATF), in their Circular No. 86-15, dated December 4, 1986, listed a number of projectiles as falling within the scope of the law [2]. This list is as follows:

1) KTW ammunition, all calibers
2) ARCANE ammunition, all calibers
3) THV ammunition, all calibers
4) Czechoslovakian manufactured 9mm Parabellum ammunition having an iron or steel bullet core
5) German manufactured 9mm Parabellum ammunition having an iron or steel bullet core
6) MSC .25ACP caliber ammunition
7) Black Steel Armor Piercing Ammunition
8) Black Steel Metal Piercing Ammunition
9) 7.62 NATO AP[4]
10) 7.62 NATO SLAP[4]
11) 7.62 × 39 Steel Core Ammunition[5]

It should be recognized, however, that it is Public Law 99-408 that defines an armor piercing cartridge, not the BATF Circular, and the BATF list is not intended to be exhaustive.

Materials and Methods

Although most of the armor piercing projectiles used in this study are by their very nature distinctive and fairly easy to identify in their undeformed state, the forensic scientist may have occasion to identify one of these projectiles in either an altered, deformed, or fragmented condition. This would necessitate using other than simple visual inspection of the projectile to effect the identification. The authors therefore have investigated three simple methods for identifying such projectiles: (1) visual inspection; (2) ferromagnetism; and (3) density determinations.

Visual Identification

Conventional identification of U.S. military armor piercing (AP) ammunition is facilitated by the color coding on the tips of the projectiles. For example, black is used to designate AP, silver to designate AP-Incendiary (API) and red/silver to designate API-Tracer (API-T) [*3*]. Some civilian handgun AP ammunition is also color coded, (for example, the .38 Special KTW, which has a green teflon coating), but most is not. Additionally, paint markings may

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[4] The 7.62 NATO AP and the 7.62 NATO SLAP cartridges are of course primarily rifle cartridges, and the wording of Public Law 99-408 seems to address only those armor piercing projectile that may be used in a *handgun.* They are included in the BATF Circular No. 86-15, however, by virtue of the fact that they may be fired in the Remington XP-100 and the Pachmayr Dominator handguns.

[5] Added by a memorandum from the BATF dated February 2, 1994.

be easily removed by washing with solvents or scraping. This imposes a limitation to the extent upon which a visual inspection of the ammunition may be relied. A number of the armor-piercing cartridges described in the ATF circular are illustrated in Fig. 1, and are described in further detail as follows.

KTW (Kopsch-Turcus-Ward)—The KTW bullet can be visually identified by its brassy yellow color. It is also covered by a green teflon coat that can be easily scraped off to see the brass beneath. This actually is the third generation of this bullet. Originally the KTW bullet was composed of what was called "kennertium," which was described by the manufacturer as a tungsten alloy. This was gray in color and covered with a green Teflon coating and a copper alloy half jacket that covered the bearing surface and the base. The second generation of the KTW bullet was a hardened tool steel projectile.

Arcane—The peculiar shape of this projectile is quite helpful in its identification. The ogival section has a concave-conical shape. Its bronze composition may give it a copper color. The body of the projectile is hollow.

THV (Tres Hante Votesse)—This projectile shares a shape that is quite similar to the ARCANE ammunition. It has a concave-conical ogive which typically ends in a blunted cylindrical point. This projectile is also hollow and has a yellow brass color. The headstamp contains the letters THV and SFM.

Czech 9 mm Parabellum—This projectile has a copper/nickel jacket. The cartridge headstamp would be marked with a triangle, a star, and the dates 49, 50, 51, or 52.

German 9 mm Parabellum—This ammunition has an iron or steel core. The original packaging is marked Pistolenpatronen 08 m.E.

