LAW ENFORCEMENT MANAGEMENT INSTITUTE

FIREARMS COMPARISON EVIDENCE

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OF THE REQUIREMENTS FOR
MODULE III

BY

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INTRODUCTION

Firearms have been known to create reliable comparison evidence on casings and bullets since the 1920's. The uniqueness of individual firearms is imparted to both bullets and cartridge casings in a way that makes the related evidence as singular and unique as a person's fingerprint. Some authors of forensic journals and investigative manuals have even referred to firearms as leaving a "fingerprint" on casings and bullets each time they are fired.

In 1925, Dr. Calvin Goddard, one of the pioneers of modern firearms identification, wrote an article entitled "Forensic Ballistics" that described the use of the comparison microscope in firearms examinations. Since that time, the term "ballistics" has been synonymous with firearms identification. Ballistics, strictly defined, is the study of the motion of projectiles, and has very little to do with firearms identification. Dr. Goddard later regretted having invented this popular name for firearms examinations because of the misunderstandings it produced in the minds of people who were appointed to consider firearms evidence at trial. Firearms evidence is created as a direct result of ballistic actions both inside and outside the firearm; however, the study that is undertaken to identify a firearm has less to do with the motions of projectiles than the markings produced on them. In later chapters of this writing, interior ballistics in rifled firearms and exterior ballistics in shotguns will be briefly discussed.

Today, the scientific validity of firearm comparison evidence is universally accepted without contest. However, the criminal investigator and crime scene technician will be concerned with the evidentiary validity of the evidence, and how definitive and conclusive it is when presented in court. Before the criminal investigator can appreciate the value of firearm comparison evidence in the prosecution of his cases, the questions of how the evidence is created and why it is unique to a particular firearm must also be explored and explained.

Evidence is of little value if it fails to support or prove the facts of the criminal prosecution under consideration. Therefore, a logical complement to a discussion of the scientific validity of firearms comparison evidence is the addition of discussion relating to the forensic value of the evidence, or how it performs "before the court". The resulting product of this endeavor is a combination of the scientific as well as the legalistic viewpoints on this subject. Citing case law where firearms comparison evidence was used successfully will undoubtedly spur the imagination of the investigator to envision how the evidence he may possess in a given case may also be used successfully.

It is the aim of this research study to not only provide the criminal investigator with a valuable investigative tool, but to also make a source of information available to the police trainer, who is responsible for the delivery of knowledge and information to other personnel within the agency. This research study will also be a benefit to the police manager who constantly strives to make his agency as effective and efficient as possible within existing budgetary constraints.

CHAPTER 2

FIREARMS MANUFACTURING TECHNIQUES

Firearms have been referred to as machines for controlling the application of force which propels the bullet, or shot charge through the air.[1] Since the earliest firearms designs were implemented and proven, arms makers have tried to refine and improve the performance of the firearm machine. These improvements have brought about the myriad of styles and models of firearms that are currently in production today. Nearly all of the innovations that were applied to the firearm were intended to improve its effectiveness and utility for the military. For example, rifling was added to barrels to increase effective range and accuracy; breech-loading actions were developed to facilitate greater speed and ease of reloading, as well as enhance accuracy; repeating actions were developed to enable multiple shots before reloading the firearm. It is conceivable that the firearm would not have evolved into its present form without the military's application of its function.

Firearm Components

All successful firearm designs possess the ability to initiate the combustion of a propellant, control the energy of the expanding gases and apply that energy to propel a projectile along a calculated trajectory at a relatively high velocity. The simplicity or complexity of the design does not alter this basic functional requirement. To accomplish this, all modern cartridge-firing firearms will have similar basic components that are designed to accomplish this fundamental function.

Breech - The breech is the part of the firearm designed to seal the rear of the chamber, preventing rearward movement of the cartridge and powder gases at the moment of firing. The breech is either permanently or temporarily affixed to the barrel at the moment of firing and withstands the physical forces generated by the firing of the cartridge in the chamber. The breech also contains a hole through which the firing pin moves to detonate the cartridge.

Firing Pin - The firing pin is the part of the firearm that moves through the breech and impacts the cartridge primer, initiating the detonation of the cartridge. The position of the firing pin on the face of the breech is determined by the type of cartridge the firearm is designed to fire.

Hammer/Striker - The hammer or striker is the part of the firearm that transfers the energy from its driver spring to the firing pin. In some firearms, the firing pin is either affixed to, or integral with the hammer/striker.

Extractor - After firing the cartridge, the extractor engages the rim of the fired cartridge and removes it from the chamber. The extractor may be affixed to the breech mechanism in order to cause extraction of the fired cartridge casing as the breech unseals the rear of the chamber. Some firearms have extractors that are installed as a portion of the chamber, actually supporting part of the cartridge casing during the firing sequence, and then moving to extract the cartridge casing after firing.

Ejector - The ejector is the part of the firearm that forcefully throws or ejects the fired cartridge casing clear of the firearm. The ejector typically works in concert with the extractor to remove the casing from the firearm. As the extractor pulls the casing from the chamber, the ejector acts on the casing to throw it clear of the firearm. The ejector is usually a stationary piece of metal located on the opposite side of the face of the breech from the extractor. Certain designs utilize the firing pin as an ejector. The firing pin is stopped in its rearward motion before the breech block stops. The firing pin thrusts forward on the primer, causing the empty case to pivot around the hook of the extractor and fly out of the gun. Other firearms are designed to use the feed lips of the magazine to eject the empty case. Some firearm designs do not have ejectors that throw the casings clear of the weapon. These firearms, typically break-open action rifles and shotguns, use the extractors to gently pull the casing from the chamber so that the shooter can grasp it and remove it manually. Quality shotguns will have selective ejectors that forcefully eject only the fired cases. Unfired cartridges are partially lifted from the chamber by the extractors. Other break open action firearms have ejectors that throw every casing clear of the chamber whether it is fired or not.[2] Most revolvers have parts that function as both extractors and ejectors. Whether the extractor/ejector throws the casings clear of the revolver or not is dependent upon the amount of force the shooter applies manually to the ejector rod.

Chamber - The chamber is the part of the firearm designed to accept a cartridge with its powder charge, primer and projectile. The chamber is usually affixed to, or aligned with the barrel, and withstands the gas pressure created as the powder burns and the projectile is moved down the barrel. Revolvers have a series of chambers in a single unit called a cylinder that is separate from the barrel, but aligns with the barrel mechanically, shortly before the moment of firing.

Barrel - The barrel is a linear bar of steel with a hole bored into it longitudinally that receives the projectile as it passes from the chamber under pressure from the burning powder. The barrel continues to apply the increasing force of the gas pressure to the projectile as it is accelerated to maximum velocity and leaves the firearm. The barrel may be rifled or smoothbore, each type acting on the projectile in a different way. Rifled barrels are designed to impart axial spin to a bullet and stabilize it in its flight to the target. Smooth bore firearms, typical of modern shotguns, have no rifling and do not spin the projectile. Smoothbore firearms may have chokes that are intended to enhance the spread and density of the shot pattern.

Toolmarks on the firearm

A firearm is a thermo-dynamic machine that is designed to convert the potential energy of gun powder into the kinetic energy of the projectile. The events that transpire as a firearm detonates a cartridge and moves a projectile down its barrel are predictable and explainable by established scientific principles and mathematical formulas.[3] The firearms designer applies these principles in the interest of producing the safest and most efficient firearm possible for a given cartridge or type of cartridge. The firearms manufacturer tests and proves a design which must work within the parameters of that design to produce a firearm that retains the design's safety and efficiency features. As multiple manufacturers attempt to produce firearms using a fundamentally similar design, competition occurs to produce that design more economically. This competition inevitably leads to the discovery of the most cost-effective methods of production for a particular firearm design.

In the interest of attaining maximum economy in their respective manufacturing techniques, most manufacturers produce a rough copy of their firearm components by one of the following methods:

1. Mass machining - The design specifications of certain components lend themselves to the mass machining process. Several parts are machined at one time in a batch. This process was used extensively by military contractors during war time to produce frames for the 1911 model .45 caliber automatic pistol and other firearms.[4]

2. Forging - Many manufacturers use the forging process to produce rough parts for final machining. This process exerts tons of pressure on an ingot of metal to force its shape to conform to the shape of a mold or template.

3. Investment casting - The investment casting process involves the manufacture of a wax duplicate of the part to be produced. A ceramic mold is formed around the wax part, then the mold is heated in a furnace to cure the ceramic and remove the wax. Molten metal is then poured into the ceramic mold, producing a metallic duplicate of the previous wax component. In some cases, very little or no final machining is required to produce a finished part.

Once the rough part has been produced, the manufacturer uses machine tools to further perfect the part and bring its measurements closer to the dimensions specified by the designer. Extensive handwork is usually required to bring the dimensions of some parts into tolerance, however in the case of some firearm designs, no further fitting or finishing work will be necessary past the initial rough production of the part. In these cases, the firearm will usually be assembled without the need for tedious handwork.

Toolmarks of any kind placed on the firearm during manufacture can be transferred to the cartridge case and bullet as the firearm chambers, fires, extracts and ejects the cartridge. The malleable brass of the casing and the soft copper or lead of the bullet is easily marred by the harder steel components of the firearm. However, not all toolmarks on or in the firearm can be transferred onto the casing and bullet. Only those firearm components that come into physical contact with the casing and bullet will transfer their impressions.

Finishing the Face of the Breech

The method in which the manufacturer finishes the face of the breech is important in the firearms identification process. The face of the breech supports the case head of the cartridge at the moment of firing. Any toolmarks on the face of the breech can be transferred to the case head during the feeding or chambering of the cartridge, and during the actual firing of the cartridge.

As previously stated, some components undergo no further hand finishing after the rough machining is completed. An example of this would be certain types of machine-guns and submachine-guns which utilize a separate breech block, particularly the Thompson submachine gun. On these firearms, the breech block is finished with a circular mill and requires no additional handwork to bring the part into tolerance. As a result, the surface of the

Thompson breech block is covered with concentric circles with the firing pin hole as the center.[5] Certain bolt action rifles and semi-automatic pistols have a circular recess in the face of the breech that encloses a portion of the cartridge case. The face of the breech on these firearms will also be formed with machine tools similar to the Thompson, but may have a smoother surface because of the use of facing cutters and surface grinders to bring the breech into tolerance. Circular toolmarks will also be present on the face of breeches finished in this manner.

Other firearms require a certain amount of handwork with a file or stone to bring the breech into dimensional tolerance. Semiautomatic pistols having a flat breech face and an ejection opening cut into the top of the slide, will typically have their breech finished by a workman filing vertically through the ejection opening. Modern revolvers will have the face of their breech finished by filing horizontally under the topstrap of the frame. Top-break revolvers will have their breech face finished similarly to the semiautomatic pistol. Because they have no topstrap to interfere, the gunsmith will usually file the breech face vertically. The direction of the filing scratch marks is usually determined by the location the workman used to access the face of the breech with his file.[6]

The firing pin hole in the face of the breech can also transfer its impression onto the soft metal of the primer cup at the moment of firing. A close fit between the firing pin and the firing pin hole is desirable on firearms firing high pressure cartridges. Ample clearance must be present to allow the firing pin to move freely through the hole without binding. However, excessive clearance between the pin and hole can allow metal from the brass or copper primer cup to flow around the firing pin and back into the firing pin hole as the gas pressure inside the chamber reaches maximum levels. Any damage to the firing pin hole will likewise be transferred to the primer cup and cartridge case at the moment of firing.[7]

Finishing of other firearm components

Other parts of the firearm also contain toolmarks applied to them during the manufacturing process. The extractor, ejector and firing pin all carry marks from contact with their tooling during manufacture. These toolmarks will be transferred to the cartridge case as these parts come into contact with it. Because of the considerable force and friction applied to these parts during the firing sequence, wear and breakage also alter the surface of these parts. As the firearm is used and serviced, damage to these parts is inevitable. File marks, scratches, dents, nicks and worn areas are all imperfections in the contact surfaces of these parts that can be transferred to the casing as the part acts on it.

The chamber of a firearm is another component that will have toolmarks present. Most chambers are cut and finished with precision ground reamers that are capable of producing an exceptionally smooth finish on the inside of the chamber. As the chambering tool dulls and wears from continued use, it will impart imperfections to the chamber interior. If the machinist is not careful when cutting the chamber, chatter from an improper rate of feed on the lathe will be evident on the chamber walls. If the barrel or reamer are not properly centered in the lathe during the chambering process, it is possible to cut the chamber to improper dimensions or cause it to be elliptical in shape rather than perfectly round. When cartridges of ample pressure are fired, these imperfections will be transferred to the cartridge case.

Some European military firearms have flutes formed into the chamber interior. Chamber flutes are longitudinal grooves that are formed parallel to the axis of the bore in the walls of the chamber. The flutes are intended to facilitate positive extraction of the fired casing by preventing it from sticking to the chamber walls as the chamber heats up and becomes fouled from repeated and continuous firing. The chamber flutes will engrave their form onto the casing as it is fired. An example of this type of firearm is the Heckler and Koch semiautomatic rifle, pistol and machine-gun.[8]

The Development of the Rifled Firearm

One of the first improvements to firearms was an attempt to make them more accurate with greater lethal range. Early long guns, called muskets, were smoothbore muzzle-loading firearms that launched a spherical lead or iron ball using black powder as a propellant. The musket is comparable to the modern smoothbore shotgun in its treatment of the projectile in both interior and exterior ballistics. Smoothbore firearms have no rifling, and cannot impart any stabilizing spin to their projectiles. The musket, although very powerful at short distances, was not an accurate firearm. Colonel Hanger, a British Army officer, commented in 1814 that a soldier's musket could usually hit the figure of a man at 80 yards, but if he hit a man at 150 yards it was because of the misfortune of the victim, not the skill of the antagonist. Colonel Hanger continued by adding, "no man was ever killed by a musket at 200 yards by the person who aimed at him".[9]

The musket's drawbacks centered around two deficiencies. First, for ease of loading, the projectile was deliberately made undersize which allowed considerable amounts of gas to leak past it when fired. This prevented the musket from transferring all of the energy available from the expanding powder gases to the projectile. Second, the musket had no rifling that could grip the projectile and impart the axial spin to it necessary for stable flight downrange.

Rifling of gun barrels was not a new innovation to firearm designers in the eighteenth and nineteenth centuries. The invention of firearm rifling is attributed to Augustus Kotter of Nuremburg, Germany in approximately 1520 A.D. The Germans had long fashioned the bolts shot from their crossbows with special heads or pieces of metal or leather attached to the shaft which caused the bolt to rotate in flight. Later, some crossbows were developed that fired the bolt through a spiral grooved guiding tube, causing them to rotate in flight.[10]

Even though rifling was known for centuries to stabilize the firearm's projectile and make it more accurate, rifles were not preferred by military shooters because they were more difficult to load than the smoothbore musket. The lead projectile could not be made undersize, and had to be hammered down the entire length of the rifle's bore, forcing it to take on the shape of the rifling. The difficulty in seating the projectile was brought about by the lands and grooves of the rifle being engraved onto the exterior of the projectile. The engraving process, combined with the accumulation of fouling from previously fired loads, made the rifle a very difficult firearm to load in a hurry. However, when the rifle was fired, the gas seal formed by the projectile's positive contact with the rifling made more efficient use of the rapidly expanding gases, and caused it to spin, making it stable in flight and more accurate. In spite of the greater accuracy potential of the rifle, the military strategists of that time preferred the musket for armed conflict because it was quicker to reload in battle.[11]

The most significant development that brought about widespread military use of the rifled firearm was the perfection of the breech-loading action. This improvement enabled the shooter to reload his rifle in a very short time without the labor involved in hammering a bullet down the barrel. A projectile of the proper size could simply be placed in the chamber until it contacted the riflings. The powder could then be poured into the chamber behind the projectile. Further improvements to the breech-loading action brought about metallic cased ammunition, with the primer, powder and bullet contained in a convenient unit called a cartridge. After the introduction of the metallic cartridge, repeating firearms were developed that enabled the shooter to fire several cartridges without reloading the firearm.

The technological developments that were applied to correct the shortcomings of the primitive muzzle-loading smoothbore musket paved the way for the super-accurate, high velocity rifled arms of today. Using modern machine tools and methods, extremely close tolerances can be achieved and maintained between the barrel interior and the bullet circumference. Specific rates of twist can be applied to various calibers and weights of bullets making them very stable in flight, and very accurate when they reach their target.

