FIREARM IDENTIFICATION

IN THE FORENSIC SCIENCE LABORATORY

By Robert M. Thompson

This project was supported by the Bureau of Justice Assistance under grant number 2008-MU-MU-K004 awarded to the National District Attorneys Association. The Bureau of Justice Assistance is a component of the U.S. Department of Justice's Office of Justice Programs, which also includes the Bureau of Justice Statistics, the National Institute of Justice, the office of Juvenile Justice and Delinquency Prevention, and the Office for Victims of Crime. Points of view or opinions in this document do not necessarily represent the official positions or policies of the U.S. Department of Justice of the National District Attorneys Association.

GUN VIOLENCE PROSECUTION PROGRAM
A program of the National District Attorneys Association
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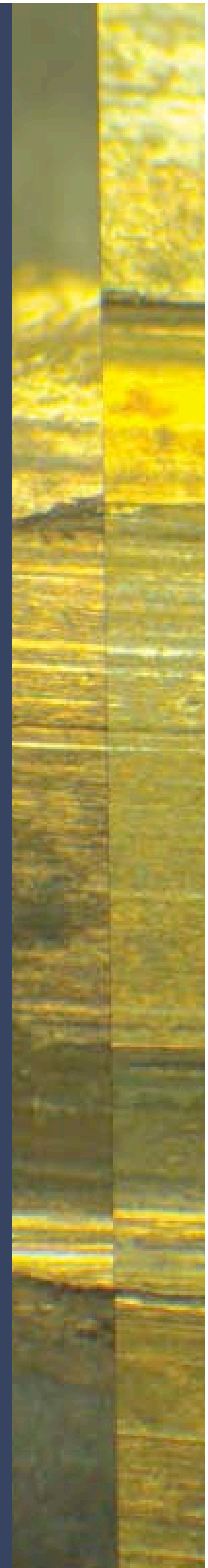

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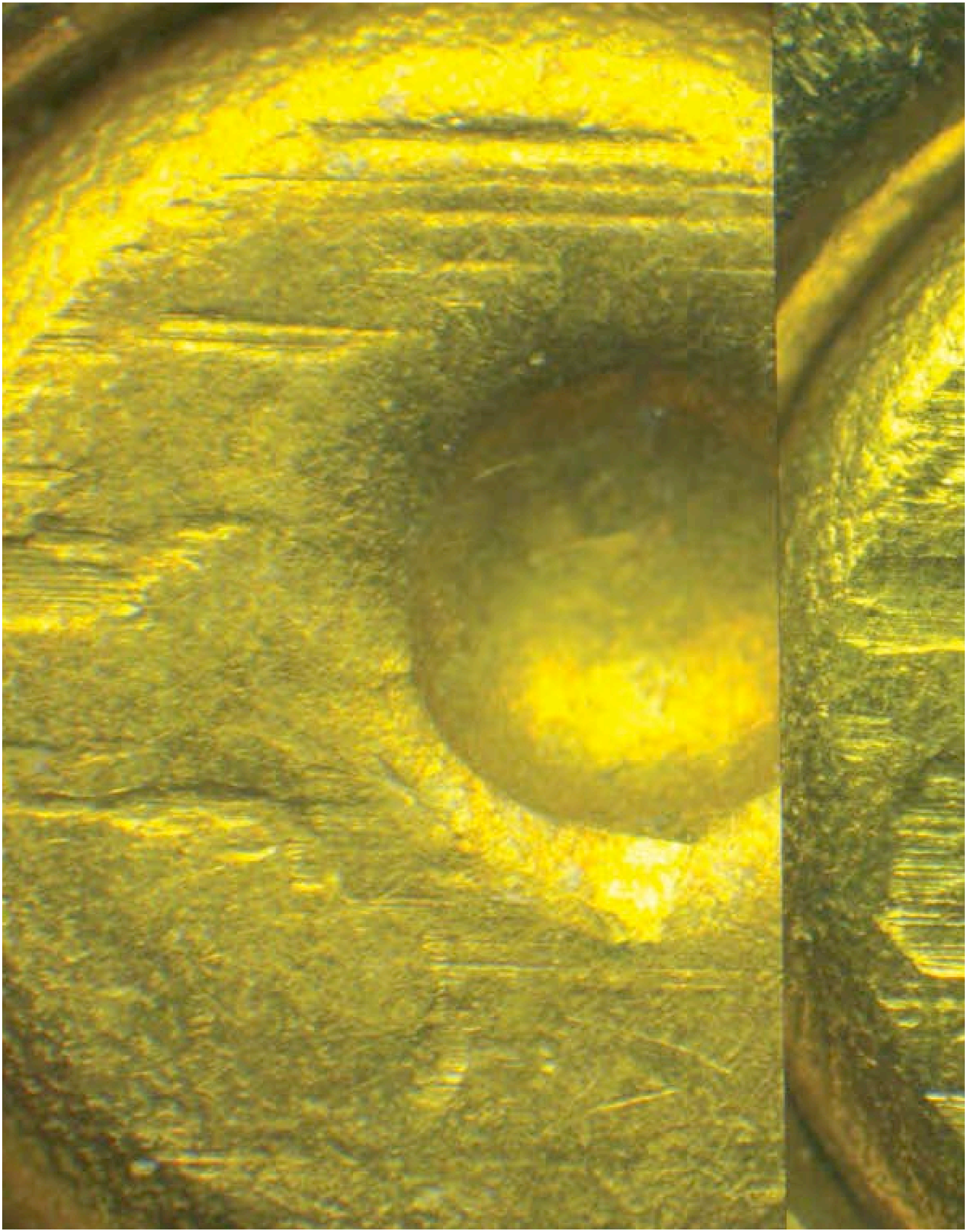

INTRODUCTION

For a prosecutor to be successful, he or she must be cognizant of the expectations of today's jury. Thanks to the modern electronic media, use of the forensic sciences has caught the imagination of the public, and the potential jury pool has demonstrated that it has certain expectations when a case is brought before it. No matter how fantastic or erroneous these expectations are, practitioners in law enforcement and experts in the forensic sciences have to deal with them in a forthright manner. The best strategy is for the prosecutor to be well acquainted with the capabilities and limits of the forensic science disciplines that may be the linchpin in the investigation and, more importantly, in the prosecution of a defendant at trial.

This monograph serves to introduce the prosecutor to the principal elements of one of the forensic specialties, the science of "firearm and toolmark identification." Many of the words and terms printed in bold in the text are defined in the glossary. The monograph provides an introductory discussion of the specialty of toolmark identification when the tool involved is a **firearm**. The tool surfaces represented here involve one or more of the following: the interior of the barrel, the chamber, parts of the action, and ammunition magazine components. These surfaces of the firearm can produce toolmarks on fired and unfired ammunition components. The forensic scientist views a "tool" as the harder of two objects where the surface of the harder "tool" produces toolmarks on a softer material. For example, the tool surface of the hard barrel interior leaves toolmarks on the softer metal of the fired bullet. Another example is when a cartridge is fired in a firearm. The softer metal used in the cartridge case construction may show toolmarks caused by the interior chamber and **action** surfaces coming in contact with the cartridge case. The action is the firearm's loading and firing mechanism.

For there to be a potential for toolmark identification, the tool working surface (1) must have individuality, and (2) the toolmarks must be reproducible for comparisons. If it is determined that the individual character of the tool working surface is reproduced in the toolmarks from repetitive markings, an examiner may be able to make an identification in later comparisons.

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THE SCIENCE OF FIREARM IDENTIFICATION

THE HISTORY of the science of forensic firearm (and toolmark) identification, and its court acceptance, spans over 100 years in the United States. The principles and the primary tools used in the science have changed very little during this time. The **comparison microscope**, the primary tool used by the profession, has not changed in its basic design for almost 80 years. Before this instrument became available, examiners relied on photomicrograph comparisons to determine identity of fired bullets or cartridge cases, which was a time consuming and laborious method. (The terms cartridge case, casing, and case will be interchangeable in usage.) With the engineering of the "optical bridge," two compound microscopes were joined together, giving the examiner the ability to observe and compare two objects at the same time under magnification. The genesis of the modern comparison microscope was accelerated with the addition of microscope stages that were designed for the mounting of fired bullets, cases, and other items bearing toolmarks. The science of firearm identification was soon propelled forward in forensic investigations in this nation and worldwide.

Today, firearm units in crime laboratories might use other complimentary microscopic and photographic instrumentation, but for matters concerning the identification of toolmarks on fired bullets, cases or any other object, the comparison microscope is an absolutely necessary instrument.

The recent computer technology for searching image databases for presumptive linkages is demonstrated by the installation and use of the National Integrated Ballistic Information Network (NIBIN). NIBIN has a firm foundation of acceptance in the forensic science community and the courts.

As was described previously, the forensic science of firearm identification is a specialized sub-specialty of toolmark identification specifically related to the firearm mechanism's working surfaces. The firearm is made up of a number of tools, many of which come

A comparison microscope

into contact with, and leave toolmarks on the softer metal of the **cartridge case** and/or **bullet**. The firearm, as with any other tool, has features that were designed by the factory. Features that are determined by the manufacturer include the size of the cartridge **chambered** by the firearm, the orientation of the **extractor** and **ejector**, and the number, width and twist direction of the **land** and **grooves** of the barrel **rifling**. These characteristics can be imparted as toolmarks on the fired bullet and case during firing, and can be classified by their **class characteristics**. These class characteristics are typically the first classification of toolmark evidence that the examiner seeks in the examination. Class characteristics help narrow the population of potential firearm sources. The following experience common to us all gives an example of sorting using class characteristics:

> You are leaving a store and have to find your car in a large, crowded parking lot. You begin by looking for a certain vehicle type (SUV, convertible, sedan, etc.), make (Ford, Chevy, Volvo, etc),

model, and color. You are looking for the class characteristics of your car.

If the class characteristics agree in every respect with the evidence item (i.e., the cartridge case or the recovered bullet) and with the test-fires from a suspect firearm, the examiner then uses the comparison microscope to compare the **individual characteristics** of both evidence and test toolmarks. Individual characteristics are random in nature, usually arising from the tool working surface incidental to manufacture, but can also be the result of use, wear, and possible care and/or abuse of the tool.

Building on the example of finding your car in the parking lot, you find what appears to be your car, but you know it is a popular model and have seen very similar cars in other parking lots and on the road. So you approach the car that looks like yours and you search for those individual characteristics that make it your own. For example, you look at the license plate, window decals, dings and dents. These all together confirm that the car is yours and not someone else's. You do not search for *every* individual feature that you know is on your vehicle, but *just enough* to determine its identity.

The characteristics that make the tool surface unique are called **individual characteristics**. When these characteristics are compared in toolmarks, and sufficient agreement is found, an identification can be established. These characteristics are from imperfections on the tool surface that make the toolmark. The imperfections, typically microscopic, usually arise during the tool manufacturing process. In addition, the surface may also gain imperfections and irregularities through use, wear, corrosion, and damage. Remember your car in the parking lot? Individual characteristics would be the dings and dents, the license tag, the rust spots, and the windshield crack. As you can see, these characteristics would be acquired over time compared to the few that would be seen on a new show room car.