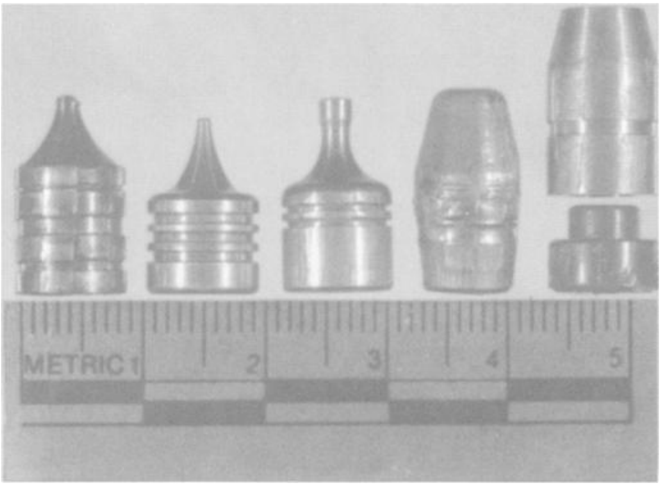

FIG. 1—*Common armor piercing handgun projectiles. From left to right, the projectiles are, respectively: Arcane, P+THV, THV, KTW, and PMC. (The PMC projectile on the far right is the PMC "Ultramag Tubular Bullet." It is unclear whether this bullet was ever produced in brass. The cartridge is no longer in production, but the 1989 manufacturer's brochure states that the bullet is 99% copper, seated on a Teflon pusher wad to make a tight gas seal. While copper projectiles are excluded from both Public Law 99-408 and the BATF circular #86-15, there would seem to be some confusion concerning this bullet. In 1987, the BATF listed this cartridge as one of the prohibited types. The current .38 Special PMC Ultramag ammunition is not armor piercing, and has a copper projectile. The stock designation for the Ultramag ammunition that is not armor piercing is 38J SPL+P66 THP (Ultramag).*

MSC .25 ACP—This bullet was initially made of bronze and had a hollow point. To comply with Public Law 99-408, however, the MSC (Maximum Sub Caliber) cartridge distributed by Personal Protection Systems Ltd. of Moscow, Pa., was subsequently changed to copper.

Black Steel Armor Piercing Ammunition—Manufactured by National Cartridge, Atlanta, Georgia.

Black Steel Metal Piercing Ammunition—Manufactured by National Cartridge, Atlanta, Georgia.

7.62 NATO AP—This bullet looks quite similar to a standard .308 cartridge, but the bullet is significantly longer. Following the convention for U.S. military cartridges, the bullet typically has a black coloring on the tip which signifies that it is of the armor piercing type. The U.S. military designation is MP61 AP.

7.62 NATO SLAP—This bullet is comprised of a ~.22 caliber tungsten alloy penetrator surrounded by a plastic sabot. Upon a casual inspection, this cartridge may be easily confused with the Remington Accelerator cartridge. The density of the penetrator, however, is nearly 14 g/cm^3.

7.62 × 39 Steel Core Ammunition—In February 1994 the BATF issued an advisory directive to all federal firearms licensees concerning this ammunition. The BATF had previously allowed the importation and commercial resale of 7.62 steel core ammunition based on the understanding that there were no handguns capable of chambering this ammunition. With the introduction of such firearms, the ammunition then came under the provisions of Public Law 99-408.

Most, but not all, of the armor piercing cartridges that are likely to be encountered are military cartridges. Many governments have produced armor piercing ammunition for their respective armed forces. These cartridges, regardless of how obscure they might be, will certainly be covered by the new legislation. In recognition of this fact, Table 1 attempts to summarize the markings that various governments have placed on their armor piercing ammunition. This is not a tidy subject, however, and the reader is referred to Hogg [*4*], Labbett [*5*], and Huntington [*6*] for additional details and certain frustration.

Ferromagnetism

Many armor piercing projectiles have either steel or iron components. The presence of ferromagnetic components is a good but not absolute indication of the armor piercing capability of an unknown projectile. The following projectiles have ferromagnetic components and would therefore be attracted to a simple magnet.