The Barrel Manufacturing Process

Since the invention of the firearm, technology has been the limiting factor in barrel production. Early gunsmiths forged barrels by bending a long flat bar of iron around a steel mandrel, and then welding the seam with a forge and hammer. The iron bar tended to conform to the shape and size of the steel mandrel as it was forged and welded. Another technique, known as the Damascus process, was to wrap hot iron bars in a spiral around a mandrel, and then weld with a forge and hammer. After welding, the barrel was reamed to size with hand made reamers, producing the finished bore diameter. Acceptable tolerances for barrels made in this fashion ran as much as .015" above nominal bore diameter.[12]

In the 1840's, a procedure for the manufacture of "cast steel" barrels was developed. This process involved the molding of an ingot of steel approximately a foot long and four inches in diameter. The hot ingot would be placed into a rolling machine that would forge it to a final length of approximately twelve to sixteen feet. The gunsmith would then cut the bar into manageable lengths and laboriously drill a hole through the length of the shorter bars forming barrel blanks. The blanks would be reamed to dimension and rifled. Another method used during this time involved punching a hole through the entire length of the ingot while it was still white hot. The ingot would then be placed into the rolling machine with a mandrel through the hole and forged to a final length of approximately twelve to sixteen feet. This produced a solid piece of barrel stock with the hole made into it. When completed, the gunsmith would cut the rough barrel blank into the desired lengths and then ream it to dimension and apply the rifling. This process was usually reserved for the more expensive rifles that were intended to fire very heavy bullets with very heavy powder charges. One obvious benefit of these methods was the production of a gun barrel from high quality steel without the traditional welded seam.[13]

Both of the cast steel methods were forerunners to the modern processes of barrel manufacture. Today, instead of the intense manual methods of processing the steel bars into barrels, machine tools perform almost all of the work. Modern gun barrels may be manufactured from one of several different alloys of steel to produce a particular quality in the finished barrel. The bars of steel are drilled longitudinally with modern deep hole drills to a dimension that is dependent upon how the barrel is to be finished and rifled.

Some manufacturers finish their barrels with a hammer forging process known as intraforming. This production method requires that an oversized hole be drilled longitudinally through the steel bar to provide clearance for a mandrel. The mandrel is made of very hard steel and has a positive impression of the rifling ground onto its circumference. The steel bar, with the mandrel inserted in the oversize hole, is placed into a hammer forging machine. The hammer forging machine hammers the surface in the interior of the hole down onto the mandrel forcing it to assume the shape of the mandrel. When the hammer forging process is complete, the mandrel is withdrawn from the center of the steel bar, revealing a perfectly finished and rifled bore.[14] Winchester, Ruger and Remington use the intraforming process to manufacture certain types of rifle and shotgun barrels.

Other manufacturers use a more traditional method to finish their barrels. The steel bar is secured in a lathe and bored longitudinally with a deep hole drill of slightly smaller dimension than the desired dimension of the finished bore. While in the lathe, the hole will be reamed to final dimension, creating the top surfaces of the lands. The reamed barrel blank will then be rifled with the appropriate twist for the bullet it is intended to fire. Several methods have been used with great success in applying cut rifling to reamed gun barrel blanks.

Cut rifling is the oldest method known to have been used in firearms. The gunsmith using this process would cut only one or two grooves at a time using a rifling machine. The rifling machine would hold the barrel in a fixed position while a cutting tool was drawn back and forth through the bore. The cutting tool was secured to a long rod that extended from a helically cut guide. The helically cut guide rotated at a predetermined twist by following a set of fixed index fingers. If a different rate of twist or different number of grooves was desired, a different helically cut guide would have to be used. With the rotation applied to the cutting tool by the helically cut guide, spiral grooves were cut into the bore at the same rate of twist as those present on the helically cut guide. When the groove was cut to the maximum depth allowed by the adjustment of the cutting tool, the guide would be indexed over to the next groove, and the procedure repeated until all the grooves were cut to a shallow depth in the bore. When all the grooves were cut to a uniform depth, a shim would be placed under the cutter to cause it to cut a deeper groove, and the cutting and indexing procedure would be repeated until the rifling in all the grooves was cut to the desired depth.[15]

Two types of cutting tools were used to cut rifling into barrels. The hook cutter had a single cutting surface that carved metal out of the grooves, and was used to rifle barrels with odd numbers of grooves. The hook cutter would cut only as it was pulled through the bore, and left a rough finish due to its aggressive method of removing metal. The scraper cutter had two cutting surfaces on opposite sides of the cutting tool that formed two grooves simultaneously. The scraper cutter could only be used to rifle barrels that were to have even numbers of grooves. The scraper cutter removed smaller amounts of metal on each pass through the bore, but was able to cut in both directions. Because it was less aggressive in the way it removed metal, scraper cutters tended to leave a smoother finish in the bottom of the grooves than hook cutters.[16] The cut rifling process was the only method used to rifle barrels until the beginning of World War 1. It is still used today in some custom rifle shops on a limited basis.

With the massive retooling effort undertaken at the beginning of World War 1, came a new method of cutting rifling into barrels. The process was known as the broach method, and involved pulling or pushing a specialized cutter through the bore of a reamed barrel blank. The broach was able to cut all the grooves simultaneously in one pass, making the rifling of barrels a very fast process. The broach was a long tool that was machined with increasingly larger diameter cutters in the exact shape of the finished bore. Each larger cutter would cut the grooves deeper than the one before it, with the last cutter cutting the grooves to final dimension.[17] The broach method is more costly to use than some other methods because the broach is complicated and difficult to manufacture, expensive to keep sharp and easily damaged. However it is still in fairly wide use today in the manufacture of pistol, revolver and rifle barrels.[18]

Near the end of World War 2, another method of rifling firearm barrels was introduced. The new process, known as button swaging, differed from previous methods because it did not remove any metal in forming the grooves in the bore. In the button swaging process, a carbide button with the rifling pattern formed onto its exterior is pulled or pushed through the bore of a reamed barrel blank. Unlike previous methods of rifling, the rifling button is held stationary while the barrel is allowed to rotate as the rifling progresses. The reason for this is the way the button is formed. The button not only has the shape of the lands and grooves machined onto its exterior, it also has the specific twist for the barrel machined onto its circumference. As the button passes through the bore, the interior surface of the barrel is forced to conform to the shape of the button. As the bore forms grooves around the exterior of the button, the barrel rotates around the button at the same rate of twist present on the button. The button swaging process work-hardens the steel as it moves through the bore, producing barrels with extremely hard interior surfaces that are very smooth in comparison to cut rifled barrels. Where the cut rifling process took hours to complete, a barrel can be button rifled in seconds.[19]

The most recent development in rifling technology is an electro-chemical method using high speed etching known as chemical milling. In this process, a carefully machined mandrel with the helical rifling pattern on its exterior surface is placed in the bore of a reamed barrel blank. An electrolytic chemical is flowed through the bore around the mandrel and electric current is applied. The rifling grooves are formed as the electrically charged solution eats metal away from the interior of the bore in select locations relative to the helical rifling pattern on the mandrel. This process was developed by the Russians for production of military firearms, and is currently being used in the United States by Remington to manufacture rifled choke tubes for their shotguns. This method is also being used by certain pistol manufacturers on a trial basis.[20]

It is fairly easy to tell how the rifling was applied to a barrel by examining the bore with a bore light or scope. If the rifling was cut into the bore after it was reamed to size, the bottom of the grooves will show striations that run from breech to muzzle where the cutter removed metal to form the grooves. The top of the lands will have striations across their width that are the remnants of the circular cutter marks made when the bore was reamed to final dimension. Barrels that have been button swaged or hammer forged will show the circular reamer marks on both the top of the lands and the bottom of the grooves. The reason for this is that the swaging and forging process both involve the displacement of metal, unlike the cutting process which involves the removal of metal in forming the grooves.

Regardless of the method in which barrels are machined and rifled, the basic features that make a rifled barrel effective will always be present. Close contact between the bullet and all the interior surfaces of the bore is essential to create an effective gas seal and impart spin to the bullet as it passes through the bore. When this close contact is present, comparison evidence will inevitably be created on the bullet that will be useful in identifying the particular firearm that fired it.

CHAPTER 3

FIREARMS DYNAMICS

The investigator who is presented with a case where firearm related evidence is to be considered, must be educated not only in the importance of the evidence itself, but also in the processes that created the evidence. An understanding of the workings of firearms and the dynamics associated with the firing of cartridges in firearms is fundamental in obtaining an appreciation for the various facets of firearm comparison evidence.

Calibers and types of ammunition

Caliber is usually applied to describe the size of the bore in firearm barrels. When a barrel is made, a hole is drilled longitudinally and then reamed to "bore diameter". The finished dimension of the reamed bore is referred to as the nominal caliber of the barrel. Since the rifling is applied after the bore is finished, the diameter of the bore measured at the bottom of the rifling grooves will always be greater than the nominal caliber. For example, in making a 30 caliber rifle barrel, the bore would be finished with a reamer to a diameter of .300". When the rifling is applied with grooves .004" deep, the diameter of the rifled bore increases .008". Therefore, a nominal 30 caliber barrel would have a diameter of .308" when measured across the bottom of the grooves.[21] The bore diameter is usually referred to in hundredths of an inch in the United States and England, and in millimeters in countries using the metric system of measurement.

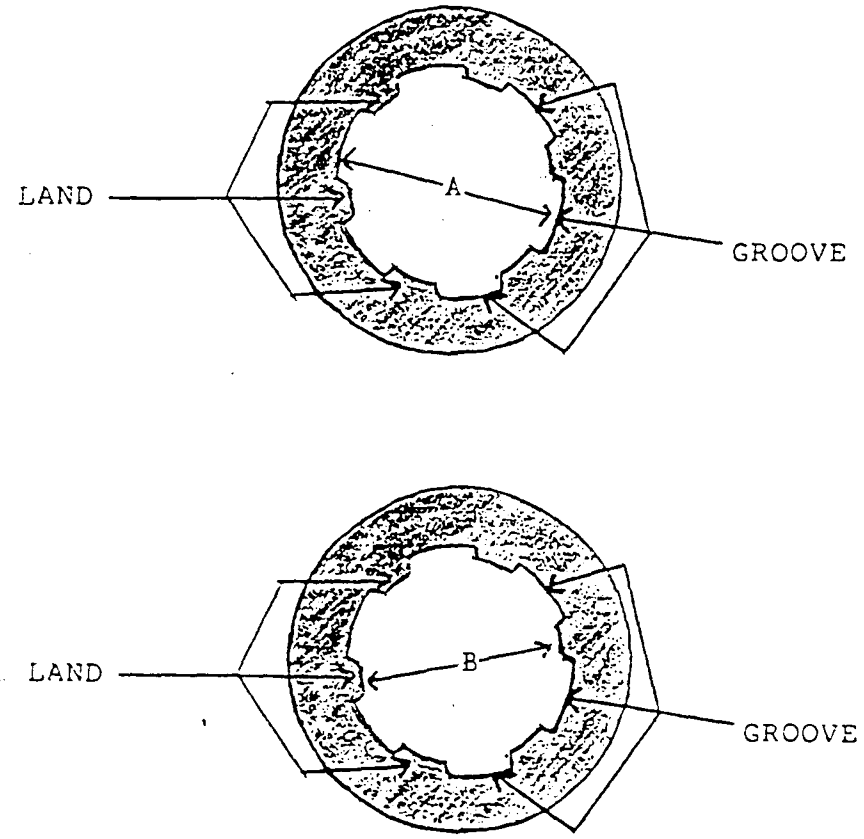

Figure 1. Cross Section of a Gun Barrel. Groove diameter is measured between opposite grooves at "A". Bore diameter is measured between opposite lands at "B".

Several types of ammunition are currently in production and available for use in modern firearms. A unique type of ammunition exists for each different caliber and type of firearm. Caliber was once used to specify the bore diameter of smoothbore muskets and their related spherical projectiles.

However, with the development of breech-loading actions and metallic cased cartridges, it became possible to chamber firearms having identical bore diameters for cartridges that contained varying weights of gun powder. This development caused the caliber designation to reflect not only the bore diameter of the bullet, but also the weight of the black powder charge in grains. For example, a cartridge with a 45 caliber bullet and a charge of 70 grains of black powder was referred to as a 45/70 caliber. As manufacturers offered different styles of bullets within the same specifications of bullet diameter and powder weight, an additional number was added to the caliber designation to denote bullet weight in grains. Hence, a 45/70/500 caliber round of ammunition in that day would have been a cartridge loaded with a 45 caliber bullet weighing 500 grains and a black powder charge of 70 grains.[22]

Manufacturers of firearms also created ammunition that was for exclusive use in their proprietary firearm designs. The ammunition was usually named for the type of firearm it was designed to function in. Examples of this would include the 45 Colt, 30/30 Winchester, and the 9mm Luger. Other caliber names were applied to denote a manufacturing line of firearms. Jonathan Browning's pistol designs that were adopted by the Colt manufacturing company fired cartridges of varying bore diameters denoted by the abbreviation, A.C.P., which stood for "Automatic Colt Pistol". Examples of this type of ammunition include the 45 A.C.P., 38 A.C.P., 380 A.C.P., and 25 A.C.P.[23]

Caliber denotation may also include its year of adoption by the military. During the Spanish-American War, the United States adopted the 30/40 Krag Jorgensen rifle as its official military issue weapon. The Krag rifle was chambered for a cartridge that was officially called the ".30 U.S. Army." In 1903, the military adopted the Springfield rifle for official issue, which was chambered for a different 30 caliber cartridge, officially called the ".30 U.S. Government". Three years later, the military improved the performance of the 30 U.S. Government cartridge by substituting a sharp pointed bullet for the older round pointed bullet. The new and improved cartridge was named the ".30-1906", or ".30-'06", for the year of its adoption.[24]

Caliber denotation has evolved to a point where the listed "caliber" may not accurately describe the bore diameter or the bullet. In such cases, the bullet may measure several thousands more or less than the caliber name describes. Examples of this include the 44 Magnum, which actually measures .429"; the 38 Special, which measures .357"; and the 38-40, which measures .401".

Components of ammunition for rifled firearms

Ammunition for firearms is constructed of certain standard components that enable the ignition of a propellant and the launch of a projectile. These components will always be present in live, unfired ammunition.

Cartridge casings

Cartridge casings are the basic frame of a round of ammunition. Usually constructed of brass or steel, the casing is made to hold the ignition system, powder charge and projectile until the round is fired.[25] Cartridges may be of two general types depending on the orientation of the primer compound.

Rimfire cartridges are formed with a hollow rim that holds the primer compound in a doughnut shaped ring around the base of the cartridge. The firing pins in firearms chambered for rimfire cartridges are positioned off center to the axis of the bore, and are designed to impact the rim of the cartridge to accomplish detonation. Rimfire cartridges will detonate if the firing pin impacts with sufficient force on any point of the cartridge rim.[26]

Centerfire cartridges are formed with a depression in the center of their bases that hold a separate primer cup. The primer compound is contained in the cup and pressed into the depression in the center of the case head. Firearms designed to fire centerfire ammunition have their firing pin oriented to impact the center of the primer cup.[27]

The hollow casing accommodates the powder charge. The size and shape of the casing is determined by the amount of powder it is designed to hold. Rifle casings may be made with straight walls, tapered walls or of a bottleneck design with a large cylindrical body that tapers down to the approximate size of the bullet. The bottleneck casing is designed to accommodate a large powder charge in order to attain a higher projectile velocity. Handgun casings are usually of tapered or straight wall design, and have less powder capacity than rifle casings.[28]

The case head is constructed in a manner that is consistent with the way the cartridge is intended to obtain proper headspace in the chamber. Headspace is a term assigned to a specific dimension measured from the breechface to the part of the chamber that stops the case's forward movement. Casings may be rimless bottleneck, rimless straight wall, rimmed, semi-rimmed, rebated or belted. Rimless bottleneck, rebated and semi-rimmed casings use the tapered shoulder near the mouth of the case to stop forward movement in the chamber. Therefore, headspace for these types of cartridges is measured from the breechface to the beginning of the casing's shoulder. Rimless straight wall casings use the surface at the case mouth to stop the case's forward movement. Headspace for these casings is measured from the breechface to the case mouth. Rimmed casings depend on the rim to catch at the edge of the chamber and stop the forward movement of the cartridge into the chamber. Headspace for rimmed cartridges is determined by the thickness of the rim. Belted casings have a raised ring or belt forward of the extraction groove that stops forward movement of the casing by contacting a recess in the chamber. Headspace for belted casings is measured from the breechface to the forward edge of the belt.