There is a toolmark classification termed subclass characteristics, sometimes referred to as "carryover." These tool surface characteristics are incidental to manufacture, are significant in that they relate to a subgroup from which they belong, and arise from a tool source that can change over time. Subclass characteristics can be reproduced on a limited number of tools. Therefore, the examiner cannot base identification on toolmarks derived from such a source knowing there is a good chance that such a toolmark could originate from several firearm barrels.

A source of such a subclass characteristic may be produced during the cutting of barrel grooves in rifled barrels, if, for example, during the cutting of many barrels on an assembly line, one of the cutters develops a large chip that is not noticed by the machinist or quality control experts. The chip on the cutter may produce a coarse imperfection in an otherwise cleanly cut groove. The detail from this defect may be reproduced on a number of consecutive barrels (i.e. carried over), until the cutting tool is discarded or re-sharpened. The experienced firearm examiner is aware of such artifacts occurring in the barrel forming process, and understands that these types of coarse, continuous toolmarks, while useful in the examination and comparison process, cannot be a basis for an identification. This is one of a number of instances in firearm and toolmark comparisons in which subclass characteristics have to be considered before an identification of a toolmark source is concluded.

Toolmarks generally appear in two forms: striated and impressed. **Striated** toolmarks are formed when a tool-working surface is placed on another surface and moved parallel to that surface. In other words, a tool makes a scratch or scrape mark on the surface of another object. The detail in this toolmark has the appearance of parallel lines, called stria. Under the microscope the stria are seen as a profile consisting of hills, valleys and ridges. If the stria is very shallow, the toolmark appears as a pattern of lines. **Impressed** toolmarks are formed when the tool surface is forced perpendicularly to another surface. This toolmark has the appearance of having been stamped. Due to the process of impressing a toolmark, stria production is very limited, and may not be formed at all. Instead, the tool working surface imperfections give the negative detail in the toolmark. The examiner uses a comparison microscope to determine identification for both striated toolmarks and impressed toolmarks.

> An example of a striated toolmark is the action that occurs with a car's windshield wiper against a wet windshield. If the wiper is well worn, nicks of various sizes will be randomly present on the blade. When the wiper is used on the windshield, a pattern of lines is drawn across the arc of the wiper movement. The placement of these imperfections cannot be accidentally duplicated on any other blade length, and the pattern of stria is individual to that particular blade. Additionally, the toolmark in the windshield is duplicated on each stroke, exemplifying the reproducibility of the toolmark.
>
> Similarly, the impressed toolmark can be characterized by the stamping of coins. The tool that impressed the coin had the negative profile of the coin. The coin produced has the impression of the tool on its softer metal. The class characteristics of a 2004 dime are visually apparent. However, microscopic imperfections impressed on the dime may be used to identify which specific tool in the mint was used to produce the coin.

For the science of toolmark identification, the underlying hypothesis is that a toolmark can be identified to a specific tool that produced it, to the *practical* exclusion of all other tools. Clearly, it is impossible to prove this hypothesis by testing all tools ever produced in the world. Instead, identification must be inferred, based on observation and experimentation. Over many years scientists have documented that the surfaces of tools that make toolmarks are microscopically dissimilar and individual in nature. This dissimilarity is observed and potentially quantifiable in what is called "known non-match" comparisons. While there is a potential for random agreement to a small extent, this agreement does not reach the quality and quantity shown between toolmarks made by the same tool working surface, or "known matches." Therefore, if the agreement of toolmarks is of sufficient quality and quantity that is expected from one tool, and greater in quality and quantity than has been demonstrated by the best "known non-match" toolmarks from different tools, an identification can be made between the two toolmarks. However, as stated before, prior to the determination of identification, the influence of sub-class characteristics has to be eliminated. The human being is very cognitive of the environment, and one of the hallmarks of human reason is the detection of patterns, whether by the senses, or by circumstances in time.

> Consider your drive to and from work. Even in busy traffic, you as an experienced driver, tune out many of the circumstances of a routine commute. Each drive is different and has random circumstances that vary to a degree over the weeks of the same commute. One day you see a new sports car that catches your eye because you appreciate sports cars. As it passes by you note its color, its lines, and perhaps the wheels. As the car recedes from sight, you reestablish the mental monotony of your trip, and in a few minutes you see an identical new sports car pass you on the road. Now, you are really interested, because this rare event just happened in one trip in a few minutes. You carefully compare car number two with the mental notes you made of car number one. You know that this

may be coincidence, the cars may not be produced with many options, and it may be rare to see two cars in such close proximity. It is an interesting coincidence (a non-match). Consider what you start to realize when you pass another and another—a number of similar cars. You now know that something special might be happening based on the coincidental discovery of these cars in such a close space of time. Something else must be going on to make this a singular event. Perhaps there was a car club, a manufacturer test market, or an auto show. Any idea that this event happened simply by chance is quickly dismissed, with confidence (a match).

The largest organization that supports the interchange of scientific information concerning firearm and toolmark science is the Association of Firearm and Toolmark Examiners (AFTE), which publishes the *AFTE Journal*. The *AFTE Journal* is peer-reviewed by an editorial committee, with a section in each issue set aside for responses by the readers. Peer review helps ensure that open discussion among practitioners is maintained and that any information being disseminated is accurate and reliable.

In 1992, AFTE adopted the "Theory of Identification" which reads:

1. The theory of identification as it pertains to the comparison of toolmarks enables opinions of common origin to be made when the unique surface contours of two toolmarks are in "sufficient agreement."
2. This "sufficient agreement" is related to the significant duplication of random toolmarks as evidenced by a pattern or combination of patterns of surface contours. Significance is determined by the comparative examination of two or more sets of surface contour patterns comprised of individual peaks, ridges and furrows. Specifically, the relative height or depth, width, curvature and spatial relationship of the individual peaks, ridges and furrows within one set of surface contours are defined and compared to the corresponding features in the second set of surface contours. Agreement is significant when it exceeds the best agreement demonstrated between toolmarks known to have been produced by different tools and is consistent with agreement demonstrated by toolmarks known to have been produced by the same tool. The statement that "sufficient agreement" exists between two toolmarks means that the agreement is of a quantity and quality that the likelihood of another tool making the mark is so remote as to be considered a practical impossibility.
3. Currently the interpretation of individualization/identification is subjective in nature, founded on scientific principles and based on the examiner's training and experience.

As part of the standardization of terms and conclusions for the firearms examiner to employ, AFTE developed a range of conclusions based on the Theory of Identification. The examiner would conservatively describe objective observations and the results of examinations, as follows:

Identification:
Agreement of a combination of individual characteristics and all discernible class characteristics where the extent of agreement exceeds that which can occur in the comparison of toolmarks made by different tools and is consistent with the agreement demonstrated by toolmarks known to have been produced by the same tool.

Inconclusive:
a. Some agreement of individual characteristics and all discernible class characteristics, but insufficient for an identification.

b. Agreement of all discernible class characteristics without agreement or disagreement of individual characteristics due to an absence, insufficiency, or lack of reproducibility.

c. Agreement of all discernible class characteristics and disagreement of individual characteristics, but insufficient for an elimination.

Elimination:

Significant disagreement of discernible class characteristics and/or individual characteristics.

Unsuitable:

Unsuitable for examination.

The Production of Firearm Toolmarks on the Fired Cartridge

When toolmarks are made on the fired bullet and cartridge case, their general appearance and orientation originate from the class characteristics of the firearm producing those marks. Routinely, when a firearm is not collected as part of an investigation, the firearm examiner measures and characterizes the marks (both striated and impressed) found on the bullet and/or cartridge case. Then the examiner compares the observations and data to reference literature and databases, and produces a list of possible firearm manufacturers and possibly models, that could be the source of the evidence. While such a list is not all inclusive of all possible manufacturers, it may be an aid in an investigation where a suspect firearm was not recovered. However, if a suspect firearm is recovered, the firearms examiner will determine if the firearm has the correct class characteristics by examination and test firing, and then if the class characteristics agree, will microscopically compare the test-fired bullets and cartridge cases to the exhibits collected in the investigation.

To better understand the placement of toolmarks on fired cartridge components, an understanding of firearm types, actions, ammunition, and firearm toolmark producing surfaces is necessary.

Firearm Types

The basic types of firearms are handguns and shoulder arms. Handguns are designed to be fired by one hand without support from the body. A shoulder arm is designed with a stock to be fired while being supported by the shoulder.

• *Handguns*

Pistol—A firearm that has a chamber as part of the barrel and is typical of semi-automatic handguns.

Semiautomatic 9mm pistol

Double-action 44 Magnum Revolver with Scope

Revolver—A firearm that has a number of chambers in a cylinder that rotates on an axis; during successive firing, a chamber rotates and aligns with the barrel.

• *Shoulder Arms*

Rifle—A firearm that has a rifled barrel and is designed to be fired from the shoulder

Lever-action Rifle

Pump-action shotgun

Shotgun—A smooth bore barreled shoulder firearm designed to fire shotshells that contain numerous pellets, or a single projectile.

Modern Firearm Actions

Firearms have loading and firing mechanisms called **actions**. Modern firearms may have differing actions depending on the design of the firearm. The most common forms are semiautomatic, automatic (also known as full auto or machine gun), revolver, lever, slide (or pump), and bolt actions. A "firing cycle" is composed of the actions performed by the shooter and the firearm mechanism to fire a cartridge, with the subsequent readying of the firearm for a discharge of the next cartridge. The most commonly encountered firearm actions are:

- *Semiautomatic*—A firearm that requires a separate pull of the trigger for each shot, and uses energy from the discharge to perform a portion of the operation or firing cycle, usually the extraction and loading portions.
- *Automatic*—A firearm that feeds cartridges, fires, extracts and ejects cartridge cases continuously for as long as the trigger is fully depressed and there are cartridges in the feed system.
- *Revolver*—A firearm that has a number of chambers in a cylinder that rotates on an axis; during successive firing, a chamber rotates and aligns with the barrel.
- *Lever*—A firearm wherein the breech mechanism is cycled by an external lever generally below the receiver.
- *Slide (pump)*—A firearm with a movable forearm that is moved in line with the barrel by the shooter. This motion is connected to the breech bolt assembly, which performs the functions of the firing cycle that is assigned to it.
- *Bolt*—A firearm where the breech closure is in line with the barrel; the closure manually reciprocates to load, unload, and cock; and locks in place by breech bolt lugs on the bolt engaging the receiver.

Ammunition Construction, Terminology, and Nomenclature

It is common today to hear or read the term "bullet" misused in the media and in television shows and movies. For example, a suspect was arrested with "bullets" in his pocket, a semiautomatic rifle that can carry many "bullets," or a cowboy in a shootout is "out of bullets." However, the unit of ammunition is properly termed a **cartridge**. The cartridge consists of a case, a primer, propellant (powder), and one or more projectiles. The projectile is the true bullet. (In some areas of the United States the bullet may also be termed "pellet.") Experienced shooters or otherwise informed jurors will be very aware of the distinction between cartridge and bullet.

Center Fire Cartridges

Cartridges come in many sizes, shapes, and bullet designs. Two types of ignition systems for the modern metallic cartridge are **rim fire** and **center fire**. Rim fire cartridges, common with .22 calibers have the primer compound inside the rim of the case head. The primer compound is shock sensitive and emits a hot jet of flame onto the powder when the case rim is struck by the firing pin of the firearm, similar to a toy cap being struck. Center fire cartridges have a separate primer seated in the center portion of the case head. When the primer is struck, the jet of flame passes from the primer through an internal opening in the bottom of the case called the flash hole, thereby igniting the powder.