Czech 9mm Parabellum AP
German 9mm Parabellum AP
Black Steel AP
Black Steel MP
7.62 NATO SLAP

However, the presence of ferromagnetic components does not guarantee the classification of the projectile as armor piercing.

TABLE 1—*Government markings of armor piercing ammunition: AP - Armor piercing; API - Armor piercing/incendiary; APIT - Armor piercing incendiary/tracer; APT - Armor piercing/tracer.*

Country	Type	Bullet Tip	Headstamp	Primer Annulus
NATO countries	AP	Black		
	API	Silver		
Former Warsaw Pact countries	AP	Black		
	API	Black/red		
	APIT	Violet/red		
	APT	Violet (obsolete)		
	API	Black with red band		
	API	Violet with red band		
United States follows NATO, plus	APIT	Red/silver		
Israel	AP	Black		
	API	Blue/black		
	APIT	Blue/red/black		
Egypt	API	Diagonal blue stripe with black and red triangles		
Finland	AP		PS	
	AP	Blue		
	API	Black/red		
Czechoslovakia follows former Warsaw Pact, plus	AP	White (obsolete)		
India	AP		W	
Turkey follows NATO, plus	AP		W	
	APT		FG	
	APT		WG	
China	API	Black		Black
	API	Black/red (obsolete)		
	APIT	Violet		
	APIT	Violet/red (obsolete)		
Spain	AP	Black		
	API	Black/gray		
	APIT	Red/gray		
Argentina	AP			Black
	API			Silver
	AP	Red		Red
	APT			Black
	APT	Green		Green
France	AP	Black		
	API	Silver		
	APT	Black/red		
	APIT	Silver/red		
Iran	AP	Black		
	API	Blue/black		
	APIT	Blue/red/black		
Japan, WWII	AP	Black case mouth		
	AP			White
Germany, WWII	AP	Black bullet		Red
	AP			Red
	AP			White
	API			Black
United Kingdom follows NATO, plus	AP		W (obsolete)	
	AP			Green (obsolete)

A number of new projectiles which are not true armor piercing cartridges have iron or steel components. A case in point is the Soviet AK-74 (5.45 × 39) bullet. This bullet is composed of a steel penetrator topped off with lead alloy. This bi-component penetrator is jacketed with steel which is coated with copper and zinc. Although there is a significant amount of steel in the projectile, it is not intended to be armor piercing; it would nevertheless be attracted to a magnet. This particular cartridge would not fall under Public Law 99-408 because no handgun is presently available which would chamber it, but at such time that a handgun is produced which would chamber the cartridge, this ammunition would then come under the law.

Density Measurements

The determination of the density of bullet components is a quick and simple test that can, in most instances, distinguish between armor piercing and conventional ammunition.

Ordinarily, most bullets that are associated with a criminal investigation are either lead, or lead core with a copper jacket. As these bullets are usually lead alloys rather than pure lead, their densities vary somewhat from that of pure lead. Armor piercing projectiles, on the other hand, fall into a distinct range of densities below those of the lead alloy/jacketed projectiles.

These data were obtained using simple density measurements by means of Archimedes Principle.

The protocol is presented as follows:

1. Bullet preparation
   a. Extract the bullet from cartridge case using an inertial bullet puller.
   b. Clean the bullet with hexane or 95% ethanol.
   c. Dry the bullet and allow it to come to room temperature.
2. Water preparation
   a. Add 1 drop of Sigma wetting solution (polyoxyethylene sorbitan monolaurate No. P-1379, (Tween-20) to 1000 mL of double distilled water.
   b. Allow the water to come to room temperature.
3. Volume determination of bullet
   a. Fill a 25 mL buret with an adequate volume of the prepared water.
   b. Dislodge any surface bubbles and allow water to stand 1–2 minutes.
   c. Record water volume.
   d. Immerse the bullet in the water in the buret.
   e. Dislodge any bubbles which may have formed and allow to stand 1–2 minutes.
   f. Record volume of displaced water in buret.
4. Bullet weight determination
   a. Weigh bullet on analytical balance.
5. Density determination
   a. Calculate specific gravity by Specific gravity = weight of bullet/weight of equivalent volume of displaced water.
   b. Convert specific gravity to density by Density = Specific gravity × Density of water at the temperature of the determination.