If adequate headspace does not exist in the chamber for the cartridge to properly enter and seat, the breech will not be able to close and seal the chamber. Most firearms with inadequate headspace will not fire unless the breech is able to close completely because of a disconnector or other safety feature they may have. Firearms with excessive headspace will usually close and fire, but are potentially dangerous to the shooter because of the risk of violent gas leaks caused by a rupture of the casing.[29] In extreme cases of excess headspace, the cartridge would be permitted to move so far into the chamber before it stopped that the firing pin would not be able to protrude far enough from the breechface to contact the primer. An example of this would be an attempt to fire .380 A.C.P. ammunition in some firearms chambered for 9mm ammunition.

Primers

The primer is an essential part of a cartridge that enables a strike from the firing pin to initiate combustion of the powder. The primer contains an explosive compound which is sensitive to friction and sudden pressure.[30] The priming compound is situated between two metal barriers that are designed to crush the compound when the outer barrier is struck by the firing pin. In rimfire cartridges, the primer compound is spun into the casing's hollow rim by centrifugal force in order to situate it between the opposite sides of the rim's fold.[31] In centerfire cartridges, the primer compound is placed into the primer cup before its insertion into the casing. The opposing metal barrier in centerfire casings is referred to as an anvil. In the United States, boxer-type primers are used which have a small brass anvil placed into the primer cup as a separate piece. In Europe and other parts of the world, berdan primers are used. Berdan primers have no anvil in the primer cup. Casings designed for berdan primers have a conical shaped projection in the center of the casing's primer pocket that serves as an anvil. Boxer primed casings have only one flash hole for the primer flame to reach the powder charge, where berdan primed casings have two, one on each side of the anvil.[32] It is somewhat ironic to note that the berdan primer, which was adopted as a standard in Europe and the rest of the world was the invention of American Civil War Colonel Hiram Berden. The boxer primer, which was adopted exclusively in the United States, was the invention of Colonel Boxer of the British Army.[33]

Older primers contained mercury fulminate or potassium chlorate as their explosive compound, both of which were corrosive to the steel in the firearm. During the time that these compounds were in use, firearms examiners claimed that they were able to judge how long it had been since a particular firearm had been discharged by the extent the bore had been oxidized. The salts that were left in the bore from firing cartridges primed with these compounds were corrosive by nature, and also attracted moisture which facilitated the rusting of the steel in the firearm. The only thing that prevented the barrel from rusting was a thorough cleaning of the weapon as soon as possible after firing.[34]

Modern priming compounds are not corrosive and do not harm the firearm in any way. Explosive compounds used in modern primers contain lead styphnate, antimony sulfide, barium nitrate and tetracene. Priming compounds for rimfire cartridges contain lead azide.[35]

Gun powder

Gun powder is a solid propellant that generates the force necessary for propulsion of the bullet by the rapid production of gases resulting from its combustion. Black powder was the first propellant to be used as a gun powder. It has been in use since the thirteenth century, and its invention is widely attributed to the Chinese.[36] Black powder for firearms was composed of 75% potassium nitrate, 15% charcoal (carbon) and 10% sulfur. The compound was mixed with water and dried in flat cakes to prevent it from separating. When it was dry, it was powdered and then sifted into different sized flakes. The rate of burn was controlled by varying the size of the powder flake.

Smokeless powder was developed for the French Army in 1876 to reduce the amount of smoke on the battlefield. It was discovered that in addition to reducing the amount of smoke produced during combustion, smokeless powders also gave increased velocities. There are two types of smokeless powder, single-base and double-base. Single-base powder is made by nitrating cellulose fibers with nitric acid. The product formed by this process is cellulose nitrate, or nitrocellulose. Other substances are added to the compound to regulate its rate of burn before it is plasticized with an alcohol-ether mixture and extruded into smaller grains. Graphite is applied to the powder grains to retard the accumulation of static electricity. Double-base powder is a mixture of nitrocellulose and nitroglycerine. Double-base powder is also extruded and parted off into smaller grains which are treated with modifiers and inhibitors to control the rate of burn.[37]

Bullets

Bullets used in firearms are typically made of lead or lead alloys. Early bullets were made of pure lead because it disrupted easily in the bore and formed a good gas seal when under pressure from the expanding powder gases. When smokeless powder was adopted, attainable velocities increased, and it was discovered that lead bullets could not stand the stresses imposed by the faster acceleration through the riflings. The lead bullets were too soft to stay engaged with the riflings without stripping metal off their circumference. Lead was still desirable as a projectile metal because of its mass, so it was decided to put an exterior jacket made of harder metal on the bullet and retain the lead as the central core. Copper-nickel alloy, copper-zinc alloy, mild steel and aluminum are several metals which have been used in bullet jackets. However, the copper-zinc alloy has become the standard for most commercial rifle and pistol bullets in the United States.[38]

Bullets sometimes have a cannelure formed into their exterior surface. A cannelure is a groove that is formed into the circumference of the bullet on the straight-sided surface that contacts the riflings in the bore. Lead bullets may have several cannelures, also called grease grooves, which hold a lubricant for the bore such as grease or wax. Jacketed bullets do not require the exterior lubrication that lead bullets must have to prevent bore fouling, so the cannelure on a jacketed bullet is intended to perform a mechanical function. In some lead bullets as well as jacketed bullets, the mouth of the cartridge casing is crimped into the cannelure to firmly hold the bullet to the casing until it is fired. In jacketed bullets, the formation of a cannelure provides an additional method of securing the jacket to the lead core. The addition of cannelures to a bullet design allows the manufacturer to make the bearing surface that contacts the bore longer without adding weight to the bullet. Longer bullets tend to be more stabile in flight. Bullets that measure more in their diameter than in overall length have difficulty in resisting the tendency to tumble in flight. The addition of one or more cannelures can make the difference in length necessary to ensure stability in flight.[39]

There are several designs of bullets that are currently manufactured for use in modern firearms. Full metal jacket bullets, abbreviated with the designation F.M.J., are typically used by the armed forces and have a copper or steel jacket that completely covers the nose and sides of the lead core. Full metal jacket bullets are formed by pressing a lead core into the rear of a jacket cup under great pressure, and then crimping the rear of the jacket around the rear of the core. The lead core is usually exposed at the rear of this type of bullet. Full metal jacket bullets do not expand upon impacting the target, and usually penetrate the target more than any other design of bullet. Semi-jacketed bullets are formed by pressing a lead core into the front of a jacket cup. Semi-jacketed bullets are normally designed to have either the soft lead core or a hollow cavity exposed at the nose. The base of this type of bullet is totally enclosed by the copper jacket. Both the soft point and hollow point bullets are designed to expand when impacting the target, and usually do not penetrate as far as bullets that are not designed to expand on impact. Some hunting bullets that are designed for use on thick-skinned animals may have a bronze, steel or plastic point pressed into the hollow nose cavity. The special point is designed to penetrate the animal's skin before it permits the rest of the bullet to expand. Armor-piercing bullets used by the armed forces have a tungsten carbide core surrounded by a steel jacket that is designed to penetrate steel armor. Teflon-coated bullets are also referred to as armor-piercing bullets, but are not capable of penetrating steel armor like the tungsten carbide core bullets. The teflon coating on these bullets tends to lubricate the contact surface between the bullet and the target on impact, delaying expansion of the bullet. Teflon-coated bullets usually penetrate deeper into barricade materials than non-coated bullets, and have also been shown to successfully penetrate soft body armor typically worn by law enforcement personnel.[40]

It is not unusual for the jacket and core from a fired soft point or hollowpoint bullet to separate after impact with the target. When the expansion process begins, the jacket is peeled backward from the nose of the bullet, and meets with greater resistance than the core. The core, having a greater mass than the jacket, tends to continue into the target, and if it is not securely affixed to the jacket in some way, it can separate from the jacket.

Handgun target ammunition is usually loaded with cast or swaged lead bullets with sharp shoulders or edges on their front surface. The sharp shoulder is intended to cut a clean hole in a paper target upon impact. These types of bullets are called wadcutters, and are typically fired at subsonic velocities to avoid leading the barrel. Full wadcutters are usually fired exclusively in revolvers and are completely cylindrical, having a flat nose. Semi-wadcutters have a conventional bullet nose that is formed slightly smaller in diameter than the sharp shoulder. Semi-wadcutters may be fired in either revolvers or semi-automatic pistols.

Exploding bullets are made by placing a quantity of lead azide into the nose of a hollow-point bullet. Lead azide, a common explosive used to prime rimfire cartridges and muzzle-loading firearms, is extremely sensitive to friction and sudden impacts. Exploding bullets of this type do not detonate with 100% reliability if they impact the target at angles less than 90 degrees.[41]

Interior ballistics

Firearms are machines that convert the force of very hot, rapidly expanding gases into the propulsion of a projectile through space. The firearm performs more tasks in the blink of an eye than is apparent through mere observation of the blast, smoke and recoil usually associated with the discharge of a firearm. A firearm is a temporary container for the pressure created by the combustion of the powder, and a launch pad for the bullet. The following is a slow motion, macro-view of the chain of events that transpire inside a firearm similar to a semiautomatic pistol when a cartridge is fired.

When the trigger releases the hammer/striker to move forward, the spring that drives the hammer/striker is allowed to relax. As the spring relaxes, its stored energy is transmitted to the hammer/striker, causing it to move forward at a relatively high velocity. Complete forward movement of the hammer/striker causes the firing pin to impact the primer held in the cartridge case head. As the outer barrier of the primer cup collapses toward the anvil under the impact of the firing pin, the priming compound is crushed between them, and detonates. The resulting explosion of the priming compound causes a flame to enter the powder cavity of the cartridge through the flash hole and ignite the powder.[42]

As the powder begins to burn, hot gases are formed that quickly fill the small powder cavity in the cartridge. The pressure inside the cartridge increases, causing more powder flakes to spontaneously ignite and burn, and more hot gases to be released. When the gas pressure inside the cartridge reaches a level that is sufficient to overcome the friction holding the bullet inside the casing, the bullet and casing are thrust apart. Held secure in the chamber, the casing is pressed backward forcefully into the breechface, its thin brass walls being molded to every contour and imperfection in the chamber interior by the intense heat and pressure. As the casing is forced to expand and fill the chamber, it forms a gas seal at the rear of the chamber, preventing the escape of any of the hot gases. At the same instant, the bullet is pushed violently away from the expanding gases and enters the barrel.[43]

Under the tremendous pressure of the hot gases, the bullet is thrust into the rifling, causing it to assume the exact shape and dimension of the interior of the bore. As the rifling lands bite into the cylindrical bearing surface of the bullet, corresponding grooves are formed on the bullet. The bullet's steady acceleration down the bore causes the grooves formed on its surface to slide over the rifling lands like a train riding on a track. Following the rifling lands further down the bore, the bullet begins to spin on its axis, being scratched and marred by every imperfection in the harder steel of the barrel.[44] Just as the bullet attains maximum velocity from the enormous gas pressure propelling it down the barrel, the pressure dwindles away to nothing and the friction between its bearing surface and the bore disappears. The bullet is now traveling through the air, the axial spin it received from the riflings stabilizing its flight and preventing the air resistance on its nose from causing it to tumble.[45]

As the bullet leaves the barrel, the empty casing's rim is caught by the extractor and pulled to the rear. The steel surface of the extractor bites into the softer brass of the casing rim as it overcomes the friction between the casing and the chamber. As the casing is pulled backward under the control of the extractor, it suddenly collides with the ejector, which leaves the imprint of its surface in the soft brass of the cartridge case head.[46] The collision with the ejector causes the casing to pivot around the extractor, and fly free of the firearm. Before the casing is able to fall to the earth, the bullet fired from its mouth reaches its target, and the firearm feeds another cartridge from the magazine, ready to start the process again.

The foregoing description was a generalized study of interior ballistics. Interior ballistics involve the events that transpire from the time the firing pin hits the primer until the bullet exits the barrel. Subjects such as chamber and bore pressure, muzzle velocity, bullet rate of spin, and recoil are all part of interior ballistics.[47] If the firing sequence previously detailed were applied to the .45 automatic cartridge, it would have only taken the bullet .00077 of a second to exit the bore once it left the casing. The pressure exerted by the expanding powder gases on the casing, bullet and interior of the firearm would have reached 14,000 pounds per square inch.[48] The bullet would have attained a velocity of over 810 feet per second at the time it left the muzzle, and it would have been spinning on its axis at the rate of one revolution for every sixteen inches of linear flight.[49]

When a gun is fired, the pressure of the gas acts backward on the gun equally as strongly as it acts forward on the bullet. Recoil is the practical application of Newton's third law of motion which states that, for every action, there is an opposite and equal reaction.[50] The recoiling force felt by the shooter on his hand or shoulder when the firearm is discharged, is evidence of the equal and opposite reaction to the bullet moving down the barrel. In a .45 automatic pistol weighing 39 ounces, the recoil from firing a 230 grain bullet with a 6 grain powder charge at 810 feet per second would produce a rearward firearm velocity of approximately 12.25 feet per second. The recoil energy produced with this pistol and ammunition is approximately 4.5 foot pounds. The only reason why the pistol is not torn from the grasp of the shooter and hurled backward several feet, is that the recoil pulse lasts less than one thousandth of a second.[51]

Understanding the forces applied to the bullet and casing during the firing of a cartridge, enable the curious mind to comprehend how firearms comparison evidence is created. The malleable materials used in the manufacture of cartridges do indeed take on the peculiarities of the individual firearm that discharges them. In consideration of the amount and type of force present during the firing sequence, it would be quite impossible for the marks on the firearm to not be transferred to the casing and bullet.

CHAPTER 4

CLASS CHARACTERISTICS OF FIRERMS

When a bullet or casing is recovered at the scene of an offense, one of the first efforts at firearm identification should be the determination of class characteristics that may be present on the firearms evidence. This initial effort should be made whether or not a suspect weapon is available for immediate examination.[52] If a suspect weapon is available, it can be quickly determined if that firearm could have fired the casing or bullet. Class characteristics can also be used as an initial criteria for screening several suspect firearms, and deciding whether to conduct a closer comparison on one or more of them. If the suspect weapon is unknown or missing, an observation of the casing and bullet can provide information pertaining to the class characteristics of the suspect weapon still at large.[53]

Class characteristics are similarities shared by several firearms within groups determined by their manufacturer, design, style, model, and caliber. Class characteristics give the firearms examiner a way to narrow the field of firearms that could have fired the suspect casing or bullet. Class characteristics alone do not provide enough information or evidence to make a positive identification of an individual firearm to the exclusion of all others. However, they can be used to exclude the types of firearms that could not have fired the suspect bullet or casing.

The first American judicial decision approving comparison testimony regarding test bullets and an evidence bullet was made in Virginia in 1879.