Center Fire Cartridge

22 Caliber Rimfire

Revolver Cartridge Lead Hollow Point Bullet

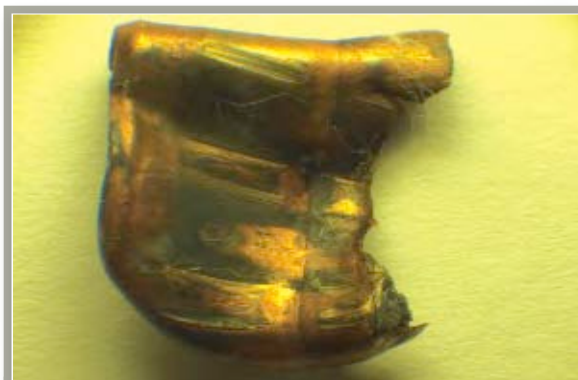
Toolmarks on Fired Ammunition Components and Their Sources

A fired cartridge case and a fired bullet. Note the firing pin impression on the primer of the cartridge case and the land and groove engraving on the bullet.

Fired Bullets

Fired bullets have impressed and striated toolmarks that are generated by the tool working surface of the rifled bore of the barrel. **Rifling** is the construction of helical grooves in the bore that impart a rotary motion or spin to a fired bullet, thereby giving the bullet more range, stability, and accuracy. When the powder in the cartridge starts burning after ignition, the extreme pressure produced by the gasses causes the rear of the bullet to deform slightly and swell to fill the inside of the barrel. The bullet deformation helps seal the gasses behind it as it travels down the barrel. This bullet deformation effect is called **obturation**. The sides of the bullet are engaged by the rifling, and the soft metal is impressed by the raised portion of the rifling called **lands** and alternately, may fill in the rifling between the lands called **grooves**. As the bullet travels down the barrel, the soft metal on the sides are engraved by the rifling until it leaves the barrel. Some of the class characteristics found on a fired bullet are (1) the caliber of the bullet (diameter), (2) the number of lands and grooves, (3) the twist of the rifling (left or right), and (4) the widths of the land and groove impressions. The ability to determine all or some of a fired bullet's class characteristics may be limited due to the condition of the bullet when it was recovered.

A fired bullet with barrel rifling impressions on the sides.



A bullet jacket, typically found in casework.

The flattened side of a fired bullet that ricocheted prior to entering the victim's body.

Barrel Manufacture Methods and the Basis for Identification of Fired Bullets

There are, and have been, numerous manufacturers of firearms with rifled barrels. Many manufacturers make rifled barrels as their main product. Each manufacturer produces rifled barrels in a particular manner best suited to the company's needs. However, they all use basic production methods to manufacture rifled barrels.

Briefly, the basic steps to make a rifle barrel from a length of steel bar stock are:

- The barrel is drilled lengthwise with a tool called a deep hole gun drill. This produces a hole, which at this stage, is not adequately smooth or sized to the specified dimension of the designed final bore size.
- A cutting tool called a "reamer" finishes the bore by removing coarse material from the hole drilling process, and perfects a true circular hole. After this action, the bore is now the proper size, relatively smooth, and consistent dimensionally down the length of the bore. The reamer leaves fine annular ring toolmarks that are close to perpendicular to the bore axis.
- The rifling in the bore may be produced by one of the following methods:
    - A cutting tool that cuts grooves singularly, or as a "gang" where multiple grooves are cut to the desired depth. The grooves cut one at a time are made by a hook cutter, two at a time with a scrape cutter. Multiple grooves cut in one pass are made by a gang broach. Of these methods, the gang broach is commonly used today for cut rifling.
    - Button rifling (also termed button swage): In this method a very hard tungsten button which has the reverse cross section of the desired rifling is pushed or pulled through a bore that has a smaller diameter than the button. Under high pressure, the metal flows around the button surface as it passes down the barrel. The rifling is "ironed in" to the barrel interior and no metal is removed.
    - Hammer forging: (In some ways may be imagined as the reverse of swaging.) A mandrel with the cross section of the rifled bore interior is placed in a slightly larger barrel bore. A system of large hammers, under tremendous force, pound from the outside of the barrel onto the mandrel inside, much like a blacksmith hammers a red-hot horseshoe into shape. The finished bore will have the imprint of the mandrel's rifling impressed on the interior.

Broach Cut 6-Left

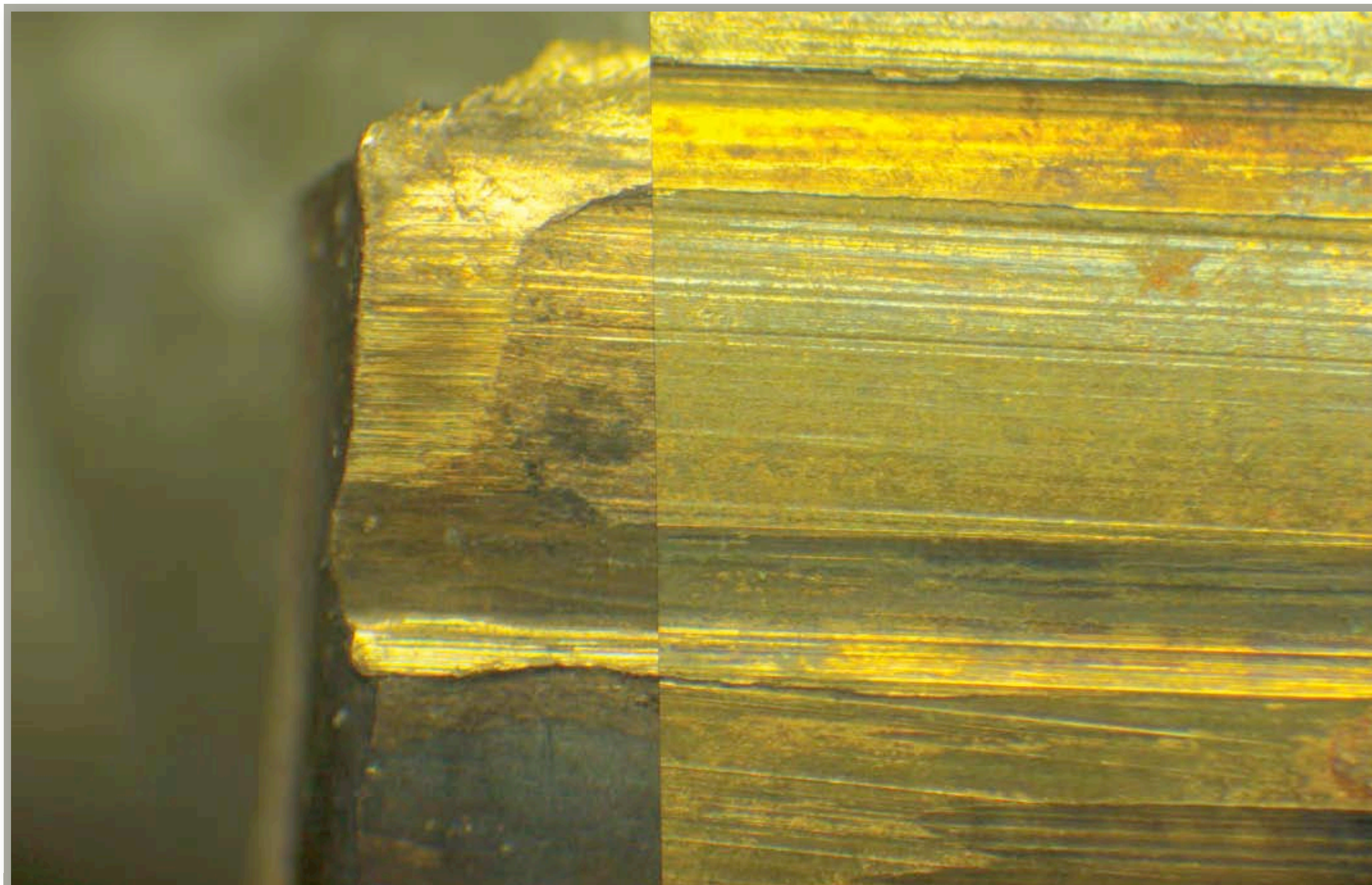
Each of these rifling processes has a number of important steps. The tools cutting and forming the rifling undergo change as the products are formed in the manufacturing process and wear down during the lifetime of the tool. If a tool becomes too dull, or does not perform to tolerance, then it must be sharpened, reconditioned, or replaced. At the microscopic level, the tool working surface—the barrel—has its own individuality. That individuality can be reproduced in the engraved toolmarks on the fired bullet. Based on this individuality of the interior of the barrel, bullets can be identified to a particular barrel.

A button swage used to form rifling in a barrel.

Barrel rifling

A gang broach that progressively cuts rifling in a barrel.

Cross section of a barrel showing toolmarks that survive the rifling procedure.

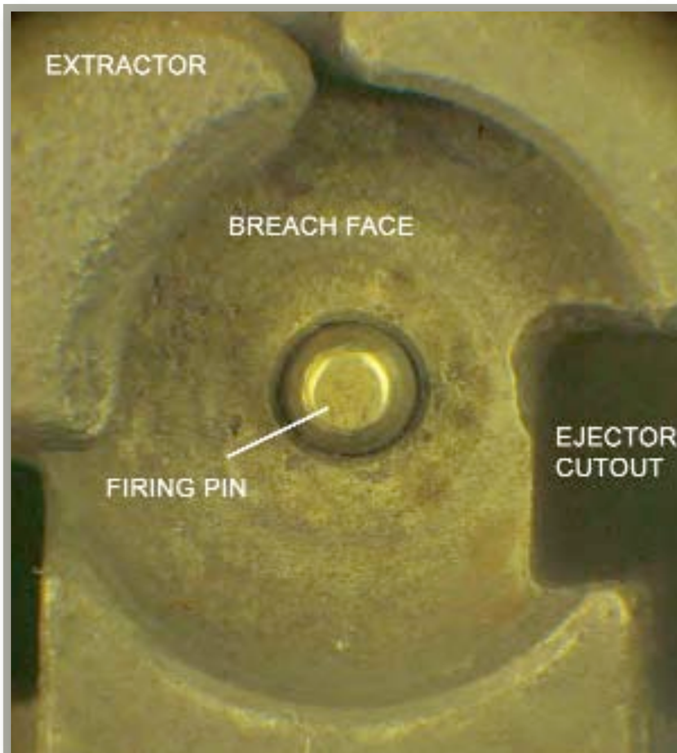


Microscopic comparison of a fragment of bullet jacket (left) and a test fired bullet from a suspect firearm (right).