Conclusions

As indicated in Table 2, lead occupies a relatively unique position with respect to the elemental densities of alloy constituents. Lead is approximately 1.2 g/cm^3 more dense than molybdenum, and

TABLE 2—*Elemental density of bullet-forming metals* [7].

Element	Density(g/cm^3 @ 27°C.)
Beryllium	1.85
Aluminum	2.70
Iron	7.86
Nickel	8.90
Copper	8.96
Lead	*11.4*
Uranium (depleted)	18.90
Tungsten	19.3

about 7.5 g/cm^3 less dense than uranium.[6] This thereby establishes a comfortable zone of demarcation between lead and other AP alloy constituents.

Similarily, in reviewing the density of bullet lead and comparing it with the density of AP alloys, as seen in Table 3, a zone of density demarcation once again appears. The density of typical projectile lead alloy is 1.9 g/cm^3 more dense than the lower proximal alloy density (leaded-tin bronze), and 5.75 g/cm^3 less dense than the upper proximal alloy density (89.5%W-3%Ni-3%Cu-1.5%Fe-3%Mo tungsten alloy). Consequently, with this in mind, and in view of the fact that most of the volume of a typical non-AP projectile, (whether it is jacketed or not), is composed of lead or lead alloy, the authors analyzed various types of AP and non-AP small-arm projectiles to determine if such a demarcation actually exists. The results of the density determinations conducted on armor piercing and other ammunition is indicated in Table 4.

A zone of density demarcation separates conventional projectiles from AP projectiles. Armor piercing projectiles may be *harder* than conventional projectiles, but most AP projectiles will be *less dense* than lead. In the ammunition examined in this study, only one exception was found.[7] The one exception, the 7.62 NATO SLAP with a tungsten alloy penetrator, has a density significantly *greater* than conventional ammunition. Conventional non-AP projectile densities fall within the range of 9.963 g/cm^3 to 11.13 g/cm^3. While density determinations appear to have considerable utility in this context, it is the position of the present authors that density measurements are a good indicator, but cannot serve as a sole indication of whether the ammunition is composed of materials

TABLE 3—*Alloy densities* [8–10].

Alloy	Density (g/cm^3 @ 18°C.)
Irons	5.5 to 8.77
Steels	7.75 to 8.19
Beryllium copper	8.23
Brasses	8.40 to 8.95
Bronzes	7.50 to 9.30
Lead (1% to 4% antimony)	11.2
Tungsten	
Of Divalent Metals	7.69
Carbides[a]	15.5 to 15.7
89.5W-3Ni-3Cu-1.5Fe-3Mo (Lowest in series)	16.95
95W-3.5Ni-1.5Fe (Highest in series)	18.00
Uranium (depleted)	18.70 to 19.08

[a] By definition carbides are not alloys, but they may be encountered in some armor piercing ammunition.