During a murder trial, a witness testified that only two or three other pistols in the community might have carried the same type of ball as the fatal one. This testimony was received in a first degree murder prosecution. It appears that no singular identification was made between the suspect bullet and a particular firearm, as only class characteristics of the bullet were considered.[54]

Class characteristics present on bullets involve the nominal caliber and diameter of the bullet, the number of lands and grooves, width and depth of the lands and grooves, direction of the rifling and pitch of the rifling.[55] One of the first determinations that can be made is the caliber of the bullet. By measuring the diameter of the bullet in several locations on its bearing surface, and then averaging the measurements, a good idea of the caliber can usually be determined. When fired, the bullet is forced to conform to the exact size of the firearm's bore. After carefully measuring the bullet, certain firearms could be included or excluded based on whether the bullet is larger or smaller than the bore diameter of the suspect firearm. Exclusions based on bore diameter could be made within a group of firearms of the same make and model, having the same nominal caliber, direction and pitch of rifling. For example, a group of Colt pistols, all with a nominal .38 caliber, were found to have actual bore diameters that measured from .348" to .395".[56] Weighing the bullet, noting bullet style, and the location of cannelures can also provide information about the manufacturer of the bullet, and what type of cartridge into which it may have been loaded.[57]

Another observation that can be made of a suspect bullet is the number of lands and grooves and their width and depth. A number of eliminations of suspect firearms can be made simply by comparing the number and dimensions of the lands and grooves.[58] An example involving an elimination of this type involved the exoneration of a man named Charlie Stielow, who was convicted of murder and sentenced to death by the State of New York in 1915. An elderly landowner and his female housekeeper were shot to death with a .22 caliber revolver during a robbery. Investigators found that Stielow, a tenant of the male victim, happened to possess a .22 caliber revolver, and subsequently charged him with the murders. After Stielow's conviction, the Governor of New York ordered a special investigation that involved a re-examination of the evidence by members of the New York Attorney General's office. It was discovered that the bullets recovered from the bodies of the victims were fired from a gun with defective rifling. The bore of the murder weapon had an abnormal land, whose width equalled the combined widths of two lands and one groove.[59] The test bullets from Stielow's revolver showed normal rifling having five lands and grooves of equal width and spacing. A measurement of the bullets further showed that the suspect bullets were .0018" smaller than the bore diameter of Stielow's revolver. In consideration of the class characteristics exhibited on the suspect bullets, it was determined to be impossible for the suspect bullets to have been fired from Stielow's revolver. The true murder weapon was later recovered, and the actual murderers charged.[60]

The widths of the lands and grooves may be measured using a filar micrometer, traveling microscope or toolmaker's microscope. The measurements are made perpendicular to the axis of the bullet. The grooves can usually be measured with a precision of plus or minus .01", however if the bullet is jacketed or does not expand to fill the bottoms of the grooves, the accuracy of the groove measurement may be extremely poor. Measurements of the lands will usually be more accurate, with a precision of plus or minus .0001". The edges of the lands may be difficult to determine because of erosion, lapping or smoothing of the barrel during manufacture, or the presence of adjacent striations running parallel with the lands. This difficulty may result in the inability to obtain an accurate fix on the location of the edge of the land, resulting in an inaccurate measurement.

The pitch of the rifling can be determined by measuring the angle the land impressions make with the axis of the bullet. This measurement is usually made with a microscope equipped with a protractor eyepiece. The angle is used in a mathematic formula to determine the length of barrel required to make one complete turn of the rifling.[61]

A visual comparison may be made without the previously mentioned equipment by placing the ends of the suspect and test bullets together and lining up the lands and grooves. Several observations may be made using this method. With the bullets held base to base, it can be determined if the bullets have a corresponding number of lands and grooves with similar widths. If the direction and pitch of the rifling twist are the same on both bullets, the lands and grooves on both bullets should form identical angles that will be seen as a continuous straight line (land or groove mark) that begins on the nose of one bullet and ends on the nose of the other. If the direction of the rifling is identical, but the pitch is different on both bullets, the continuous line across the bullets will form an angle where the bases meet. If the suspect firearm is unavailable for the production of a test bullet, sample bullets with known rifling characteristics can be used for comparison to determine the rifling's direction and pitch .

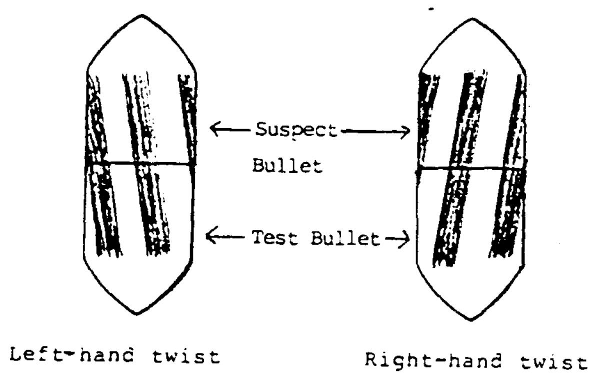

Figure 2. Base-to-Base Comparison of Bullets.

The direction of the rifling will be either left- or right-handed. The left-hand rifling is referred to as Colt-type rifling, and the right-hand rifling is referred to as Smith and Wesson-type rifling. The direction can be easily determined by observing the rifling marks on the side of a bullet. Viewing the rifling from the base of the bullet to the nose, the rifling marks will be noted to cant or twist slightly to one side of the approximate center axis of the bullet. If the marks twist to the right as they travel toward the nose, the rifling is right-handed. If they twist to the left, the rifling is left-handed. [62]

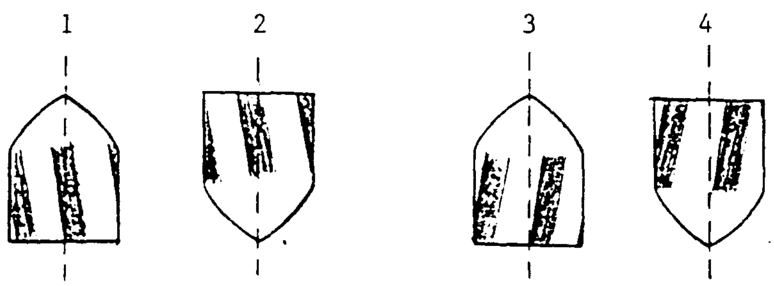

Figure 3. Rifling Twist on Bullets. Bullets 1 and 2 show left-handed twist. Bullets 3 and 4 show right-handed twist.

Class characteristics must be considered in light of all of the evidence that is present. Making a premature determination based upon what some would refer to as obvious, could be a mistake. The following example demonstrates how the consideration of the direction of the rifling found on a suspect bullet kept an innocent man from being charged, and the guilty going free.

A single .45 caliber bullet was recovered from the victim of a shooting. The investigators observed the bullet to have a full metal jacket, the type and weight normally loaded into ammunition for the Colt .45 Automatic pistol, and so assumed that the Colt Automatic was the suspect weapon they were looking for. A man was located in the area with a Colt .45 automatic pistol in his possession, and immediately became a suspect in the shooting. A local firearms expert that was given the opportunity to examine the suspect bullet found that the direction of the rifling on the bullet was right handed. Since the Colt automatic pistol characteristically has a left handed rifling, it would have been impossible for any Colt pistol to have fired the bullet. Of the handguns available at the time that could chamber and fire the .45 A.C.P. cartridge, only one had a right hand twist, the Smith and Wesson Model 1917 revolver. Therefore, taking all the class characteristics of the suspect bullet into consideration, the Colt Automatic could definitely be excluded. A proper conclusion would be that the suspect weapon was a .45 caliber firearm with a right hand rifling twist that could chamber and fire the .45 A.C.P. cartridge. This conclusion would include the Smith and Wesson Model 1917 revolver, or any other firearm with similar characteristics.[63]

One class characteristic that can be valuable for linking fired bullets with fired casings has to do with the cartridge itself. Some commercial and military ammunition have their bullet affixed to the casing with a stab crimp. The purpose of this type of crimp is to prevent the bullet from being driven out of the casing during recoil, or backward into the casing during feeding. The stab crimp is applied after the bullet is loaded into the casing by placing a rather deep indentation into the side of the case and bullet. Some manufacturers use several rectangular indentations spaced equally around the circumference of the case mouth, while others use a single dimple at one point on the case. The single dimple method is commonly used in foreign-made ammunition for pistols. The stab crimp marks may be evident on both the fired bullet and casing.[64]

Class characteristics that can be present on cartridge casings include extractor marks, ejector marks, marks from feeding and chambering the cartridge, firing pin marks and caliber denotations on the case head. One of the most readily identifiable characteristics is the shape and style of the casing. Manufacturers typically stamp their brand name and caliber designation on the case head for easy identification of the cartridge.[65] In military casings, the date of manufacture and the initials of the manufacturing plant are stamped onto the case head. Absent of a caliber designation, the shape and dimensions of the casing itself provide ample information to deduce the caliber of the cartridge. If the bullet and casing are both available, the possibilities of determining a definite caliber and chambering of the suspect weapon are increased.[66]

The combination of extractor marks and ejector marks evident on a casing form what is known as a "system". Different manufacturers arrange these parts on the breech in a way that is consistent with the firearm's designed method of extraction and ejection. The relative position of these marks gives evidence to the type and design of firearm that could have fired the casing.[67] Extractor and ejector marks may not be present on casings fired in a revolver. The slower, hand ejection of revolvers do not normally leave marks on the fired casings. Exceptions could be made where the chamber and extractor are not properly fitted, or high pressure ammunition is fired and the casings stick to the chambers. Creation of marks in this case would be possible. Single action revolvers have no provision for the cylinder to move away from the breech, and typically require the casings to be punched out of the chambers from the front through the loading gate in the rear of the frame. The part that punches the casings out is called the ejection rod. The ejection rod impacts the inside of the casing near the flash hole at the base, and can leave a mark during the process.

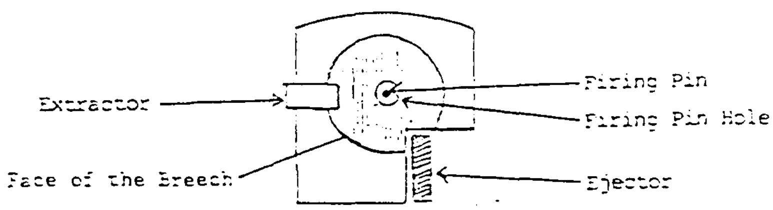

Figure 4. The location of various essential parts on the face of the breech form a "system" of extraction and ejection.

Some firearms have excessively long firing pins or designs that do not make a provision for the firing pin to fully rebound back into the breech before the casing is ejected. As a result, the firing pin nose tends to remain in its indentation on the primer throughout the extraction and ejection process. When the casing is forcefully ejected, the firing pin nose forms a scrape downward from the primer indentation at an angle relative to the position and action of the ejector.[68] An example of a firearm that leaves this type of mark as a class characteristic of its design is the Russian Tokarev 7.62mm semi-automatic pistol.[69] Firing pin scrape marks can also be produced by individual firearms that have become so fouled or rusted that the firing pin sticks in a forward position throughout the extraction and ejection process. Whatever the cause, firing pin scrapes are valuable evidence that can be used to identify a class of firearms that characteristically produce this type of mark when fired. Firing pin scrape marks are also useful in reorienting the fired casing correctly to the same position it occupied in the chamber of the suspect weapon.[70]

The shape of the indentation made by the firing pin is also a class characteristic on the casing. Differing shapes of firing pins are most common in rimfire firearms, but can also be present in certain types of centerfire guns. Manufacturers of rimfire firearms seem to adopt a firing pin shape that they feel is superior in crushing and detonating the primer. Firing pins can be any shape, and include round, square, trapezoidal and elliptical. The dimension and shape of the rimfire firing pin tends to become a standard within a particular make and model of firearm once it is produced in quantity.[71] In centerfire guns, the shape of the firing pin could be a peculiarity of an individual firearm visible and obvious to the naked eye. An elliptical shaped firing pin or one that possesses a unique facial defect could be considered a class characteristic that would exclude all other firearms without that feature.[72]

The depth of the firing pin indentation is not a class characteristic of any particular firearm. While it is true that firearms are machines and will always strike the primer with the same force each time they are fired, the depth of the indentation is dependant on the ammunition more than the firearm. To understand this, it is necessary to review the forces at work when the cartridge is fired. As the chamber pressure builds and the bullet is separated from the casing, the case head is forced backward onto the face of the breech. During this process, the firing pin is still protruding through the breechface at its maximum length. The rearward recoil force also tends to hold the firing pin at maximum length. If the pressure generated by the powder charge is sufficiently high, toolmarks on the breech face will be transferred to the case head and primer cup. The depth of the firing pin indentation will also correspond to the intensity of the chamber pressure during firing. The firearm's mechanical energy alone does not completely form the firing pin indentation. The cartridge's pressure level acts to perfect the final appearance of the indentation. Any given firearm, firing an assortment of cartridges with different pressure levels, will leave a different depth firing pin indentation on each one dependant on the pressure level of the individual cartridge.

Another ammunition-related factor that effects the depth of the firing pin indentation is how the ammunition headspaces in the chamber. For example, in rimmed cartridges with rims of narrow width, the case head may not be held closely to the breech face. Rimless cartridges that are too short, or have their shoulders formed improperly will travel too far into the chamber and leave a gap between the case head and the breech face. Even with excessive headspace, cartridges can still be fired if the firing pin protrudes far enough from the breech face to impact the primer. The most important point of this subject is that the depth of firing pin indentations are useless as a means of identifying firearms.[73]

Eccentricity is another class characteristic involving the firing pin indentation. Eccentricity involves the variance of the firing pin indentation relative to the center line of the bore. Fired casings may exhibit off-center firing pin indentations that indicate the firing pin is not in perfect alignment with the center line of the bore. The degree of eccentricity tends to remain constant for all casings fired by a particular gun, however some exceptions do apply. Some semi-automatic firearms may have excessive clearance between the firing pin and the firing pin hole in the breech. This condition could cause a variance in eccentricity on different casings fired in those guns because the firing pin is not held in the exact same position from shot to shot. Another possible cause of eccentricity involves the dimensions of the chamber. If the cartridge fits loosely in the chamber, it may not be sitting perfectly centered at the moment the firing pin strikes it. This condition could cause a variance in eccentricity as well as bulged casings. Eccentricity can only be reliably considered as a class characteristic if the suspect firearm is available for inspection.[74]

The angle at which the firing pin strikes the primer is an important class characteristic in determining the type of firearm that fired a particular casing. This is especially true in cases involving shotguns. Most semi-automatic, pump, single-shot and bolt-action shotguns have firing pins designed and situated for straight forward travel into the primer, similar to other centerfire firearms. However, side-by-side and over-under double barrel guns situate their firing pins to strike the primer at an angle. Over-under guns usually have the upper firing pin slanting downward and the lower pin slanting upward toward the center of their respective chambers.[75] Side-by-side shotguns can be manufactured with their firing pins slanting inward or downward, or on an angle traveling both inward and downward toward the center of the chambers.[76] The angle at which the firing pin impacts the primer will be evident in the primer indentation on the fired casing. Extractor marks that may be present in combination with the angle of the firing pin indentation can be used to determine the casing's possible position in the chamber at the moment of firing. From this determination, it can be suggested that a certain type of action was used to fire the casings.

Marks caused by feeding and chambering the cartridge can also be present on fired casings and unfired ammunition. Magazine-fed firearms have provisions to hold the cartridge in a particular position until the bolt or breech block forces it into the chamber. Firearms with tubular magazines have shell stops that prevent the cartridge from entering the receiver until the proper time for feeding. The shell stops can impart their mark to the case head as they catch, stop and release the cartridge. Most tubular magazines are mounted under the barrel, which makes it necessary to have a carrier or lifter that raises the cartridge in line with the face of the breech so it can be chambered. In some cases, the carrier will also leave a mark or scratch on the casing from the lifting and feeding process.[77] Examples of firearms of this type are semi-automatic and pump shotguns, lever-action rifles and various rimfire rifles of all types of actions.

Firearms that utilize a box magazine hold the cartridges in a vertically stacked position under the pressure of a magazine spring. The sides of the magazine are curved inward over the top, forming feed lips. The feed lips hold a cartridge in the breech bolt's line of travel when the bolt is at the rear of the receiver. As the bolt moves forward, its lower edge contacts the upper rear edge of the cartridge, moving it forward until it clears the feed lips and enters the chamber. The bottom of the bolt holds the next cartridge in the magazine down away from the feed lips during the firing sequence. As the bolt moves to the rear extracting the fired casing, it rides over the top of the cartridge in the magazine, scratching it. As the bolt clears the top of the cartridge in the magazine, the cartridge is pushed up to the feed lips by the magazine spring. Both the bolt and the cartridge are now in place to repeat the feeding cycle. As the cartridges are moved forward out of the magazine, the feed lips can scratch the sides of the casing. These scratches are sometimes very distinctive and reproducible and as such, can be useful in firearms comparisons.[78] While stripping the cartridge from the magazine during the feeding process, the lower edge of the breech/bolt can impact the case head of the cartridge with enough force to leave a mark on the case. This type of mark is usually more evident in semi-automatic and fully automatic firearms where the breech bolt attains a relatively high velocity during the cycling of the action.

Markings on casings that appear to have been made by feeding, extraction and ejection do not necessarily mean that they were made at the time the cartridge was fired. The sides of cartridges can be scratched as they are loaded into the magazine, revealing marks on the fired casings of both the manual loading into the magazine and the mechanical unloading from the magazine as the cartridge is chambered.