Fired Cartridge Cases

Breech/bolt Face and Firing Pin Toolmark Individuality on Fired Cartridge Cases

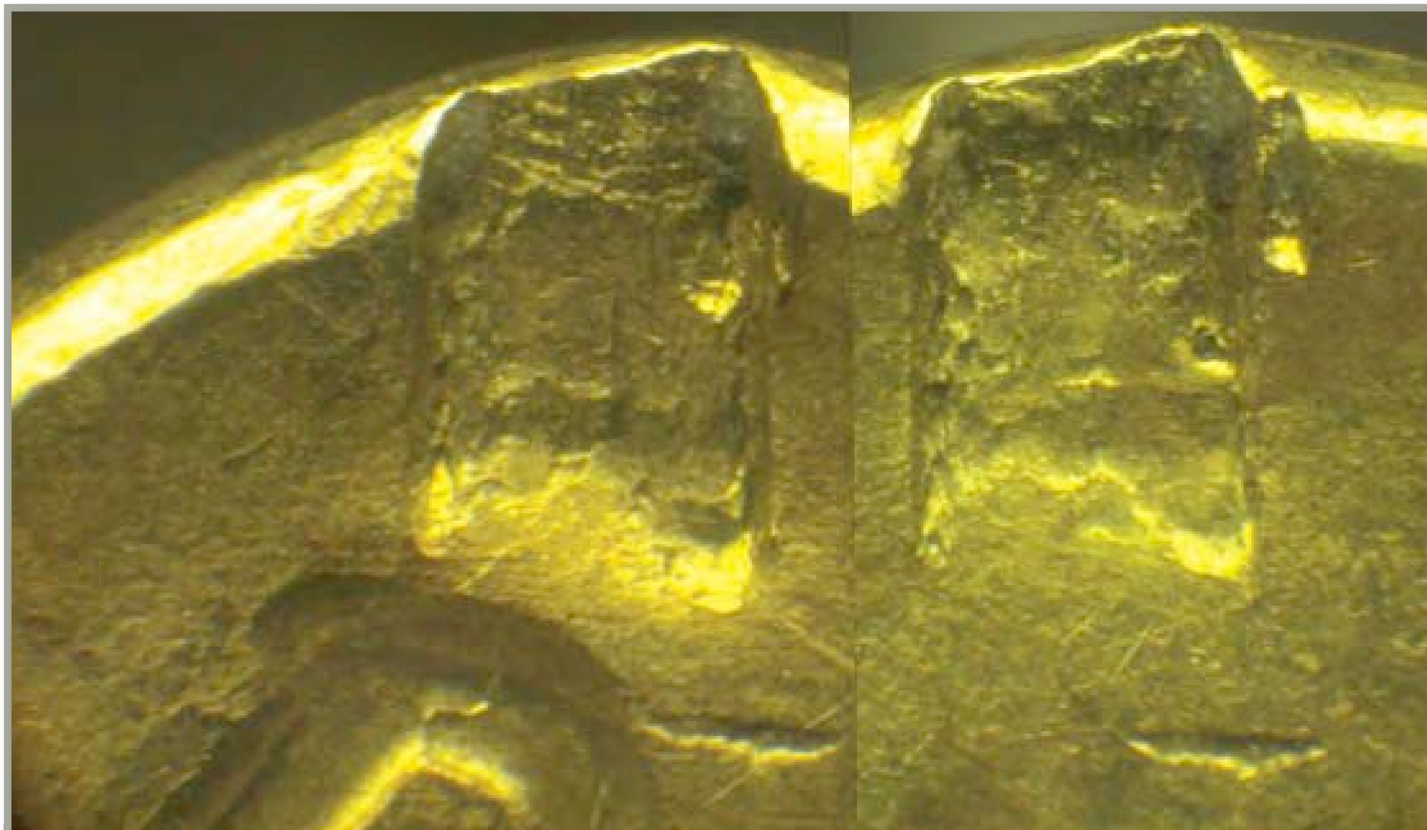
Fired cartridge cases are often left at shooting scenes because the shooters are not inclined to waste time searching for the ejected and fired cartridge cases. A fired case may have a number of surfaces that bear both impressed and striated toolmarks from the firearm mechanism that fired it. As with bullets, cartridge cases can also bear class characteristics of the firearm that may provide the examiner with information needed to assemble a list of firearm manufacturers in the event the firearm itself is unavailable for comparison.



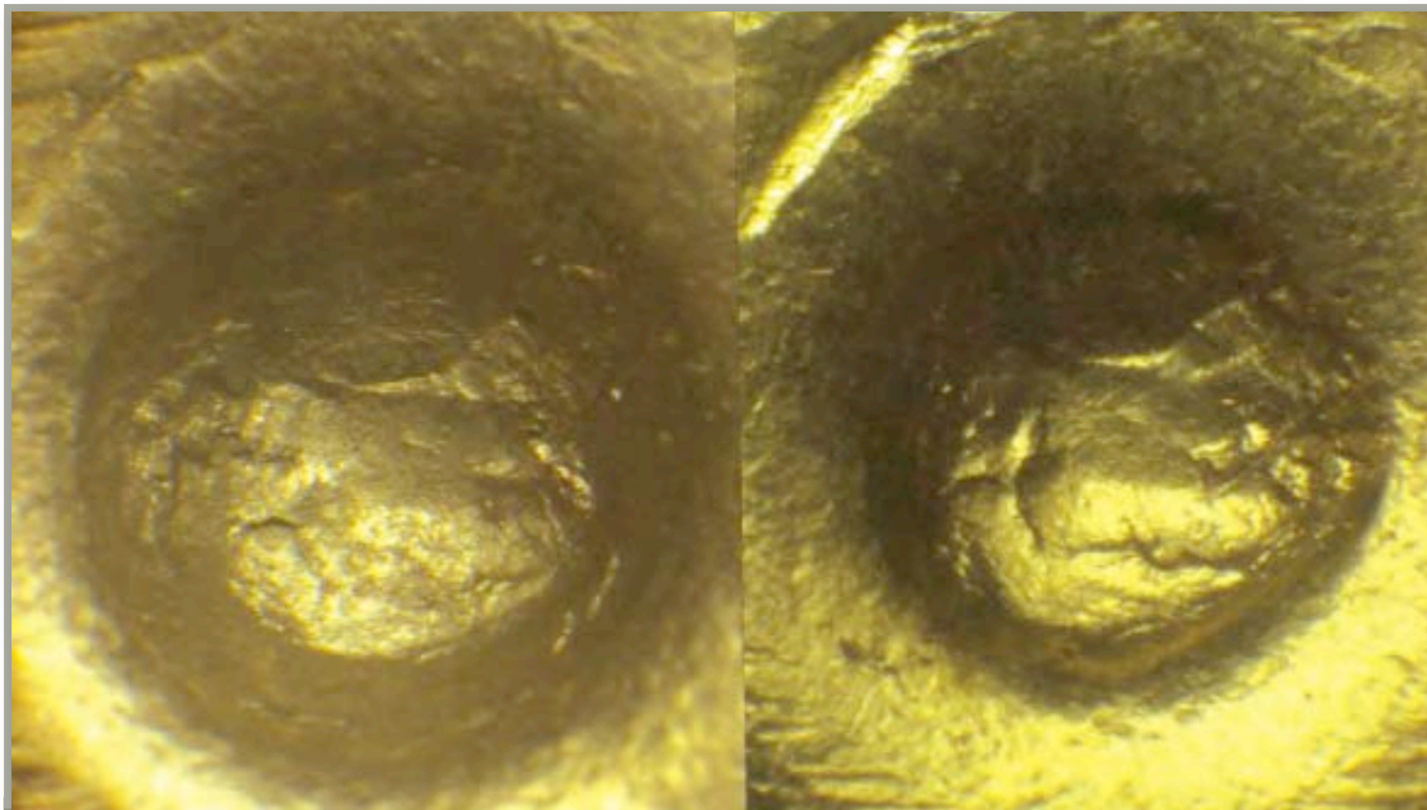
Breech face and firing pin. The extractor is in the upper left, 9 to 12 o'clock.

When the firing pin or striker impacts the cartridge primer, it leaves an impressed toolmark on the soft metal of the primer, and any microscopic imperfections on the surface of the firing pin can be transferred onto the primer. These toolmarks are usually individual in nature and can be reproduced during firings.

Firing pin impression comparison of two fired .22 caliber cartridge cases.

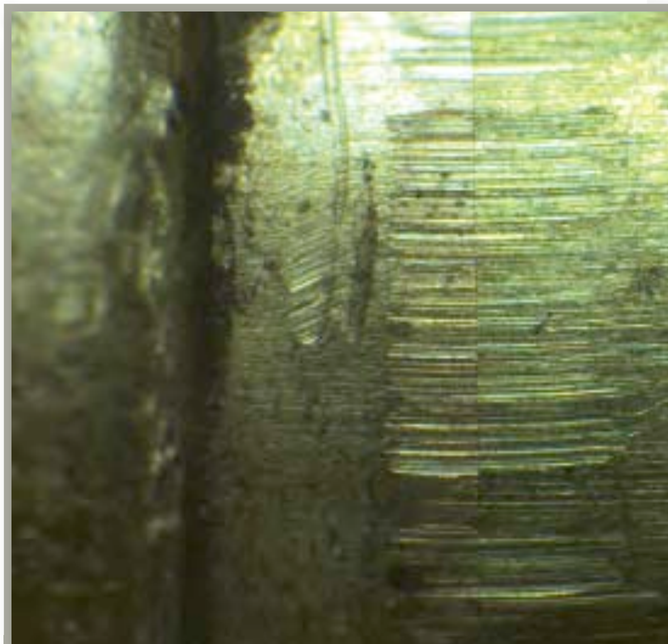


Microscopic comparison of the two firing pin impressions.

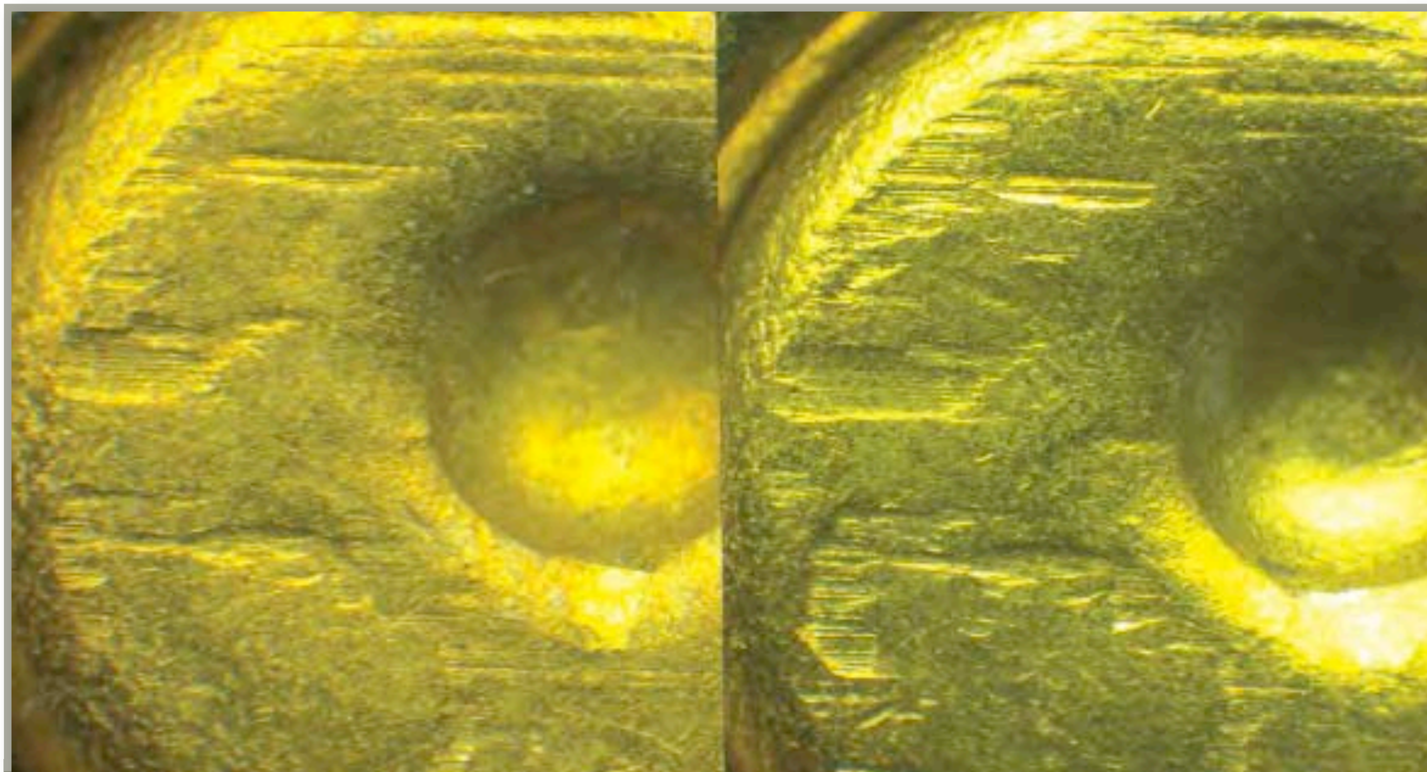


Microscopic comparison of the detail found in the firing pin impressions.