TABLE 4—*Densities and descriptions of projectiles measured.*

Description	Density (g/cm^3)
Armor Piercing	
5.45 mm AK 74, Russian, steel penetrator surrounded by lead, surrounded by iron alloy, jacketed in copper.[a]	7.21
5.56 mm M-855, U.S., steel tipped penetrator with lead body, jacketed in copper with green coated tip.[b]	9.01
6.5 mm AP, Japanese WWII, lead core, brass jacketed with copper wash.[c]	9.25
7.62 mm NATO AP, steel penetrator, lead cap, complete copper jacket, black tip, DM 42.	8.04
7.62 mm NATO AP, steel penetrator, lead cap, complete copper jacket, black tip, SL 43.	8.00
7.62 mm NATO AP. steel penetrator, lead cap, complete copper jacket, black tip, LC 53.	7.87
7.62 mm NATO SLAP, tungsten alloy penetrator.	13.71
8 mm Mauser, German, WWII, steel penetrator with copper jacket.[c]	8.20
.38 Special THV, solid brass, double grooved.	8.00
.38 Special THV, solid brass, triple grooved.	8.00
.38 Special Arcane, red brass or bronze.	9.12
.38 Special KTW, steel penetrator with copper base and green teflon coated tip.	7.64
.38 Special KTW, solid brass with green teflon coated tip.	8.17
.38 Special PMC, solid brass cylinder with removable blue plastic plug in base.	8.60
Jacketed with Lead Core	
Copper Jacket	
5.56 mm, U.S. Govt., Twin Cities, 1969, 55 gr	10.21
.30 Homady projectile, boat tail, 150 gr	10.22
.30 Luger, Remington-Peters, 93 gr	10.98
.30 Luger, Western, 93 gr	9.96
.30 Mauser, Western, 86 gr	10.14
.32 Short Colt, Winchester-Western, 80 gr	10.46
9 mm Hornady projectile, FMJ, 124 gr	10.53
9 mm Israeli CARB, black coated tip, 115 gr	10.63
.357 Magnum, Winchester Super-X, 158 gr	10.84
.38 Sierra projectile, pistol silhouette, 170 gr	10.50
.380 Auto, WRA, 95 gr	10.22
.38 Auto, Remington-Peters, 130 gr	10.55
Nickel Jacket	
.380 Auto, UMC, 95 gr	10.28
.380 Auto, Remington UMC, 95 gr	10.26
.380 Auto, WRA, 95 gr	10.55
Lead Alloy	
.32 S&W, Remington-Peters, 85 gr	10.37
.357 Magnum, Remington-Peters, 158 gr	10.76
.38 Smith & Wesson, Remington-Peters, 145 gr	11.13
Tracer	
5.56 mm French FAMAS TRACER, red tip	7.72
5.56 mm U.S., orange tip	7.13

[a]This cartridge poses some problems in how it is to be considered. It has a ferromagnetic core but is not truly intended to be an armor piercing cartridge. The cartridge would not seem to be covered by Public Law 99-408 because it is not chambered in any known handgun. However, while it may not be considered by military authorities as a true armor piercing design, it is nevertheless capable of penetrating some types of armor by virtue of its design.

[b]This cartridge is specifically excluded, however, from Public Law 99-408 by the 1987 BATF update to Circular 86-15.

[c]This cartridge is most definitely an armor piercing cartridge. It would not, however, be considered as armor piercing under the wording of Public Law 99-408 or subsequent BATF circulars.

[6] Depleted uranium has not thus far been introduced in handgun ammunition, but it is used in large caliber ammunition for some crew-fed weapons and may eventually migrate to smaller ammunition sizes.

[7] The present authors have not had an opportunity to examine a specimen of the *original* KTW cartridge, which is reported to have been made of tungsten. If that is the case, it would probably represent another exception. The current KTW projectile is brass.

used in the construction of AP projectiles. It may in some instances be necessary to cross-section the projectile and examine the entire configuration, including the core, to definitively identify AP handgun ammunition; construction and design of the projectile may include features that cannot be discerned through density determinations alone.[8] Although some AP projectiles (for example, .38 Special THV, .38 Special Arcane) reviewed in the present work can be identified by gross morphological inspection, there are a number of AP projectiles which sufficiently resemble conventional projectiles to the extent that some confusion may ensue. Furthermore, there are some non-AP projectiles (for example, 9 mm Israeli CARB with black coated tip) which may be confused as AP using the U.S. military color coding system, but which may be correctly excluded as non-AP by the density characterization method.

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[8] Although rare, projectiles manufactured from essentially pure copper (density 8.96 gm/cm^3) and alloys of copper and zinc (density 7.14 g/cm^3) are not unknown. However, copper and zinc components are not addressed by Public Law 99-408 or the BATF circular.

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