It is not uncommon for a person to practice loading and unloading cartridges from a firearm. These types of marks can be made whenever the cartridge is manipulated through the firearm. One of the casings found in the Dallas School Book Depository after the assassination of President Kennedy had three identical marks randomly located around the rim. The marks were identified as being produced by impacting the firearm's ejector. Obviously, the fired casing would have only been ejected once. It is suggested by the presence of the other two ejector marks that the cartridge had undergone the same mechanical operation of extraction and ejection at least two other times before it was actually fired. One explanation for this is that the cartridge was marked by the ejector during some type of practice or dry-firing operation.[79]

Desperate persons who may have difficulty in obtaining the proper ammunition for their firearm may resort to make-shift methods in making ammunition they do have work in their firearm. Some suspect bullets may present very little or no rifling engraving on their bearing surfaces. This phenomenon occurs when an undersized or sub-caliber bullet is fired through a firearm. For example, the .32-20 cartridge can be chambered and fired in the .38 special or .357 magnum revolver. Other sub-caliber cartridges can have adhesive tape or paper applied to the casing to obtain a friction fit in the chamber. Revolver cartridges with their rims filed off can be chambered and fired in semi-automatic pistols. An example of this would be the .32 Colt revolver cartridge, with its rim removed, being chambered and fired in the .32 semi-automatic pistol. Other, more daring individuals may even attempt to drive a slightly larger cartridge into the chamber of a firearm with a hammer.[80]

The investigator should also be aware of other possibilities involving suspect bullets and the weapon that might have fired them. Using a device known as a chamber adapter, it is possible to fire cartridges of lesser length and/or diameter in firearms of similar nominal caliber. For example, .25 A.C.P. cartridges may be fired in any pistol or rifle having a nominal caliber of .250", .256" or .257". Pistol or revolver cartridges of .32, 7.62mm or 7.63mm caliber may be fired in any rifle having a nominal caliber of .300", .303" or .308". Other combinations of chamber adapters are possible with other calibers of cartridges, and are limited only by the caliber of the host firearm.[81] Using chamber adapters in firearms with a similar nominal caliber will produce bullets with the same rifling qualities as the firearm that fired them. Breechface markings on the fired casing will also reflect the features of the firearm that fired them.

Another type of chamber adapter exists that fires a bullet of smaller diameter than the nominal bore diameter of the firearm. These adapters may be manufactured out of scrap pistol barrels that have their own rifling characteristics. If properly made and installed, these adapters could fire a bullet that would not touch the interior of the host firearm's barrel. An example of this type of adapter was made by the author out of an old .45 A.C.P. barrel to fit the chamber of a 12 gauge shotgun. Bullets fired from this adapter have the rifling characteristics of the Colt .45 semi-automatic pistol. The breechface markings on the fired casing would exhibit the qualities of the particular 12 gauge shotgun that the adapter was chambered in when the cartridge was fired. These types of adapters could be made from any rifled barrel that was sub-caliber to the host firearm, and would be limited only by the imagination and skill of the gunsmith who produced them. Using only the evidence of the bullet and possibly the casing, any speculation about the type of firearm that fired the suspect bullet would be faulty. It would be impossible to replicate test bullets from a suspect firearm for comparison purposes without the benefit of the particular chamber adapter used in the firearm when the suspect bullet was fired.

Investigators should be aware of the various methods available to the criminal in launching his projectiles during the commission of an offense. Much thought should be given to not only the likelihood of a particular firearm being the one that fired the suspect bullet, but also to the possibilities of modifying a firearm to make it fire the type of bullet under suspicion. Declarations based on the class characteristics of the evidence should be generic enough to avoid limiting the scope of a search for the suspect firearm.

CHAPTER 5

THE IDENTIFICATION OF FIREARMS

The modern method of firearms identification was pioneered by two men who worked in professions that are not traditionally considered typical for firearms identification work. The comparison microscope was designed by Philip Gravelle, a famous microscopist and photographer, in the 1920's. The comparison microscope was originally invented for commercial ventures in industry to do such tasks as compare the color of pigments and the width and texture of fabric. However, Mr. Gravelle possessed a keen interest in firearms that lead him to envision other uses for his invention. With his knowledge that manufacturing left subtle imperfections on the internal surfaces of firearms, Gravelle realized that his invention could overcome the fallibility of the human memory when looking at a succession of bullets under the microscope and trying to compare them. The comparison microscope was first used in 1927 by Dr. Calvin Goddard. Dr. Goddard was a physician who had an intense curiosity about ballistics and firearms. He was so intrigued by firearms, he changed his specialty from medicine to ordnance during his tour of duty in the Army during World War 1. Later, back in civilian life, he resumed his medical practice at Johns Hopkins University, and became one of the leading firearms examiners in the country.[82]

In firearms identification, there are three possible conclusions that can be reached through a microscopic comparison of suspect bullets or casings with a suspect firearm. Any one of the three reveal vital information to the criminal investigator that will affect the course of his investigation. The three conclusions are:

1. The bullet and/or casing was fired by the suspect weapon.

2. The bullet and/or casing was not fired by the suspect weapon.

3. Insufficient microscopic markings remain on the bullet and/or casing to determine if it was fired by the suspect weapon, or the condition of the weapon precludes the possibility of making an identification.[83]

Obviously, if a positive identification between the suspect bullet or casing and a suspect firearm can be made, the investigator has hard and fast evidence that can indict a suspect. In the case of a conclusion that states that the firearm under suspicion definitely did not fire the suspect bullet or casing, the investigator is informed that the true actor and his firearm are still undetected, and more work needs to be done to find him. The third conclusion provides the investigator with notice that, due to the lack of microscopic evidence remaining on the object, it is impossible to link the suspect bullet or casing with any firearm. This last conclusion is perhaps the most irritating, for while it may be possible to identify some of the class characteristics of the firearm that fired the bullet or casing, it will never be possible to make an absolute conclusion about the individual firearm that fired them.

Comparison Evidence On Cartridge Casings

The consideration and comparison of the class characteristics of a suspect casing with the known qualities and features of several groups of firearms serve to narrow the field of firearms that could have fired the suspect casing. Once the field is narrowed to a few select possibilities, other features on the casing are compared that can be regarded as obvious peculiarities of the suspect casing within that field of firearms. Features such as the shape and location of the firing pin indentation, or the shape of a damaged firing pin hole in the breech face are considered that may be unique to the suspect casing, or if not totally unique, shared by only a very few other firearms within that group of firearms. This process of narrowing the field of possible suspect firearms is similar to the classification and sub-classification work done by a fingerprint examiner in preparation for a one-to-one comparison between a latent print and inked impressions of one or more known individuals. Just as consideration of the broader qualities of the latent print enable the fingerprint examiner to weed out all other prints that could not have been made by the suspect, consideration of the broader qualities of the suspect casing enable the firearms examiner to weed out the firearms that could not have made the imprints on the suspect casing.

The uniqueness of the breech face, firing pin, extractor and ejector have been widely referred to as one of the firearm's 'fingerprints'. Dr. Calvin Goddard, one of the pioneers of American firearms identification stated that there are two definite fingerprints made by a firearm on the cartridge casing each time it is fired; one by the firing pin, and one by the breech face on the primer cup.[84] While the marks made by the other parts of the firearm on the cartridge casing can be used as class characteristics to narrow the field of suspect firearms under consideration, they cannot be used to definitely identify a singular firearm as the one used to fire the suspect casing. If these other marks are used to identify a firearm as suspect in a given case, it can only be stated with certainty that the suspect casing was chambered in the identified firearm, not that it was fired in it.[85] The reason for this is the obvious fact that a cartridge can be chambered in countless firearms before the trigger is pulled on one of them and the round is discharged. Further, the fingerprint created on the soft brass of the primer cup is a static imprint of the breech face that can only be made by the intense pressure of the burning gun powder in the chamber after the firing pin impacts the primer.[86]

In the comparison of firearms evidence such as casings, it should be noted that the breech face and firing pin themselves are not directly compared to the suspect casing. The scratches and imperfections on the face of the breech and the nose of the firing pin are positive images of the fingerprint of those parts, and could be likened to the actual finger of a suspect before the latent print is made on the evidence. Fired casings possess a negative image of the firearm's fingerprint. Ridges that are present on the breech will be evident on the casing as furrows, and vise versa. The suspect casing can be considered a latent fingerprint of an unidentified firearm, and the test casings that are fired in a known firearm can be considered the inked impression of an identified individual. In order to conduct a comparison of any type, test casings must be produced by firing cartridges similar to the suspect casing in the suspect firearm. Therefore, the comparison to determine positive identification between a suspect casing and a suspect firearm is conducted by viewing the negative images made by firearms on the fired casings.[87]

When the firearms examiner has obtained test casings of known origin that share a large percentage of the class characteristics of the suspect casing, a casing-to-casing microscopic comparison is in order. At this point, the number of suspect firearms has usually been narrowed down to one or two that could have fired the suspect casing. The test casings are compared with one another to select the one that possesses the greatest number of peculiar markings that appear to be in common with the suspect casing. The suspect casing is then compared with the selected test casing using a comparison microscope on low power to determine if they share the same pattern of breech face markings. The comparison microscope is actually two separate microscopes that share a common bridged eyepiece. The images of both casings are projected into the eyepiece and viewed simultaneously in a split field. While viewing the marks from both casings, they are alternately rotated until the corresponding marks are brought together in the field of view, separated only by the dividing line of the comparison eyepiece. When the marks form a consistent pattern between both casings, the lines or scratches will appear to begin on one casing and continue onto the other. The composite view of both casings will appear the same as individual views of the separate casings by reason of the continuation of the matching scratch marks across the division between the casings. When a match like this is made, it can be shown beyond any reasonable doubt that the casings were fired from the same gun.[88]

When a positive match has been determined through the comparison microscope, the match must be documented photographically. Photographing the visual match enables the firearms examiner to document his findings, based on an examination of the evidence, for presentation in court. Several techniques can be employed that will demonstrate the quality of the match in a different way. A photograph of the split image as seen through the comparison microscope is useful if the evidence can best be presented in that format. However, in the case of firing pin impressions, or to illustrate the area around the firing pin impression, a cut out method is preferred. In this method, the area surrounding the firing pin on the photograph of the test or suspect cartridge is cut out and affixed in perfect alignment with the scratch marks of the other. This shows a continuity of the marks relative to the firing pin indentation. Another method is to take a split image photograph through the comparison microscope, with the ocular split over the point of the peculiar mark in or around the firing pin indentation. This illustrates the continuity of the marks in relation to a unique or characteristic mark on the firing pin indentation.[89] A collage of photographs can be used in circumstances where it is desirable to demonstrate the continuity of a mark that may be repeated several times on one or more casings. An example of this would be the comparison made on the ejector marks found on the casings located in the Dallas School Book Depository after the assassination of President Kennedy which was discussed previously. A collage of three separate photographs made under the microscope was presented as firearms evidence during the investigation which showed a positive match of all three of the marks.[90] Examiners should choose the best method for photographically illustrating their findings, so that a jury can see for themselves that a match exists.[91]

Comparison Evidence on Bullets

The marks made on the bearing surface of the bullet by a firearm's rifling are unique to the firearm that created them, and cannot be duplicated by any other firearm. With the modern manufacturing methods available today, it would seem possible to create two barrels of identical dimension and surface quality. However, there are no two barrels in the world that will engrave a bullet in the exact same way, anymore than there are two people in the world that will leave the same fingerprint.[92] Even with advanced techniques of machining that leave very few marks in the barrel, imperfections still remain that will always cause striations on a bullet when it passes down the bore. Under the microscope, these striations will be evident and identifiable.

Test bullets today are fired through the suspect firearm into a media that is known to stop the bullet intact. Suitable media include oiled cotton fibers, oiled sawdust or water. However, prior to World War 1, bullets were not test fired through the firearm, they were pushed through the barrel with a suitable rod. One of the first judicial decisions to stand on solid footing in the United States was Commonwealth v. Best, a Massachusetts case decided in 1902. In this case, the defense objected to testimony comparing the photographs made of the suspect and test bullets, arguing that the forces impelling the bullets were different in kind, and that the bore of the barrel might have rusted in the time between the shooting and the test bullet being forced through the barrel. In an opinion by Oliver Wendell Holmes, then the Chief Justice of the Massachusetts Supreme Court and destined to become a Justice of the United States Supreme Court, it was held that, "the sources of error suggested [by the accused] were trifling. We see no other way in which the jury could have learned so intelligently how that gun barrel would have marked a lead bullet fired through it."[93] This decision underscored the value of firearms comparison evidence regardless of the physical method used to obtain it. The scientific validity of the comparison was the paramount issue in the mind of the court, not the way in which the bullets were forced down the bore. It must have been evident in the photographs taken of the suspect and test bullets that they were engraved with identical striations, and therefore had both passed through the same barrel.

The decision in Commonwealth v. Best did not have any bearing on other cases for several years. It seemed that The Courts in other States ignored the decision rendered in the Best case for almost twenty-seven years. In fact, some Court's attitudes toward the subject of what was referred to as "ballistics evidence" displayed an overt effort to denounce its validity in court. As late as 1923, the Illinois Supreme Court labeled ballistic evidence as "preposterous" in an opinion handed down in People v. Berkman. However, in 1928 and 1929, The Supreme Court of Kentucky published lengthy opinions supporting the scientific validity of ballistics evidence. These opinions were the beginning of widespread judicial acceptance of firearms identification through bullet comparison.

Whether the Courts universally accepted firearms evidence or not, the experts that worked closely with the evidence during this period of time were well aware of its validity and its incriminating power. In what has been heralded as the most notorious criminal case of the twentieth century, this point was made clear.[94] On the afternoon of April 15, 1920, Frederick Parmenter, a paymaster for a Massachusetts shoe company, and Alessandro Beradelli, a guard for the company, were delivering a $15,776 cash payroll to the company's factory when they were robbed by five armed men. Both victims were murdered during the commission of the robbery. On May 5, 1920 two men named Sacco and Vanzetti were arrested and charged with the murders. Extensive firearms evidence was introduced during the trial, and virtually every known firearms expert on the east coast was called to testify. Several bullets removed from the bodies of the victims and several casings from the crime scene were suspect in the case, and a positive identification was required to turn the evidence against Sacco and Vanzetti from circumstantial to real. It was determined that the majority of the suspect bullets and casings were fired from a .32 A.C.P. caliber Savage pistol which was never found. However, the issue at trial was the identity of the firearm that fired the "mortal bullet" removed from the body of Beradelli. It was suspected that the bullet and several of the suspect casings were fired from a Colt .32 pistol found on Sacco at the time of his arrest. Several expert witnesses for the prosecution testified that the suspect bullet and some of the casings were definitely fired from Sacco's pistol.[95] Dr. Albert Hamilton, who was ultimately called as an expert firearms witness for the defense, testified that neither the suspect bullet or the suspect casings could have been fired in Sacco's pistol. (As a point of reference, Dr. Hamilton was also the firearms expert used by the prosecution in the Stielow case described previously that erroneously caused Stielow to be convicted of a murder he did not commit.)[96] Although Dr. Hamilton testified that he did not believe Sacco's pistol fired the "mortal bullet" recovered from Beradelli's body, he committed an incredible act during the trial that lends a degree of doubt not only to what he truly believed, but also to his professional ethics. At the end of his testimony on the Hamilton-Proctor motion, he exchanged the barrel of Sacco's pistol with the barrel of one of the new Colt pistols he had used for a demonstration. The judge stopped Dr. Hamilton before he was able to leave the courtroom with the barrel from the evidence pistol in his pocket.[97] Whether this switch of the weapons' barrels was deliberate or accidental has never been determined, however it does make a reasonable person wonder if Dr. Hamilton was fully aware that Sacco's pistol had fired the suspect bullet, and had not only perjured himself, but was also attempting to destroy incriminating evidence.