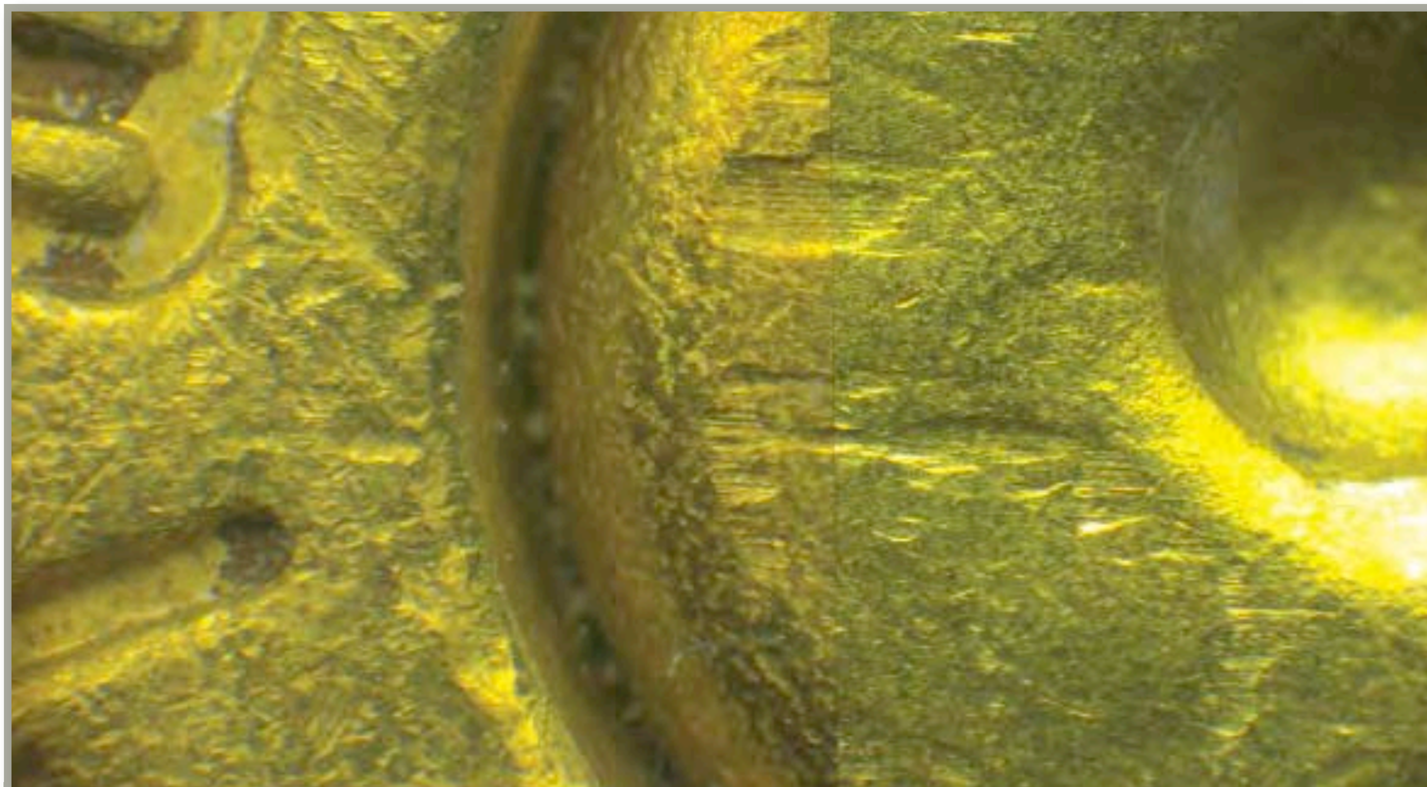
As the powder burns and creates pressure, the case swells inside the chamber and seals the gasses from escaping, except down the barrel behind the bullet. This sealing effect, as described with fired bullets, is also called obturation. The softer metal of the case (brass, aluminum, soft steel) may receive toolmark impressions from the chamber sides called **chamber marks**. As the bullet passes down and out of the barrel, the head of the case impacts the breech or bolt face that holds the case in the chamber. The imperfections of the breech face impress a negative impression on the case head and are called **breech face** marks.



Microscopic comparison of chamber marks on the sides of two cartridge cases.



Microscopic comparison of the breech face detail on two cartridge cases.



The same fired cases as previously shown, microscopically compared side by side.

Ejector marks

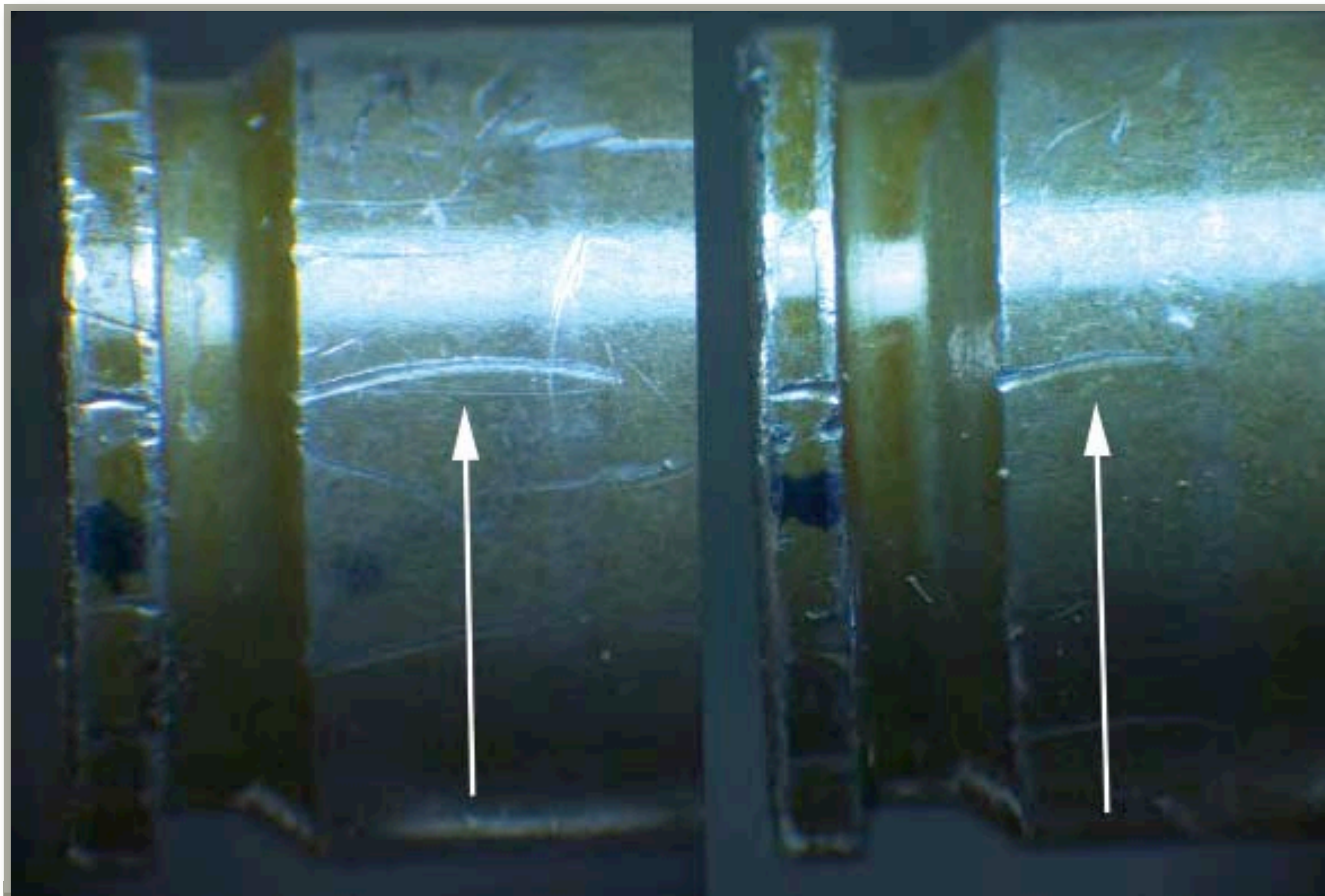
An ejector is a firearm part that assists in the removal of a fired case from the firearm. This ejection process clears the chamber area for subsequent loading of another cartridge into the chamber. The ejector is typically attached to the frame, remains stationary, and kicks the case out of the ejection port after chamber extraction. If there is enough force in this event, the case will have an impression of the ejector, and this toolmark may be identifiable to a particular ejector. (Not all ejectors are of this design. Some are integral to the bolt or firing pin.

Microscopic comparison of ejector impressions on two cartridge cases.