The precedent-setting case for the validity and admissibility of firearms evidence was finally decided by the Kentucky Court of Appeals in 1929 in Evans v. Commonwealth. This was a manslaughter case in which the Court of Appeals held that a witness qualified as a firearms expert could illustrate by blackboard drawings that tool marks on different pistols were so different as to permit identification of the bullets fired from the respective weapons. The Court also permitted the firearms expert to demonstrate his ability to identify the bullets fired from each of the pistols by setting up a comparison microscope in the courtroom with the bullets prepared for comparison. The jury was then allowed to view the striation engraving on the bullets through the comparison microscope for themselves, making individual assessments of its worth and validity. The Court of Appeals held that allowing the jury to view the evidence in this manner was not erroneous or prejudicial in any way. The Court also held that the evidence of a firearms expert identifying bullets as being fired from the pistol of the accused was properly admitted and was not of such a highly technical, unreasonable and extremely doubtful nature as to make it inadmissible. In 1930, the Supreme Court of Illinois published an opinion in People v. Fisher that reversed its prior opinion that ballistics evidence was preposterous.[98] Today, trial courts will take judicial notice of the reliability of firearms evidence when it is presented through qualified witnesses.[99]

Even though the aim of the firearms identification process is the discovery and identification of the firearm that fired a particular suspect bullet, it should be noted that the actual comparison is carried out on bullets that have been fired through the bore of a firearm, not on the firearm itself.[100] An examination of the bore with a helixometer can provide an accurate measurement of the pitch of the rifling, and the presence of any foreign particles or rust spots in the bore. However, it would be impossible to arrive at any meaningful conclusion pertaining to the identification of an individual firearm and the suspect bullet by examining the interior of the barrel itself.[101] The reason for this is the manner in which the evidence markings, or striations, are created on the surface of the bullet. Unlike the markings found on fired casings, which are caused by a direct impact with the breech or firing pin, bullet striations are formed by the bullet sliding past rough spots on the lands and grooves over the entire length of the barrel.[102] The bullet is scratched by every rough spot it passes on its path down the bore. The striations that remain on the bullet when it leaves the muzzle are made by the most prominent features on the lands and grooves that last contacted the bearing surface of the bullet. It should be noted that the top of the lands in the barrel is actually the remaining portion of the hole that was initially drilled and reamed in the barrel before the rifling was applied. Although it is possible to polish most of the obvious imperfections out of the bore before rifling the barrel, it is impossible to obtain a surface on the steel that will not mark a bullet as it moves down the barrel.[103]

The lands of the barrel tend to leave a more distinct mark on the bullet than the grooves, and are usually relied on more heavily for identification purposes. The reason for this is that the lands tend to bite deeply into the bearing surface of the bullet, leaving a very distinct mark. If the bullet is too small, or the bore of the barrel is too large, the bullet may not touch the bottom of the grooves, and would consequently have either no groove mark or only a very light groove mark engraved on its surface.[104] Lead bullets tend to conform to the full bore diameter more easily than jacketed bullets. Because of its harder gilding metal jacket, the only markings that are reliably transferred to a jacketed bullet are those made by the lands.

Before it is practical to undertake a microscopic comparison of the suspect bullet and the test bullet, the class characteristics of both bullets must be identical. It would be a waste of time to consider conducting a microscopic comparison between a .45 caliber suspect bullet having a five groove left hand twist and a .38 caliber test bullet having a six groove right hand twist. The class characteristics of both bullets must be identical before proceeding with any closer comparison or examination. When a test bullet from a suspect firearm is found to match the class characteristics of the suspect bullet, a microscopic comparison is in order.

The bearing surface of the bullet near the base of the bullet should be the area where the most distinctive engraving is located. If groove marks are present on the bullet, they will likely be found near its base. There are two reasons why the bearing surface at the base of the bullet usually contains most of the recognizable engraving detail. First, most bullets will exhibit heavy damage on their noses from impacting the target. Therefore, the base of the bullet may be the only location where striation evidence can be located and compared. Second, the base of the bullet receives the full force of the chamber pressure as the bullet is pushed down the bore. The bullet tends to disrupt under the pressure, causing the base to conform to the shape and dimension of the bore.[105]

Five or more test bullets should be fired through the suspect firearm for initial comparison with each other. The test bullets should be compared under low magnification to determine which one possesses the most outstanding or prominent striation engraving. A family similarity should be shared by each bullet on each corresponding land. This initial examination will give the examiner an idea of what types of qualities might be shared by five or more bullets fired from the same gun. The test bullet possessing the most distinct striation patterns should be selected for comparison with the suspect bullet.

When the best test bullet is selected, it is mounted in the comparison microscope and compared with the suspect bullet. The land on the suspect bullet having the most prominent striation pattern is compared with each land on the test bullet. When a match is obtained, the striae on both bullets should appear as a continuous pattern that begins on the surface of one bullet, and flows across the field of vision, ending on the other bullet. In appearance, a successful match of striae will appear as the surface of a singular bullet, absent the center dividing line of the comparison ocular.

The process is repeated until every existing land on the suspect bullet is compared with every corresponding land on the test bullet. If no matching striation pattern can be found after careful comparison of all the lands on each of the bullets, a conclusion can be reached that the firearm that fired the test bullet is not the same firearm that fired the suspect bullet. However, if a matching striation pattern is located, the comparison process should also reveal a family resemblance on all the corresponding lands of both bullets. Beginning with the land that possesses the matching striation pattern, both bullets should be rotated in unison to the next land and closely compared. If a matching striation pattern is found on every corresponding land of both bullets, the conclusion that they were both fired from the same barrel is irresistible.[106]

When a matching pattern of striations is found on both the suspect and test bullets, a photographic record should be made to document the findings of the examiner. The photograph should be made through the ocular of the comparison microscope, similar to the procedure outlined previously for fired casings. The photograph is intended to depict the features of the striae on both bullets as they appeared to the examiner at the time the photograph was taken. The field of vision as seen through the ocular should be split with the suspect bullet on one side, and the test bullet on the other. The striations should be aligned as closely as possible between the two images to demonstrate the extent of the match. The aim of photographing the match is to produce an image identical to the one the examiner saw when he became convinced that the two bullets were fired from the same barrel. The photograph may then be presented later in court, in lieu of setting up the comparison microscope and evidence for individual jurors to view, enabling the jurors to see the match for themselves and draw their own conclusion.[107]

The suspect bullet should then be compared with the other test bullets to verify the consistency of striation patterns on other known bullets. This subsequent comparison with other test bullets will negate any claim by the defense that the examiner used only that evidence which would give favorable results. The suspect bullet should also be compared with bullets from similar firearms having the same class characteristics. This effort would show that the suspect bullet not only corresponds with known test bullets from the suspect firearm, but that it does not correspond to known test bullets from guns of the exact same type as the suspect firearm.[108]

Accidental marks or striations on a bullet can be troublesome, but are easily explained. Accidental marks can be caused by a particle of dirt or metal fouling in the barrel at the time the bullet was fired. Obviously, when that particle is blown out of the barrel or carried out with the bullet, it will not be present to mark subsequently fired bullets. An accidental mark present on one test bullet, but absent from others fired after it support this explanation, and show that accidental marks should be disregarded if all other identifiable surfaces on both the suspect and test bullets match.[109]

Several other marks that sometimes appear on fired bullets can also be perplexing unless it is clearly understood how they are made. When the rifling marks are observed on a bullet to be wider at the front than they are at the base, the wider portion is referred to as a skid mark. When the bullet first separates from the casing, it moves straight forward without any axial spin until it makes contact with the rifling in the bore. The bullet's resistance to begin spinning under the influence of the rifling causes it to skid straight ahead for a short distance before it begins to spin. The barrel's lands tend to plow a furrow along the bearing surface of the bullet until the bullet's resistance to axial spin is overcome, and it begins to rotate.[110] Skid marks are not considered to be of any value in the firearms identification process because they are formed by the lands at a different angle than normal rifling striations.

Shaving marks on the noses of bullets are sometimes encountered, where it appears that a portion of the side of the bullet nose has been sheared away. Shaving marks only appear in revolvers with actions that are out of time and do not reliably align the chambers with the breech end of the barrel at the moment of firing. If the firing pin detonates the cartridge before the chamber is perfectly aligned, the bullet impacts the side of the forcing cone at the rear of the barrel. When this occurs, the portion of the bullet impacting the outside edge of the forcing cone is sheared away. It is possible for a revolver to split a bullet in half if the action is in very poor condition. Because the revolver may only shave a portion of the bullets it fires, it may be difficult to reproduce this effect when attempting to acquire test bullets for examination and comparison.[111]

Firearms identification through bullet comparison is very reliable, providing that enough of the suspect bullet remains for a comparison. Obviously, if the suspect bullet has no appreciable striation marks or engraving left on its bearing surface, there is nothing to compare with subsequent test bullets. Similar cases may present themselves where the damage to the engraving is done inside the firearm instead of at the target on impact. Severe corrosion of the bore can all but obliterate striations made by the rifling. A suspect bullet fired through a barrel with a completely rusted bore will have striation engraving on its exterior that will in no way resemble the striation created on a bullet fired from a barrel which is perfectly clean. It is possible to identify the suspect bullet with the suspect firearm if the rust has not been removed by cleaning or repeated firing, either by the suspect or the examiner trying to get large numbers of test bullets. The test bullet fired in immediate succession to the suspect bullet from the suspect firearm will most likely show similar if not identical striation engraving from the rust in the bore. As more bullets are fired through the rusted barrel, the soft, brittle rust is gradually worn away, and identification between the suspect bullet and the last test bullet fired through the suspect firearm becomes less likely, if not impossible. For this reason, no more than five test bullets should be fired through a rusted bore, and they should be marked in a way to show their order of firing.[112]

The problems in securing an admissible identification in rusted firearms is demonstrated in a murder case where the defendant was known to have a physically violent argument with the victim shortly before the offense. After the argument, the defendant was thrown out of the victim's place of business and immediately went to his residence and obtained an old rusty revolver which he owned. The victim was later found dead, killed by gunshots fired by an unknown person. The firearms examiner found that the cylinder of the defendant's revolver fitted badly, and had a prominent patch of rust in the bore. The suspect bullet showed a shaving mark on the nose as if the cylinder had been poorly aligned at the moment of firing, and exhibited striations that appeared consistent with the location of the rusty patch in the bore. One test bullet was fired through the revolver, and the examiner was able to secure a positive identification between it and the suspect bullet. The examiner then proceeded to fire fifteen more test bullets through the revolver for comparison with the suspect bullet. The friction of each bullet passing over the rusty patch so effectively removed the scale that had marked the suspect bullet and the initial test bullet, that positive identification was impossible on the other fourteen test bullets. When the case went to trial, the examiner testified that he obtained identification on the first test bullet fired from the revolver.

On cross examination, the examiner was asked if he had fired additional test bullets, to which he replied that he had fired a total of fifteen. When asked if he obtained a match on any of the subsequent test bullets, he replied that he had not. The only positive match was obtained on the first test bullet. As a result, the defendant was acquitted.[113]

In a case where the bore was rusted after the firing of the suspect bullet, an examination with a helixometer should be made of the bore to determine the extent of the rust and its exact location. If the bore is not too badly rusted, most of the rust scale can be removed during a thorough cleaning of the barrel by soaking and judicious scrubbing. However, care must be taken not to scratch the bore with the cleaning tool or the loose rust scale. If the rust was not extensive enough to pit the bore, and the rust scale was successfully removed without scratching the bore, adequate test bullets may be obtained that will possess much of the same striation engraving of the suspect bullet.[114]

Metal fouling in the bore can have a similar, less severe effect on the ability of a firearms examiner to find comparable areas of striation engraving on the bullet's surface. Metal fouling can accumulate in the bore from the heat and friction of firing, wearing small portions of the bullet exterior off as it engages the rifling and begins to accelerate down the bore. This type of fouling is usually limited to the portion of the bore closest to the breech, and may be composed of lead, copper or nickel from the bullet's outer surface or jacket. Metal fouling usually only occurs at high bore temperatures, extreme bullet velocities or in barrels that are excessively rough. When metal fouling is deposited in the bore, its particles also form striations on the bullet as it passes by.[115]

Even without metal fouling present in the bore, a soft lead bullet can be disfigured beyond comparison if it is fired at an abnormally high velocity. In this case, the bullet is forced to engage the riflings at such a high velocity that its soft bearing surface cannot hold a grip on the rifling lands and achieve axial spin before it leaves the muzzle. The lands literally strip the bearing surface off of the exterior of the bullet in their attempt to impart axial spin to it. The practical result is that the bullet would possess one great skid mark on its exterior, and may have very little striation engraving of any value that could be used in a comparison with test bullets. A measurement of the bullet in this case may also reveal that its diameter has been appreciably reduced by the lands shaving metal from its bearing surface.

Criminals have often sought ways to conceal the identity of their weapons after the fact by damaging them in some way. In Edwards v. State, a Maryland case decided in 1951, the accused had removed the rifling in his firearm with steel wool to prevent comparisons of the bullet. In spite of his attempt to prevent the identification of his firearm through bullet comparison, the firearm was identified by breech face markings on the fired cartridge casings, and subsequently entered into evidence.[116]

Some other firearm barrels have been bent, flattened or shortened in an attempt to thwart the comparison of bullets by firearms examiners. In most cases, flattened barrels can be restored to round and bent barrels may be straightened or fired as they are. However, shortened barrels sometimes result in inconclusive examinations. As a bullet passes through the bore, striations made on the bullet by the rifling at the breech of the barrel may be obliterated by other striations produced by the rifling near the muzzle end of the bore. Consequently, the striations made on test bullets fired through the suspect firearm after the barrel is shortened may not exactly match the striations on the suspect bullet.[117]

Other firearms may present problems in matching their bullets even when they are in good condition. One source stated that as many as 80% of the replicate test bullets fired through .22 caliber guns could not be identified with each other. Consequently, the identification of a suspect bullet with replicate test bullets could not be expected. In larger calibers, 80% of the guns examined produced replicate test firings. The identification of a suspect bullet with replicate test bullets in larger calibers seems more probable than an identification when .22 caliber bullets are involved.[118] The reasons for this phenomenon were not stated, and are possibly not completely understood.

Several studies have been undertaken to determine the likelihood of two consecutively rifled barrels having the same "fingerprint" under the microscope. One test, conducted in the United States on pistol barrels, used a rifled barrel blank that was cut into six different pistol barrels. One bullet was fired through each barrel and then shipped to a firearms examiner in Chicago. The examiner was able to match the fired bullets correctly with their respective barrels. The explanation offered for the outcome of this experiment was that the rifling cutter was blunted or dulled as it passed through the bore. In other words, the surface of the steel at the beginning of a cut to form a groove in the barrel was different than the surface of the steel at the end of the cut. Therefore, any length of barrel cut from a given blank, no matter how uniformly it was manufactured, would possess its own identity or fingerprint.[119]

Another test, conducted in England, used four .38 caliber Webley and Scott revolvers fitted with barrels that had been consecutively rifled on the same machinery. The single cutter rifling method was used, and the same rifling cutter was used on all of the barrels. Five bullets were fired through each revolver and the bullets compared under the microscope. It was found that all bullets could be matched to the particular revolver that fired them with no problem whatsoever. It was also found that some of the more prominent striations present on one groove of the first revolver were also present on one groove of the second revolver. Likewise some of the more prominent striations on one groove of the second revolver were present on one groove of the third revolver. However, no match of any features could be made between the fourth revolver and the other three. It was noted that the matches obtained on singular grooves of the different revolvers had only the deepest scratches and striations in common. The microscopic striation engraving on all the grooves was found to be unique for each revolver barrel, with none of the microscopic qualities shared among the different guns.[120] Since the grooves examined on the test bullets were actually formed by the lands of the barrel, this test indicates that any similarity in the rifling of two or more barrels, consecutive or not, is more dependant on the drilling and reaming process than the rifling process. The grooves of the barrel where the rifling marks are made may not leave adequate striation markings on the bullet if the bullet does not completely fill the bore and bottom out in the grooves.[121] This finding also tends to show that the method of rifling the barrel would have less impact on the individuality of a given barrel than the way it was drilled and reamed before the rifling was applied.

The wear in a barrel from prolonged firing is another matter for discussion. As a barrel wears, the bore diameter is slowly enlarged through the wearing away of the steel by the friction of the bullet. Naturally, as the metal is microscopically removed from the lands of the barrel, the features it imparts to the bullet in the form of striation engraving is also changed somewhat. The velocity and composition of the bullet have a direct effect on the rate at which this wear takes place. Lead bullets, fired at subsonic velocities could change the microscopic appearance of the finer bullet striae after approximately fifty rounds. Jacketed bullets, fired at slightly higher velocities could change the microscopic appearance of the finer bullet striae after approximately twenty-five rounds. While the microscopic appearance of the finer bullet striae do change after each bullet is fired through the barrel, test bullets may still possess some of the deeper striations found on bullets fired earlier through the same gun. Prolonged firing through a gun barrel does produce wear and change. However, the firing of a reasonable volley of test bullets, usually no more than five, would not appreciably change the bore enough to deny identification with the suspect bullet.[122]

An example that would illustrate the ability of a firearms examiner to make an identification between two or more guns firing a massive string of bullets all at one time would be the Saint Valentine's Day Massacre. On February 14, 1929, seven members of the "Bugs Malone" gang were killed by machine-gun fire inside a garage in Chicago. It was suspected, and widely held, that the police had executed the victims because some of the actors gained access to the building by dressing in police uniforms. Because of the seriousness of the offense, and the potential involvement of corrupt police officers, the official in charge of the investigation formed a group of civilian professionals to assist in rendering a conclusion. One of the civilians asked to participate was Dr. Calvin Goddard, one of the county's leading firearms examiners. Dr. Goddard examined each fired casing and bullet, recovered from both the crime scene and the bodies of the victims. It was determined that two firearms were used in the offense, a .45 caliber Thompson submachine-gun with a 20 round box magazine, and a .45 caliber Thompson submachine-gun with a 50 round drum magazine.[123] All of the suspect bullets and casings were compared with test bullets and casings from the police inventory of Thompson submachine-guns, and it was found that none of these weapons had been used in the commission of the offense. After a while, the case was solved when a suspect was apprehended with a Thompson submachine-gun in his possession that matched a portion of the suspect bullets and casings.[124]

Even after a submachine-gun had fired round after round of .45 caliber ammunition down its barrel during automatic fire, its barrel could still be identified with the bullets it had fired. The point to be made in this case is that the wear of continued and prolonged firing does wear the firearm's barrel and change the microscopic striae in its bore, however, new striae are deposited where the old are worn away. Although it is possible to change the identity of a barrel in microscopic proportions with each bullet fired, it is impossible to take its identity away.[125]

CHAPTER 6

COMPARISON EVIDENCE ON UNFIRED CARTRIDGES

Unfired cartridges may bear identifiable toolmarks on both their bullet and casing. These marks are of no value unless they were formed by interior contact with an identifiable firearm that can be found in the possession of a suspect. In most cases, the only conclusion that can be drawn from these types of toolmarks is that the cartridge was fed and chambered into, then extracted and ejected from the suspect firearm. An example of this was given previously where the casings found in the Dallas School Book Depository after the assassination of President Kennedy showed multiple ejector marks on the case head from being forcefully ejected from the firearm several times before the cartridge was actually fired. In addition to marks on the casing from repeated chambering and extraction, the bullet may also show marks on or about its nose where it impacted the feed ramp of a semi-automatic firearm as it was fed from the magazine into the chamber.

Obviously, no inference can be made that an intact cartridge was fired in any firearm, however, a firing pin indentation on an intact cartridge can indicate that an attempt was made to fire the cartridge, and the detonation was unsuccessful. Other evidence may be apparent on the cartridge that could indicate that the firearm malfunctioned while attempting to feed it. In semi-automatic firearms with faulty magazines, the next cartridge to be fed is sometimes released from the magazine too early or too late, resulting in the firearm's action jamming over a round that is in an improper position to enter the chamber. If the cartridge is released too early, the nose of the bullet may show a mark where it was jammed into a portion of the receiver by the bolt, preventing the bolt from closing and the round from entering the chamber. Marks may also be present on the case head where the bolt impacted as it attempted to feed the round and close the breech. If the cartridge is released from the magazine too late, a large dent or scrape mark may be present on one side of the casing where the bottom of the bolt impacted the side of the casing instead of the case head. This same situation could occur if the cartridge hung in a lower position in the magazine and failed to rise in line with the bolt before the bolt began to move forward. Marks may also be present on the nose of the bullet if it contacted the feed ramp, chamber or other parts of the receiver before jamming the bolt. Intact cartridges such as these may be found at the scene of an offense with other fired casings. If the firearm was jammed by one of the causes listed above, and the actor desired to fire more cartridges, he would be compelled to clear the jammed cartridge from the firearm before he could continue firing. If a fired casing is found that exhibits the characteristic marks of a jammed cartridge, it may indicate that the actor was able to manipulate the action and chamber the jammed cartridge, or that the cartridge was reused after a previous jam prior to the offense or immediately after clearing the cartridge during the commission of the offense. In addition, marks made by the feed lips of the magazine may be present if the cartridge was fed from the magazine of the firearm.[126]

Manufacturer's toolmarks, present on the case head, are placed there deliberately to identify the make and caliber of the cartridge. These marks constitute a trademark where the maker intends to associate the ammunition with his factory or company. Another type of ammunition that may be used in criminal offenses is not manufactured in a factory, nevertheless, it still bears the trademark of its maker on many surfaces of the cartridge. Handloaded, or reloaded ammunition is often found in the possession of individuals who shoot their firearms a great deal. In pistol and revolver calibers, individuals usually reload their ammunition for economic reasons, as reloaded ammunition can be made at a reduced cost. The process of reloading cartridges uses many different types of tooling to form a completed cartridge. The casing is resized back to proper dimension by insertion in a sizing die. The sizing die acts on the exterior of the casing in much the same way that the barrel of a firearm acts on a bullet. As the casing is inserted and withdrawn from the sizing die, scratch marks are produced on the casing by the harder surface of the die. A comparison of these marks may be possible if the casing has not been resized more than once. Because reloaded ammunition uses fired casings, the examiner should also take into account marks on resized casings that were made by the firearm, such as feed lip scratches from the magazine, and scratches on the exterior of the casing made by the chamber interior as the casing was extracted. If the casing was resized more than once, any type of comparison would be useless, as the scratches would blend together and form no meaningful pattern.

Another mark that may be present on handloaded ammunition can be found on the primer. Part of the reloading process involves the repriming of the casing. As the new primer is inserted into the casing, the pressure of the reloading press causes the minute imperfections on the face of the priming ram to be impressed into the soft brass of the primer cup. These imperfections can be a scratch, dimple or file mark pattern. Concentric circles from the machining of the ram may also be transferred to the primer. However, some of the marks on the primer may not be made by imperfections on the face of the ram. During the reloading process, it is possible to form an indentation on the primer if a foreign particle of powder, brass or lead happens to fall on the ram. When these particles become attached to the ram, they tend to stay attached until the operator notices the particle and removes it. Therefore, in a particular lot of handloaded ammunition, it would be possible to have several cartridges with particle indentations on their primers, and the remainder with seemingly perfect primers. When the cartridges are fired, any marks placed on the primer during the loading process are replaced by those made by the firearm under the greater pressures of the burning powder.

The bullets in handloaded cartridges may also possess different kinds of toolmarks. Pure lead or lead alloy bullets in handloaded ammunition are sometimes cast from molds. When the molten lead is poured into the mold, a bullet is formed that takes on the exact dimensions and facial qualities of the mold. When the bullet is removed from the mold, a device on the mold known as a sprue cutter slices the remaining extra lead from the base of the bullet, leaving it square and even. The slicing action of the sprue cutter leaves a toolmark on the base of the bullet that is unique to the individual mold. The cast bullets are usually sized and lubricated by pressing the bullet into a sizing die. Not only does the die mark the sides of the bullet, the part of the sizing press known as the top punch also makes its impression on the bullet's nose as it forces the bullet into the die. Any of these processes can leave identifiable marks on the cast bullet that could link it to the particular mold, die or top punch used in its manufacture. These same processes are used in the production of balls for muzzle-loading firearms and larger diameters of buckshot for shotguns, and the marks produced by molding would also apply to them. However, the sizing process is usually omitted in the production of lead balls.[127]

Whether the bullets are made by an individual or purchased ready-made, the nose of the bullets can be marked again when they are loaded into the casings during the final assembly of the cartridge. A nose punch integral with the bullet seating die makes contact with the bullet nose as the bullet is pressed into the casing. As the pressure increases to seat the bullet, the impression of the nose punch may be formed on the bullet. The formation of this type of mark is possible regardless of the type of bullet being loaded.

The final mark that may be found on reloaded ammunition is the crimp made on the casing after the bullet is seated. The crimp on the casing is formed by a special die that rolls or tapers the mouth of the casing inward to grip the bullet. The crimping action of the die may leave marks on the casings during this operation.

CHAPTER 7

SHOTGUN EVIDENCE

Shotguns are very similar to other types of long arms, in both appearance and function. The same major components present in previously described firearms are also present in shotguns. The basic tasks of detonation, combustion and propulsion are also performed very efficiently in the shotgun. The only characteristic difference between shotguns and other firearms is the shotgun's lack of rifling in the bore of the barrel. Described as a "smoothbore", the shotgun is practically identical to the muzzle-loading smoothbore musket in its ballistic treatment of multi-projectile ammunition.

The shotgun usually has a larger bore diameter than ordinary rifled firearms. The bore diameter is referred to as the shotgun's "gauge". The gauge or bore designation is a very old standard that was determined by the number of pure lead balls the same diameter as the bore that would weigh one pound in aggregate. For example, a shotgun bore that measures .73" in diameter would be gauged with pure lead balls of .73" in diameter, weighing 583 grains. There are 7000 grains in a pound, so it would take approximately 12 balls of that size to make a pound. That shotgun would be referred to as a 12 bore, or 12 gauge. All shotgun bore diameters (calibers) will be referred to by their respective gauge, except one. The .410 shotgun is a true caliber, not a gauge. The numerical designation for this shotgun is descriptive of its bore diameter in inches, similar to a rifled firearm. If the .410 were to be referenced by its gauge, it would be found that the .410" balls weigh 100 grains, taking 70 balls to make a pound. This would make the .410 a 70 gauge shotgun.[128]

TABLE 1

MEASUREMENTS OR PROPERTIES OF
LEAD BALLS JUST FITTING THE BORE

	Approx. diameter		Weight or mass		Number of balls	
Gauge	inches	mm	grams	grains	per pound	/per oz.
4	1.05	26.7	113	1750	4	.250
8	.84	21.2	57	875	8	.500
10	.78	19.7	45	700	10	.625
12	.73	18.5	38	583	12	.750
14	.69	17.6	32	500	14	.875
16	.66	16.8	28	437	16	1.000
20	.62	15.6	23	350	20	1.250
24	.58	14.7	19	292	24	1.500
28	.55	14.0	16	250	28	1.750
32	.53	13.4	14	219	32	2.000
70	.41	10.3	6	100	70	4.375

Shotgun ammunition

Shotgun ammunition, also called shotshells, contain the same centerfire priming and casing design as other centerfire cartridges that have been previously discussed. Shotshell casings may be composed of heavy paper, brass or plastic. Full brass casings are not typically seen in widespread use today, however some of the military shotshells have full brass casings. Paper shotshells were produced through the 1960's, until Winchester-Western developed the compression-formed shotshell.[129] The compression-formed shotshell is basically a plastic casing with a reinforced base composed of brass plated steel that forms the casehead, rim and primer pocket. No matter how the shotshell is constructed, the same types of comparison evidence will be present on the casing after the shotshell is fired. Breechface markings, firing pin indentations, extractor and ejector markings may all be present, and will be unique to the individual shotgun that fired the shell.

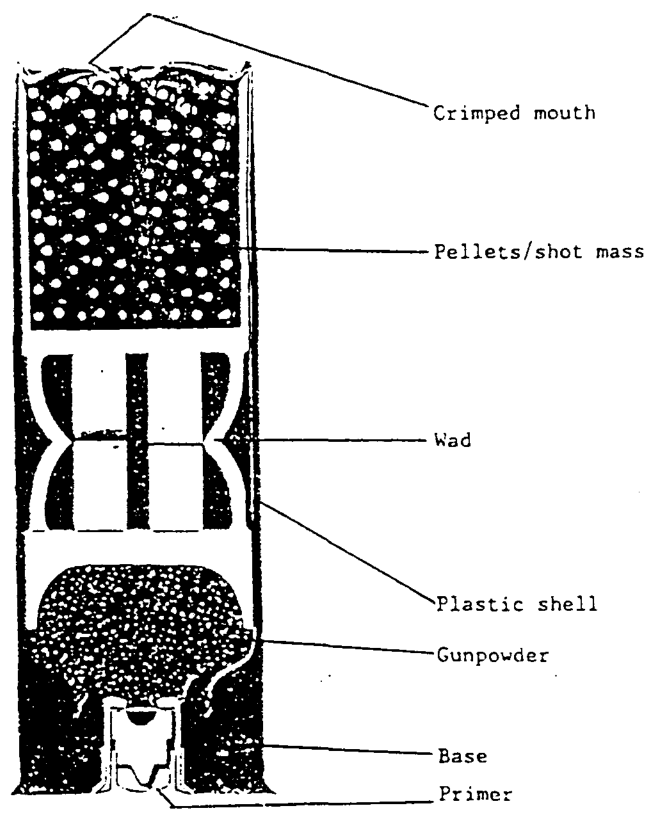

Figure 5. Cutaway view of a shotgun cartridge. (Illustration courtesy of Winchester-Western Company.)

The main difference between shotgun cartridges and the other types is the composition of the projectile. Shotshells have an aggregate projectile composed of several small pellets or shot. The pellets are manufactured in different sizes for hunting various sizes of small game. Generally speaking, small shot are for taking small game, and large shot are for taking large game. In addition to multi-pellet projectiles, the shotshell may also be loaded with a single round ball or slug that is approximately the same size as the gun's bore diameter. However, without rifling to stabilize the projectile's flight, its accuracy is relatively poor.

The shot is separated from the gunpowder inside the shell by a barrier known as a wad. The wad not only separates the components inside the shell, it also acts as a gas seal between the shot and the hot gases created as the gun is discharged and the shot moves down the bore. In older shotshells, the wad was made of paper, cardboard or felt. Modern shotshells use a plastic wad that encloses the sides of the shot mass, separating it from the interior of the bore.[130]

TABLE 2

BUCKSHOT SIZES AND WEIGHTS [131]

Size	Diameter in Inches	Diameter in Millimeters	Approx. number of Balls per pound	Weight in Grains
000	.36	9.14	103	68.0
00	.34	8.64	122	57.5
0	.32	8.13	144	48.5
1	.30	7.62	175	40.0
2	.27	6.86	238	29.5
3	.25	6.35	299	23.5
4	.24	6.09	341	20.5

TABLE 3

Birdshot Sizes and Weights

Size or Number	Diameter in Inches	Diameter in Millimeters	Approx. Number of Pellets per Ounce Soft/Chilled*		Weight in Grains Soft/Chilled*	
1	.16	4.06	71	73	6.16	5.99
2	.15	3.78	86	88	5.08	4.97
3	.14	3.53	106	109	4.12	4.01
4	.13	3.30	132	136	3.31	3.21
5	.12	3.02	168	172	2.60	2.54
6	.11	2.79	218	223	2.00	1.96
7	.10	2.54	291	299	1.50	1.46
7 1/2	.095	2.41	338	347	1.29	1.26
8	.09	2.28	399	412	1.10	1.06
9	.08	2.03	568	585	.77	.75
10	.07	1.78	848	868	.52	.50
11	.06	1.52	1346	1380	.33	.32
12	.05	1.27	2326	2385	.19	.18
Dust	.04	1.02	4565	----	.10	--

* The addition of antimony to the metal used in chilled shot makes the alloy weigh less than pure lead for the same diameter pellet.[132]

Shotgun dynamics

As discussed previously, rifling was added to firearm barrels to impart axial spin to their projectiles and stabilize them in flight. However, the stabilizing axial spin that is deemed beneficial and necessary in rifled arms would be very detrimental to the shot mass's ability to stay in a closely packed group outside of the barrel. If any axial spin were imparted to the shot mass as it exited the barrel, it would cause the pellets to spread quicker as a result of the centrifugal force exerted on the outer edges of the shot mass. For this reason, shotgun barrels that are designed to fire pellet-bearing ammunition will usually be smoothbore. Some shotguns may be fitted with rifled barrels or rifled choke tubes, however those firearms are intended to fire single projectiles over a great distance similar to a rifle.

The reason that shotguns are being discussed separately from other types of firearms has more to do with the internal and external ballistics of the ammunition than the shotgun itself. It is relatively simple to explain how a rifled firearm stabilizes the flight of a bullet, making it fly true and hit the target where the shooter is aiming. However, there are other forces at work in a shotgun's treatment of the shot projectile, and how the shot projectile acts after it leaves the muzzle.