Action Marks on Fired Cartridge Cases and Unfired Cartridges; Investigation Potentials

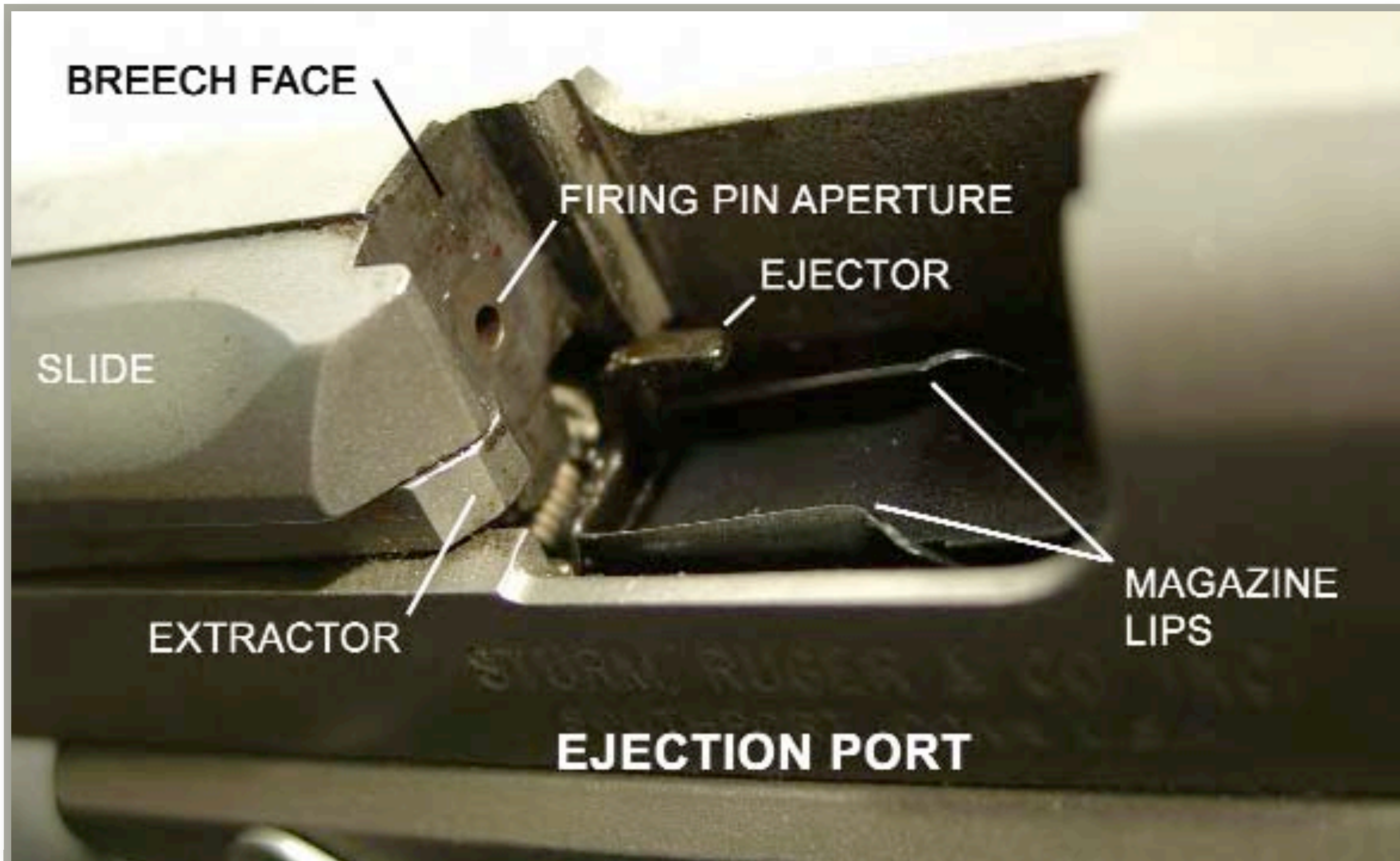
A number of firearm tool surfaces may leave marks on the cartridge case when a cartridge is fired in a firearm. Toolmarks can be produced when a cartridge is loaded, chambered, and extracted without a discharge. Take for example a semiautomatic pistol. The ammunition magazine may leave toolmarks on the side of the cases when the cartridges come in contact with the magazine lips. The cartridges in the magazine are under spring tension and are held in place by magazine lips. The lips may scrape the sides of each case as they are pushed into a chamber, or as they are loaded into, or removed from, the magazine by hand. These toolmarks on the cases may be produced while the magazine is unattached to the firearm. If there is sufficient individualizing detail in these marks (which can be very limited), an identification to a particular magazine may be established. This is important to an investigator because a magazine left at the scene, or confiscated from a suspect, may be compared to ammunition or fired cases recovered at the scene, or ammunition that is seized in the course of the investigation, even when the firearm is not recovered.

A cartridge in an ammunition magazine. The top cartridge held in place by the two magazine lips.



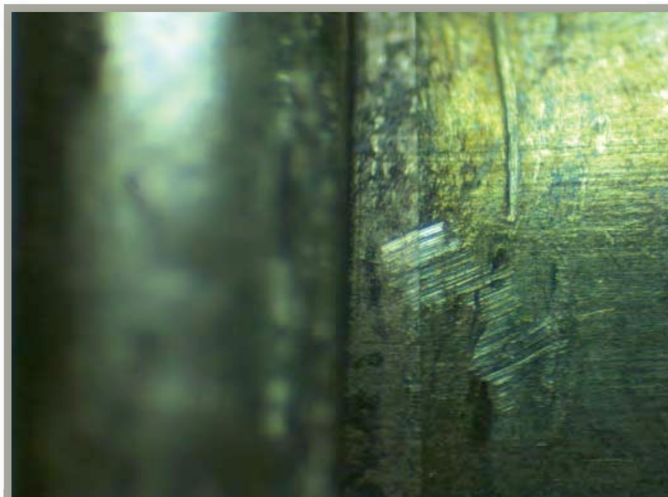
The nearly horizontal arching toolmarks on the sides of the two cartridge cases were made by a lip of an ammunition magazine.

The side view of an ammunition magazine with the orientation of the cartridges that are to be inserted.



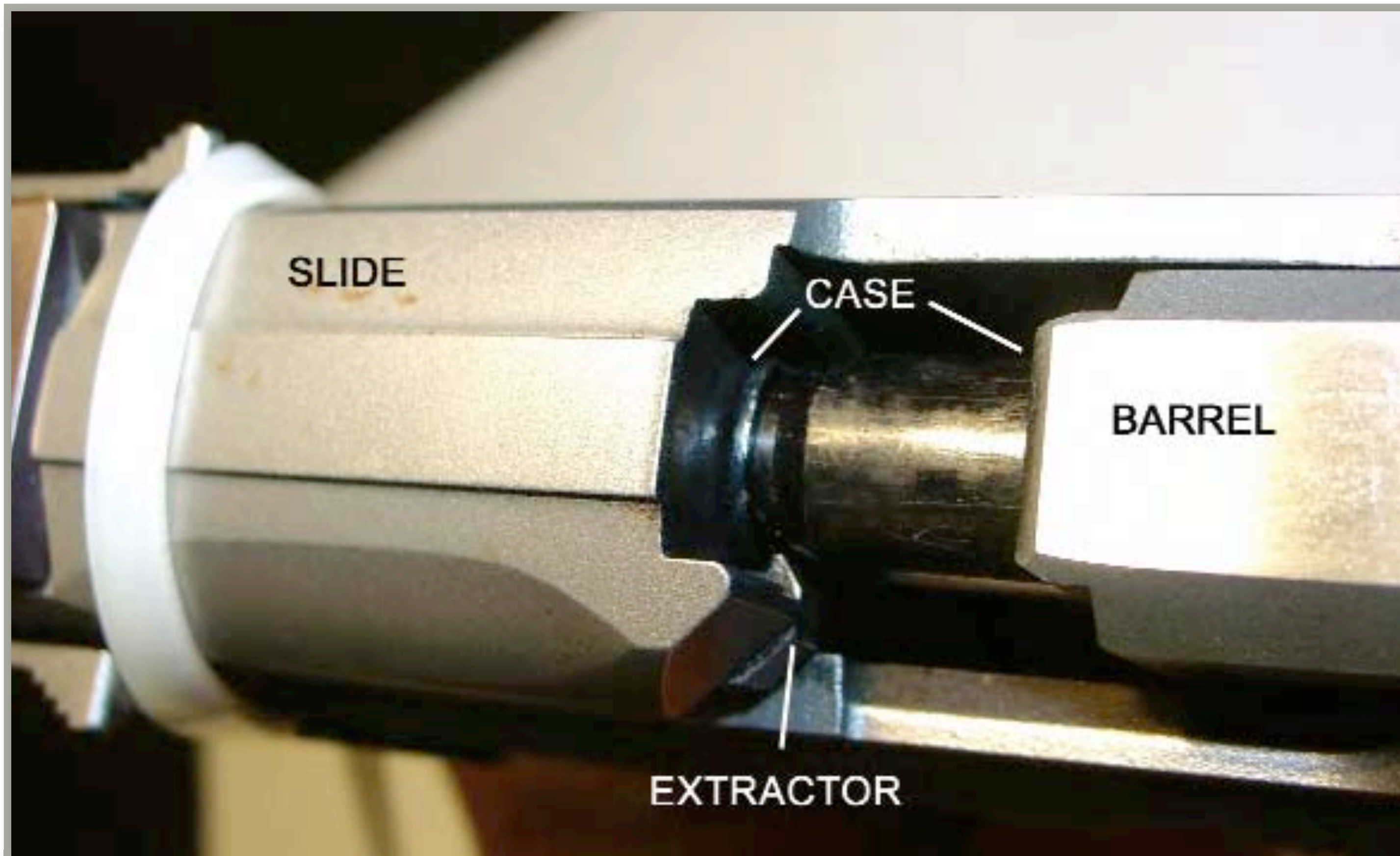
A view through the ejection port of a pistol. To the left is the pistol slide and breech face. In the center of the breech face is the firing pin aperture. To the left of the breech face is the extractor. To the lower right of the breech face is the ejector. Both magazine lips can be seen below and forward of the slide.

Similarly, cartridges may be loaded into, and extracted from, a firearm chamber without firing. A tool that helps this process is called an extractor, which is found on the bolt or slide of the firearm. The tool resembles a claw, which grabs the case head at the base of the cartridge, and may produce scrape marks across the edge of the head. These marks may be produced when the cartridge is worked manually through the action or fired in the firearm. As described above, these marks may be a means to identify cartridge cases between scenes and other ammunition sources without a firearm being recovered.

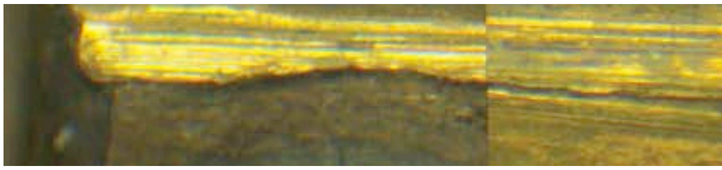


Microscopic comparison of toolmarks produced by an extractor on the sides of two cartridge cases.

These toolmarks described in the preceding photographs and text, especially the breech face and firing pin impressions, are routinely encountered in casework and are the primary areas that examiners use to determine identity. However, some firearms may produce additional toolmarks on fired cases that are either representative to a particular firearm and its function, or a group of firearms that produce atypical toolmarks due to a particular design.



Looking down the pistol's ejection port: A cartridge case is being pulled from the chamber of the barrel by the means of a hook in the slide called an **extractor.**



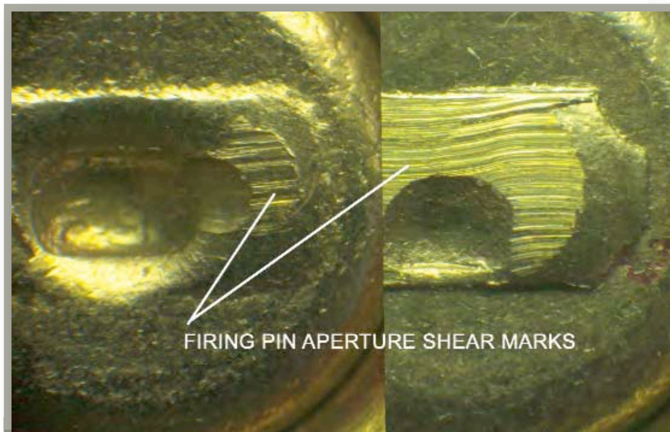
THE EXAMINATION PROCESS AND TRIAL PREPARATION

WHILE THERE IS no single approach to the examination of firearm evidence, and different laboratory examination protocols exist, there are many things in common between forensic laboratories. Since a particular examination is in many ways a custom product because of the variety of firearms evidence and investigation scenarios, the prosecutor must become familiar with the general laboratory protocols utilized by their firearm examiner. The following is a general approach that may be employed in an examination. It is by no means a standard that is used by every laboratory in every case.