The sole purpose of a rifled firearm is the launch of a single projectile in a manner that promotes straight and stable flight. However, the shotgun's purpose is to launch a multitude of projectiles in a manner that tends to keep them in a dense mass for as long as possible in their straight flight to the target. The problem that has been dealt with more than any other in the development of the shotgun has been keeping the mass of shot dense and closely packed for as long as possible after it leaves the muzzle. Several forces are at work on the shot mass that tend to make it disperse. As the pellets at the front of the mass leave the muzzle, they are immediately confronted by air resistance, and begin to slow down. As the forward pellets begin to slow down, the inertia of the mass attempts to continue forward, causing the pellets to collide and move away from the shot mass. When the individual pellets stray from the mass, they begin to assume their own trajectories, and become individually vulnerable to the effects of the air resistance. Once the pellets separate from the mass and become individual projectiles, the same ballistic problems that effected the round musket balls without the benefit of axial spin, also effect the individual pellets. When they are affected by air resistance away from the shot mass, their trajectories become erratic relative to their deviance from the point of aim of the firearm. This deviance of trajectory is demonstrated by the varying sizes of the patterns the pellets make on impact with targets at different distances.

Most shotguns are fitted with constrictions near the muzzle of their barrels that channel the shot mass into a smaller diameter portion of the barrel, squeezing it into a narrower mass with a greater length. This type of constriction is known as a choke. Shotgun chokes have varying degrees of constriction that are designed to make the pellet pattern denser at longer ranges. The degree of muzzle constriction is determined by the pattern requirements at the standard testing range of 40 yards. A cylinder bore is a barrel that will put approximately 50% of the total number of pellets into a 30 inch circle at 40 yards. A modified choked barrel will place 60% of the total number of pellets into the circle, and a full choked barrel will put 70% of its pellets into the circle. The designated choke of a gun, as stamped into the barrel, can be misleading. The manufacturer's claim to a gun being full choke may only mean that the gun shoots close to the 70% requirement.[133]

In reality, the size and density of the pattern of any shotgun, choked or not, is also greatly dependant on the characteristics of the shotshell that is fired through it. Different sizes of shot act differently as they pass through the choke, as well as how they act in flight as they leave the muzzle. The type of wad used in the shotshell can have an effect on how the pellets move through the choke. The composition and weight of the wad may also cause it to overtake and disrupt the shot mass shortly after it leaves the muzzle. Finally, any variance in the velocity of the shot may cause the resulting pattern to vary in size and density. Higher velocities cause the shot to spread apart more rapidly, while lower velocities help to keep the shot together.[134]

Comparison of Shotgun Evidence

As previously mentioned, shotshells possess the same types of toolmark striation and indentation evidence as other metallic cartridges. These types of evidence on the shotshell casing are identifiable, and can be used in comparisons with test casings to identify a suspect firearm. However, the shotgun has no rifling impression to impart to its projectile, nor is its projectile a single bullet in close contact with the bore. The shotgun produces no consistently identifiable striation evidence on the shot mass or the wad that could be used in a comparison with test rounds.

The wad itself, however, is a valuable piece of evidence because of the class characteristics it possesses, as well as its relative position within the crime scene. The class characteristics of the wad can be used to determine such things as the exact gauge of the suspect cartridge and firearm, the manufacturer of the cartridge and the size of the pellets and their approximate aggregate weight. The diameter of the base of the wad will be the same approximate size as the bore diameter of the suspect firearm. The diameter of the wad is stated to approximate the bore diameter, because the presence of a choke in the barrel may swage the wad to a lesser diameter than the diameter of the bore. The size and weight of the pellets can be estimated by the size of the indentaticns they made in the plastic wad when they were loaded into the cartridge.[135]

The location of the wad in the crime scene is also important evidence that can help in estimating the distance from the muzzle to the target at the moment of firing. The wad leaves the muzzle at the same time as the shot mass, but begins to slow down more rapidly due to the air resistance and its lesser weight. Depending on the velocity of the wad and its weight, the wad will usually separate from the shot mass and lose most of its harmful velocity within 30 feet from the muzzle. Some wads will travel quite a bit farther, and others will travel less, depending on the construction of the wad. If the wad is found in the victim's clothing or in the wound, it is likely that the shot was fired within 30 feet of the victim.[136] In the Kentucky case, Brown v Commonwealth, a shotgun wad removed from the head of a murder victim was admitted into evidence to establish the size of the pellets loaded into the cartridge, and the possible manufacturer of the cartridge. Even though the suspect wad did not match any of the wads in other cartridges available to the suspect, it was admitted as evidence to establish that the size of the pellets in the suspect cartridge matched those found in other cartridges available to the suspect.[137]

The size of the shot pattern can also be used to estimate the distance from the muzzle to the target. If the approximate diameter of the pattern on the target can be measured, the range from the suspect muzzle to the target can be estimated. Shot patterns less than one inch in diameter are usually fired from a range of 0-18". Shot patterns measuring 1.5 inches are usually fired from a distance of 18-36", and a pattern of 1.5-2" diameter is usually fired from a range of 3-5 feet. At ranges beyond five feet, the individual characteristics of the shotgun and the cartridge need to be verified by firing test patterns for comparison. At close ranges, it is not possible to determine the specific gauge of the shotgun by the size of the shot pattern alone.[138]

The most reliable method of determining the range of a shot using the pellet pattern as a reference is to test fire and pattern the suspect shotgun using the same type of loads as the suspect cartridge. Since the size and weight of the pellets, the type of the wad and the velocity of the shot mass all determine how the gun patterns at different ranges, cartridges of the exact same type and manufacturing lot as the suspect cartridge must be used to get accurate comparison patterns. The best comparison patterns are obtained when the suspect weapon is test fired and patterned using cartridges found in the possession of the suspect that match the suspect cartridge. Firing test patterns at various ranges will enable the investigator to estimate the range of the suspect shot with an average error of 1.5 feet.[139]

The method of test firing the suspect weapon with identical suspect cartridges to determine the range of the shot by comparison of the pellet patterns was labelled "a standard test" by the court in Williams v State, a Texas case decided in 1944. However, where due care is not taken to duplicate as closely as possible the condition of the suspect firearm, the type of suspect cartridge fired and the atmospheric conditions as those at the time of the alleged crime, the test may be excluded.[140]

A quick, non-scientific method using the diameter of the shot pattern to estimate the range of a shot out to 50 yards is a "rule of thumb" that the diameter of the shot pattern increases one inch for every yard of distance it travels from the muzzle. For example, a shot pattern ten inches in diameter could be estimated to have been fired from a range of ten yards. This method is surprisingly consistent with actual ranges of fire, but must be considered a rough estimate as the average error in using this method is 3.4 feet.[141]

The choke of a shotgun barrel has a great deal of influence on the size of the shot pattern at various ranges. As previously mentioned, the purpose of the choke is to produce a dense, closely packed shot mass that forms a dense pattern at the target. The following table illustrates the effect of the choke on the size of the shot pattern at various ranges. These values may vary in individual shotguns, and are used for illustrative purposes only.

TABLE 4

Approximate Diameter in Inches
of the Spread of a Shotgun Charge
at Various Ranges [142]

	Range in Yards						
Boring of Shotgun	10	15	20	25	30	35	40
Cylinder Bore(No Choke)	19"	26"	32"	38"	44"	51"	57"
Improved Cylinder Choke	15"	20"	26"	32"	38"	44"	51"
Modified Choke	12"	16"	20"	26"	32"	38"	46"
Full Choke	9"	12"	16"	21"	26"	32"	40"

Careful test patterning of the suspect shotgun with cartridges identical to the suspect cartridges will produce a basis for comparison with the suspect pattern that will yield a valid estimation of the range of the suspect shot. Indifference to detail could produce a comparison that would be excluded by the court.[143]

CHAPTER 8

ELEMENTAL COMPARISON OF PROJECTILE METALS

In some cases, the recovered portions of bullets and shotgun pellets are too badly damaged for any type of comparison on striation markings or other class characteristics. When this occurs, the firearms examiner still has options that he can exercise to obtain much useful information from the remains of the projectile. Elemental comparisons of the projectile fragments can reveal class characteristics of the lot, or even the box of ammunition the suspect bullets came from. Homemade cast bullets, as well as homemade, jacketed bullets can be identified using these processes. From fragments too small for any other type of examination or comparison, elemental analysis and comparison can provide information to the investigator that could aid in solving a case.

One of the methods available for the analysis of projectile metals is emission spectrography. This process can distinguish between the base metal, which is usually lead, and the various other metals used to alloy cast and swaged lead projectiles. For example, this process can distinguish between commercial alloys having antimony as a hardening element, and homemade cast bullet alloys having tin as a hardening element. Major impurities can also be recognized, such as arsenic, silver and copper. The impurity levels of the various alloys are what is most interesting and beneficial to the investigator, for the presence and/or combinations of these impurities form a characteristic unique to a particular lot of projectiles formed from a given batch of alloy.

Although emission spectrography works well in identifying the presence of various elements present in the projectile, its ability to quantify the amounts of those elements can be imprecise and is usually very time consuming. Atomic absorption spectrophotometry can also be used in elemental analysis, and is more precise in quantification of the amounts of various elements than emission spectrography; however, it is also very time consuming and usually results in some destruction of the sample material.

The best process currently in use for the elemental analysis of projectile metal is neutron activation analysis. Current methods of neutron activation analysis are nondestructive to the projectile sample, and produce very good qualitative, as well as quantitative results. One of the most important cases where neutron activation analysis was used was an analysis on the bullet and bullet fragments from the assassination of President Kennedy. All four production lots of the 6.5mm Mannlicher-Carcano ammunition produced by the Western Cartridge Company were analyzed. It was found that the silver and antimony content of the individual bullets were fairly homogeneous. However, considerable variation was noted between bullets from the same production lot, and even between bullets within the same box of cartridges. When the bullet found on the stretcher under Governor Connally and the fragments removed from the Governor's wrist, fragments found in the presidential limousine and fragments removed from the President's brain were analyzed, it was found that the silver and antimony concentrations of the fragments were consistent from their having come from only two bullets.

While elemental analysis of projectile metals cannot provide a positive identification of the individual firearm that fired the projectile like striation comparison, it can offer information that may be valuable to the investigator. Although some of these analytical processes may be very costly to perform, the value and cost effectiveness of the information they may reveal may be beyond measure.[144]

[illegible] Thompson was with his wife on the second floor of their home in Bloomfield, New Jersey. At approximately 8 P.M., Mr. Thompson heard a noise coming from the first floor of the residence and went to investigate. As soon as he reached the first floor, witnesses stated that the sound of a scuffle could be heard, followed by the muffled sound of a gunshot. A man was seen fleeing the Thompson residence immediately after the gunshot was heard. About that same time, Mr. Thompson stepped onto his front porch and walked to his neighbor's house, where he collapsed. He later died after being taken to the hospital. During an autopsy of the victim, a bullet was found between his clothing and skin and given to the police as evidence.

The investigators on this case had knowledge of another burglary that had occurred approximately a month before, that exhibited the same method of entry as the murder. A revolver had been taken in that burglary, and it was suspected that the stolen revolver had been used in the murder of Mr. Thompson. The police interviewed Dr. Black, the victim of the prior burglary, and learned that the weapon stolen from his residence was an old Smith and Wesson five chamber revolver. During their conversation, Dr. Black stated that the last time the weapon was fired was on New Year's Eve two or three years prior to the burglary, when he fired one bullet into the ground outside his home. The police dug up the bullet that Dr. Black had fired into the ground, and submitted it to a firearms examiner for comparison with the suspect bullet. It was found that the bullets matched, and the examiner was able to testify that the two bullets were fired from the same gun.

Later, a suspect named Anthony Boccadoro was arrested and charged with the murder of Mr. Thompson. The stolen revolver was linked to him by witness testimony referring to other articles in his possession that were confirmed stolen from the burglary of Dr. Black's residence. On February 4, 1929, his conviction was upheld by the Court of Errors and Appeals of New Jersey. If the bullet recovered from the residence of Dr. Black had not been available for comparison, it is doubtful that a prosecution in the murder case would have been successful. The suspect firearm was never recovered.[145]

In the early morning hours of February 10, 1948, Mary Johnson was shot and killed in her Phoenix, Arizona residence. Investigators found a fired .22 casing near the victim and entered it into evidence. The victim's ex-husband immediately became a suspect in the murder because of several jealous threats he had made, and repeated domestic violence between him and the victim. Investigators learned that the suspect, Charles Lane, made several attempts to borrow a firearm from some of his acquaintances on the night before the murder, before obtaining a .22 Winchester rifle from his friend, Mac Ross. The cartridges for the gun were borrowed from another friend, Jimmie Brown. Lane told Ross and Brown that he intended to go hunting with the gun the next day. The rifle was never returned to Mr. Ross, nor was it ever recovered. When Mr. Ross was interviewed, he stated that he and some friends had done some target shooting with the rifle approximately three weeks prior to the murder on a nearby river bed. The casings were recovered from the river bed and compared with the casing found near the victim. It was determined that the casings matched, and had definitely been fired by the same gun. In spite of the fact that several months had passed between the time the casings were left in the river bed and the time the police retrieved them as evidence, the Court still held that they were admissible.[146]

On July 14, 1967, the body of Gary Jaasma, a sailor in the United States Navy, was found behind a bowling alley in Asan, Guam. It was noted that the victim had apparently died from multiple gunshot wounds. Three carbine casings were found near the victim at the time the body was found, and two days later, a single .38 caliber bullet was found imbedded in the ground where the body of the sailor had been found. On July 15, 1967, a search warrant in an unrelated offense was executed on the residence of Antonio and Francisco Ignacio. The Ignacio brothers were subsequently charged with auto theft and possession of a firearm by a felon. While they were in custody, several witnesses were interviewed that testified to hearing the Ignacio brothers speak of shooting a sailor. This lead police to suspect the Ignacio brothers of murdering Mr. Jaasma, and a comparison was undertaken on the suspect casings and bullet, and the firearms found during the search of the brothers' residence. The firearms examiner determined that the .38 caliber bullet and carbine casings were fired by two of the firearms in the possession of the Ignacio brothers at the time of their arrest. On July 31, 1967, The Ignacio brothers were indicted for the murder of Gary Jaasma. During the trial, the defendant objected to the admission of the .38 caliber bullet recovered from the ground two days after the discovery of the body. The defense stated that the crime scene had not been secured or protected during the two days preceding the discovery of the bullet, and neither the chain of custody or the authenticity of the bullet could be positively proven. The Court stated that the delay in finding the bullet went to the weight of the evidence, and not its inadmissibility. As a result, the bullet was admitted into evidence, and in consideration of all the evidence presented in the case, the Ignacio brothers were convicted in the murder of Gary Jaasma.[147]

Evidence of any type should be procured and documented as well as possible. If a suspect firearm can be identified using the delayed discovery firearms evidence, it is up to the jury and the court to deal with the implications made by that identification. The investigator should not be overly concerned with how much weight a particular bit of evidence may be given at trial, for the admissibility of the evidence is a matter for the court, and the weight that is given to the evidence in contemplation of the guilt of the suspect is a matter for the jury.

CHAPTER 10

CONCLUSION

Investigators and supervisors in police investigative units often tend to avoid making elementary comparisons of firearms-related evidence because they believe it is too complicated for them to perform competently. Indeed, the more technical microscopic comparisons do fall into the realm of the expert firearms examiner, however a great number of comparisons are done on class characteristics before a microscopic comparison is feasible. For this reason, investigators working cases involving firearms evidence should receive adequate technical training in the subject to enable them to make elementary comparisons when practical. This research paper has provided information that can serve as a foundation for those who desire more knowledge of the subject.

Police managers are also faced with structural and budgetary decisions that affect how their agencies address the local investigation of crime. Managers who consider developing a firearms comparison capability in their agency, tend to think of the extreme cost and burden of a separate unit with high technology equipment, doing nothing but firearms examinations. Very few managers, except those in very large agencies, could justify the expense of such a unit. The most cost-effective, and widely accepted solution is to leave all the firearms examination work to regional laboratories. This solution, based solely on cost considerations, ignores the fact that investigators could be trained to make competent elementary firearms comparisons in the field before a laboratory examination of the same evidence would be practical. Investigators trained in elementary firearms comparison evidence could actually save tax dollars by eliminating unnecessary laboratory examinations.

The police trainer will also find this research paper useful as a training aid and source of information. Many applications of this information are possible, to include its use as a guide for a course taught on firearms comparison evidence, or a reference in courses taught on related subjects such as investigation of violent death, and crime scene search.

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