Depending on the needs of the investigation, fingerprints, trace evidence, serological stains, and other evidence issues may have to be resolved prior to the handling of the firearm. For example, the more important issue in an investigation may be the fact that the victim's blood is in the barrel of the pistol—more important than the comparison between the fatal bullet and the barrel.

Having resolved other forensic issues, the fired bullets and cases are examined for identifiable toolmarks. This is especially important in the evaluation of bullets that are damaged. If no toolmarks of value are on the evidence bullets, an identification cannot be concluded. However, for some items of evidence, certain class characteristics of the bullet and case may be determined. Details such as the bullet weight, bullet dimensions, composition, manufacture marks, number of lands and grooves, direction of rifling twist, and land and groove impression widths may be recorded and measured. For cartridge cases the caliber, head stamp information, case and primer composition, shape and placement of the firing pin impression, ejector and extractor marks, chamber marks, magazine marks and breech face impression pattern may be documented. This information is then compared with a test-fired bullet and/or cartridge cases from a firearm that may be linked to the crime scene and/or suspect.

If more than one fired bullet and/or case is to be examined, class and individual characteristics can be microscopically compared to determine whether or not the bullets or cartridge cases may be identified to each other. This process can help determine the potential number of firearms involved in the crime. If a firearm is not available, the examiner may be able to produce a list of potential firearm manufacturers that could have fired the ammunition. This list would be an investigation aid, and not inclusive of all firearm sources.



Breech face and firing pin marks on two cartridge cases produced by two similar, but different pistols. The striated marks on both are due to movement of the barrel after firing and prior to cartridge case ejection. These marks are described as "firing pin aperture shear."

Measuring the width of a bullet's land impression using a comparison microscope. On the left is a fired bullet, a micrometer is on the right.

If a firearm is submitted, the examiner may document the overall characteristics of the firearm, such as manufacturer, serial number, model designation, safety functionality, action design, cartridge capacity, submitted ammunition and/or magazines, trigger pull, and operability. Once test-fired, the fired bullets and cases are examined for class characteristics. If there are differences in class characteristics between the firearm and evidence, the examination may end at this stage with an exclusion or **elimination**. But if the class characteristics agree, the firearms examiner would use microscopic comparisons between the test-fired components and the evidence to determine if the individual detail agrees sufficiently to identify the evidence bullets or cases as having been fired from or in the submitted firearm. As discussed previously, these comparisons may also produce an **inconclusive** result.

While there is not one standard note taking or report writing requirement, it is generally accepted as best practice that the observations taken during the examination are noted in the examination case file and that any other documentation such as sketches, photographs, and reference sources are also retained. These materials serve as a memorial of the examination and as a basis for the determinations and conclusions. The examiner's report should describe the submitted items of evidence, generally what was observed in the examination, and the conclusions reached based on those examinations. The conclusions in the report must be supported by the results of tests, observations, and documentation. The examination results and conclusions are typically peer-reviewed by another qualified examiner before the report is released.

A crucial step in the prosecutor's preparation for trial is a pre-trial conference with the examiner in the case. By a review of the report and the case notes, the prosecutor can be cognizant of what evidence was examined, what examination methods were used, how the conclusions were reached, and their limits. Any additional observations and conclusions not in the report but present in the case notes, can be learned at this stage. The prosecutor must review these documents and should interview the witness well in advance of trial. The opposing side may, through discovery, review the same documents and may confer with a defense expert as part of the defense trial preparation.

The pretrial conference offers numerous benefits and will give the prosecutor a solid understanding of the items of physical evidence, and the best order in which to introduce them. He or she will have an understanding of the technical terms and will have logical, jury-friendly questions prepared for the examiner's direct testimony. The prosecutor will know the limits of the results and be able to anticipate answers before the questions are asked so that he or she is prepared for cross-examination. Additionally, a pretrial conference will allow the prosecutor the opportunity to learn of any potential weaknesses in the evidence, provide him or her with the opportunity to discuss possible areas of cross-examination by the defense, and discuss testimony likely to be offered by the defense expert (and its strengths and weaknesses).

The examiner must be objective and only be an advocate for his or her work. The examiner must not weigh the testimony in favor the prosecution or defense. Juries are quite sensitive to any apparent favoritism in testimony, and the examiner will be less credible if this is perceived by the jury. Additionally, any ethical forensic scientist testifies to opinion only within his or her training and expertise. Again, pretrial conferences with the examiner will help in this regard.

Science and the Law: Frye/Daubert and Court Acceptability of Firearm and Toolmark Identification

It is beyond the scope of this monograph to prepare the prosecutor for all the issues that may be brought up in a *Daubert* or *Frye* admissibility hearing. Needless to say, the prosecutor must be well prepared in advance for such an important court hearing. A brief discussion follows, but it is incumbent upon the prosecutor to review and discuss with the examiner that is to be testifying, the relevant literature regarding the scientific support for the acceptability of "Firearm and Toolmark Identification," (*see* Appendix, Resources).

Science is generally described as a systematically organized body of knowledge about a specific subject. The word is derived from the Latin "*scientia*" meaning "to know." There is a foundation of knowledge about firearm and toolmark identification that has been organized over time and is described in forensic textbooks, scientific literature, reference material, training manuals, and peer reviewed scientific journals.

The foundations of firearm identification were developed using the scientific method, a process of gathering knowledge through observation, testing, and experimentation. The scientific method is generally described in the following steps:

1. The problem being investigated is stated;
2. Information concerning the problem is gathered;
3. A hypothesis is developed that may provide an explanation for the problem under investigation;
4. The hypothesis is tested by experimentation;
5. The observations and data derived by the experimentation are recorded and analyzed;
6. Based on the new information, the hypothesis is determined to be valid or not; and
7. If the hypothesis failed, a new one is formed that includes the recently acquired knowledge and the process of testing (steps four to six) is repeated.

If the hypothesis is tested repeatedly, and has not been falsified or disproved, then over time the hypothesis may be developed into a theory. The theory can then be used by scientists to solve similar problems. The theory, however, is still subjected to testing and experimentation through normal scientific inquiry. If it continues to remain valid throughout this continued testing, the theory becomes based on an expanding body of knowledge that is further refined to better explain the solution of the original problem.

In *Daubert*, the issues that may be addressed in the determination of acceptability are:

- the testability of the scientific principle using the scientific method,
- known or potential error rate,
- the existence and maintenance of standards of control,
- peer review and publication, and
- general acceptance in the relevant scientific community. In this case, the relevant community is composed of practitioners in firearm and toolmark identification science.

In preparing for a *Daubert* or *Frye* admissibility hearing, keep in mind the following:

- The firearms and toolmark forensic specialty is based on the scientific method. It is an organized body of knowledge based on a foundation and principles that are testable by observation and design of experiments that seek to determine the accuracy of conclusions made under those principles.
- The known or potential error rate of the science is an

important consideration for the court. No human endeavor, no matter how carefully constructed, is error-free. The court is most interested in the frequency of misidentification, even when using accepted techniques, protocols, and instrumentation. Certainly the estimation is not "0%," which some may describe as a theoretical error rate, or that the science is infallible. While there is no known study that has determined the error rate in actual casework, reviews of proficiency testing data show that the error rate for misidentifications for firearm evidence is approximately 1.0%, and for toolmark evidence it is approximately 1.3%.[1]

- It must be noted that proficiency testing was never designed to determine error rate in the profession, but rather it is used as a laboratory training and quality assurance tool. Certainly, the error rate of the individual examiner may be discussed. If proficiency tests performed by the examiner were all accurate, then the error rate for the examiner would be 0% for these tests. However, if an error had been made, it is critical that the circumstances of the error be evaluated. Perhaps, the error was made while the examiner was in training status.
- Any potential for error is further reduced by the *Daubert* guideline for "the existence and maintenance of standards of control" most commonly achieved by the review and opinion of a second examiner. This type of peer review helps to ensure the accuracy of the results. In addition, quality control and quality assurance measures help maintain work integrity, and are usually described in written guidelines on file in most forensic laboratories.
- Another hallmark of a scientific discipline is the publication of scientific information in peer-reviewed journals. In this way, information on techniques and the validity of a method is disseminated to practitioners, who in turn may support or challenge the information. Scientific information is also disseminated via presentations at professional association meetings and seminars.
- The relevant scientific community is represented by the Association of Firearm and Toolmark Examiners (AFTE), an international body of practitioners in this science. Peer reviewed articles are published in the *AFTE Journal*. Additionally, standardized terms and technical reference information are published in the *AFTE Glossary*.

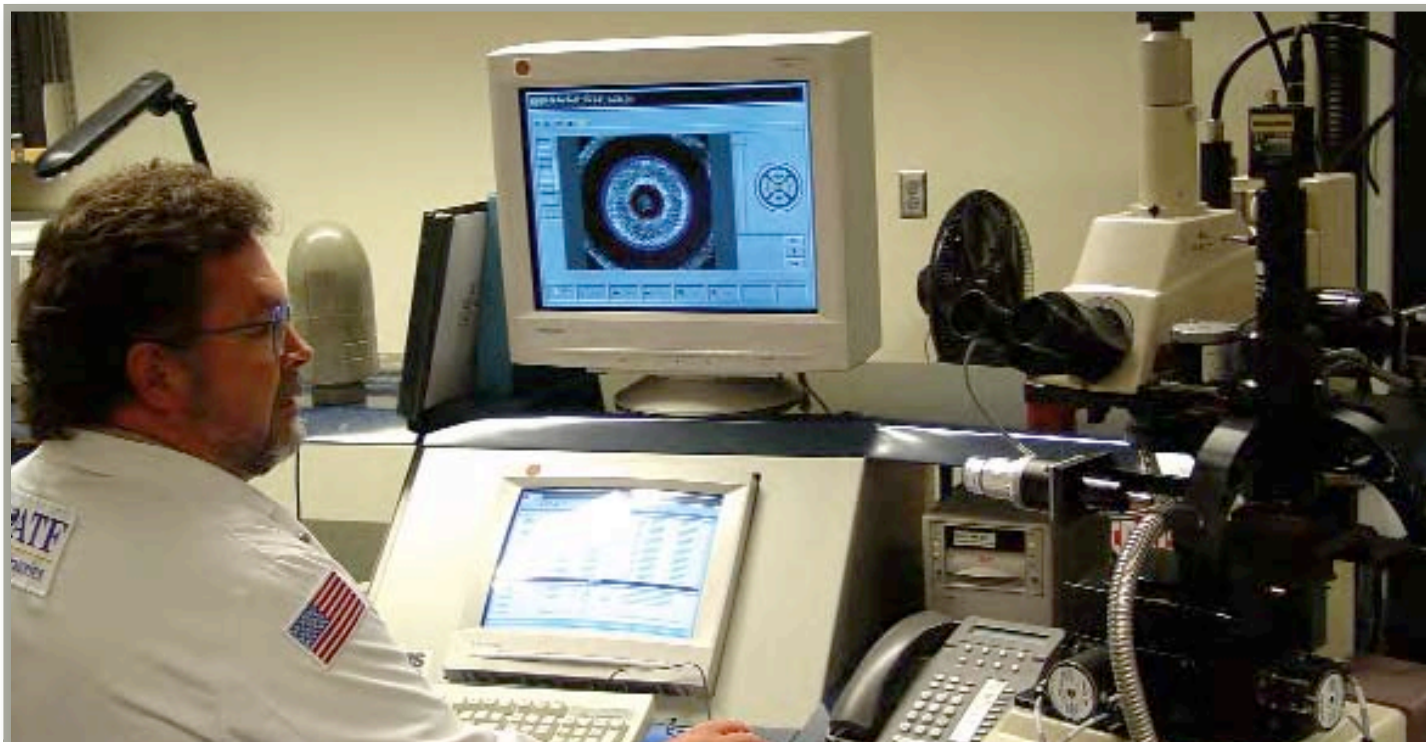
Automated Computer Search Technology

As we have seen, the firearm as a device containing a number of separate tools can produce unique and reproducible toolmarks on fired bullets and cartridge cases. The digitizing of the surfaces of the fired cartridge components in a form that can be searched in a database is the basis for the modern National Integrated Ballistic Information Network (NIBIN). Prior to this technology, the examiner had to rely on "cold searching" an open file of test-fired cartridges to open case evidence. This effort was laborious, if even attempted, and was not amenable to sharing with neighboring jurisdictions. However, in the early 1990s a prototypical system to produce a digital map of the individualizing detail on fired bullets and cartridge cases was developed and tested. This technology was developed by Forensic Technology Incorporated (FTI) and was named the Integrated Ballistic Identification System (IBIS). The images acquired in the crime laboratory on an IBIS were converted into a form so that a mathematical algorithm could be used to compare other fired bullets and cartridge case images in a compiled database. In this way, thousands of fired bullets and cases could be compared, scored, and images retrieved to find presumptive links to other firearm related crimes or to recovered firearms. The early testing and investigation results were so successful that the databases have been combined into a national searchable system called NIBIN.

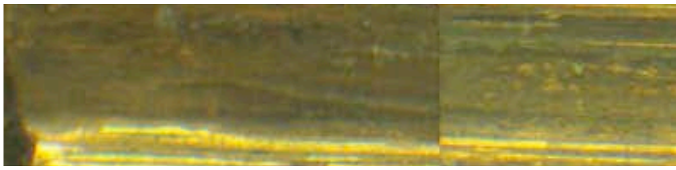
The NIBIN Program is funded and managed by the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), but the system is run from 206 sites primarily in local and state crime laboratories representing 174 agencies. As of 2007 approximately 1,400,000 pieces of firearm and crime scene evidence have been entered resulting in over 23,000 "cold hits." NIBIN is currently producing approximately 4000 cold hits a year. A cold hit is when an association is made using only this technology and when no link is otherwise suspected in the investigation. A typical cold hit scenario could start when a bullet recovered at autopsy, together with cases found at the scene, are entered into the local IBIS. Some time later, a link is found to test-fired bullets and cases from a seized pistol recovered in a vehicle stop. The IBIS presents the potential hit to the examiner, and the original evidence and test fires are compared at the laboratory to confirm the identification.

The use of both IBIS and NIBIN together could be characterized as a search engine for firearm evidence. A piece of evidence would be equivalent to a keyword or subject. The keyword is searched on the Internet for more information that may be important to the reader. The closest words or terms are graded, the closest matching information is scored the highest, and the information packets are brought up in a ranked list for further viewing.

This search on the Internet is similar to the bullet/casing image search on the IBIS. An entered image is correlated or compared to each individual image that corresponds to the class characteristics in the database. The images that are the most similar are scored higher than pairs that are less similar. The complete database comparison results in a ranked score list. The examiner is only concerned with the best scoring pairs. Those pairs of digital images are compared visually on computer monitors to see which potential links should be compared microscopically. In this way, thousands of evidence entries can be compared not only within a laboratory's database, but also within a shared database of a number of other crime laboratory jurisdictions. The NIBIN linking of national databases enables the examiner to query individual databases or groups of databases throughout the United States.



Place image: The IBIS instrumentation



APPENDIX

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Drug-Linked Firearms Cases: A Primer for Prosecutors; American Prosecutors Research Institute, May 2005.

Firearm/toolmark Identification: Passing the Reliability Test Under Federal and State Evidentiary Standards; Grzybowski, Miller, Moran, Murdock, and Thompson; AFTE Journal, Volume 35, Number 2, Spring 2003.

Firearm and Toolmark Identification—Meeting the Daubert Challenge; Grzybowski and Murdock; AFTE Journal, 1998: 30(1).

Firearm and Toolmark Identification Criteria: A Review of the Literature; Nichols; Journal of Forensic Sciences, 1997 May; 42(3).

Firearm and Toolmark Identification Criteria: A Review of the Literature, Part II; Nichols; Journal of Forensic Sciences, 2003 March; 48(2).

Glossary of the Association of Firearm and toolmark Examiners; Fourth Edition.

Resources

Web-based information can be found on:
www.FirearmsID.com
www.AFTE.org
www.swggun.org
www.NIBIN.gov
www.ATF.gov

For additional assistance in preparing for a FRYE/DAUBERT hearing, and answers to other gun crime prosecution questions, contact the National District Attorneys Association's Gun Violence Prosecution Program or call 703.549.9222.

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Scott Doyle, Erik Dahlberg, Firearms ID.com, Robert Thompson, Association of Firearm and Toolmark Examiners (AFTE), and the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF)

GLOSSARY

From the *Association of Firearm and Toolmark Examiners Glossary,* Fourth Edition, 2001

Action
The working mechanism of a firearm.

Semiautomatic—A repeating firearm requiring a separate pull of the trigger for each shot fired, and which uses the energy of discharge to perform a portion of the operating or firing cycle (usually the loading portion).

Automatic—A firearm design that feeds cartridges, fires, extracts and ejects cartridge cases as long as the trigger is fully depressed and there are cartridges in the feed system. Also called "full auto" and "machine gun."

Revolver—A firearm, usually a handgun, with a cylinder having several chambers so arranged as to rotate around an axis and be discharged successively by the same firing mechanism. *See also* "revolver."

Lever—A design wherein the breech mechanism is cycled by an external lever generally below the receiver.

Slide—An action that features a movable forearm which is manually actuated in motion parallel to the barrel by the shooter. Forearm motion is transmitted to a breech bolt assembly that performs all the functions of the firing cycle assigned to it by the design. Also known as "pump action."

Bolt—A firearm in which the breech closure:
1. is in line with the bore at all times
2. manually reciprocates to load, unload and cock,
3. is locked in place by breech bolt lugs and engages abutments usually in the receiver. There are two principal types of bolt actions: the turn bolt and the straight pull.

Bolt Face
See Breech Face

Bore
The interior of a barrel forward of the chamber.

Breech Face
That part of the breechblock or breech bolt which is against the head of the cartridge case or shotshell during firing.

Bullet
A non-spherical projectile for use in a rifled barrel.

Cartridge
A single unit of ammunition consisting of the case, primer, and propellant with one or more projectiles. Also applies to a shotshell.

Cartridge, Center Fire
Any cartridge that has its primer central to the axis in the head of the case.

Cartridge, Rimfire
A flange-headed cartridge containing the priming mixture inside the rim cavity.

Cartridge Case
The container for all the other components that comprise a cartridge.

Chamber
The rear part of the barrel bore that has been formed to accept a specific cartridge. Revolver cylinders are multi-chambered.

Chamber Marks
Individual microscopic marks placed upon a cartridge case by the chamber wall as a result of any or all of the following: (1) chambering (2) expansion during firing (3) extraction.

Class Characteristics
Measurable features of a specimen that indicates a restricted group source. They result from design factors and are therefore determined prior to manufacture.

Comparison Microscope
Essentially two microscopes connected to an optical bridge that allows the viewer to observe two objects simultaneously with the same degree of magnification. This instrument can have a monocular or binocular eyepiece. Sometimes referred to as a "comparison macroscope."

Deep Hole Drilling
A modern technique for barrel drilling involving rotation of the blank on a nonrotating bit, under high pressure lubrication. Also, an operation in which the depth of the hole is 10 or more times greater than the diameter of the drill.

Ejector
A portion of a firearm's mechanism thatejects or expels cartridges or cartridge cases from a firearm.

Extractor
A mechanism for withdrawing the cartridge or cartridge case from the chamber.

Firearm
An assembly of a barrel and action from which a projectile is propelled by products of combustion.

Firing Pin
That part of a firearm mechanism that strikes the primer of a cartridge to initiate ignition. Sometimes called "hammer nose" or "striker."

Function Testing
The examination of a firearm concerning its mechanical condition and operation. It is usually performed to determine if all safety features are operable and/or if the firearm is capable of firing a cartridge.

Groove
See "rifling."

Handgun
A firearm designed to be held and fired with one hand.

Impression
Contour variations on the surface of an object caused by a combination of force and motion where the motion is approximately perpendicular to the plane being marked. These marks can contain "class" and/or "individual characteristics."

Individual Characteristics
Marks produced by the random imperfections or irregularities of tool surfaces. These random imperfections or irregularities are produced incidental to manufacture and/or caused by use, corrosion, or damage. They are unique to that tool and distinguish it from all other tools.

Land
The raised portion between the grooves in a rifled bore.

Magazine
A container for cartridges that has a spring and follower to feed those cartridges into the chamber of a firearm. The magazine may be detachable or an integral part of the forearm.

Obturation
1. The sealing of gases due to the expansion of a cartridge case as a result of chamber pressure.
2. The sealing of gases due to the expansion and/or upset of the bullet base as it travels down the bore.

Pistol
A handgun in which the chamber is part of the barrel. A term sometimes used for "handgun."

Primer
The ignition component of a cartridge.

Projectile
An object propelled by the force of rapidly burning gases or other means.

Propellant
In a firearm, the chemical composition, which when ignited by a primer, generates gas. The gas propels the projectile. Also called "powder"; "gunpowder"; "smokeless powder."

Range of Conclusions Possible When Comparing toolmarks
The examiner is encouraged to report the objective observations that support the findings of toolmark examinations. The examiner should be conservative when reporting the significance of these observations.

- **Identification**
  Agreement of a combination of individual characteristics and all discernible class characteristics where the extent of agreement exceeds that which can occur in the comparison of toolmarks made by different tools and is consistent with the agreement demonstrated by toolmarks known to have been produced by the same tool.

- **Inconclusive**
  A. Some agreement of individual characteristics and all discernible class characteristics, but insufficient for an identification.
  B. Agreement of all discernible class characteristics without agreement or disagreement of individual characteristics due to an absence, insufficiency, or lack of reproducibility.
  C. Agreement of all discernable class characteristics and disagreement of individual characteristics, but insufficient for an elimination.

- **Elimination**
  Significant disagreement of discernable class characteristics and/or individual characteristics.

- **Unsuitable**
  Unsuitable for examination.

Reamer
One of many spiral or straight-fluted multi-edged cutting tools used to size and shape a hole.

Revolver
A firearm, usually a handgun, with a cylinder having several chambers so arranged as to rotate around an axis and be discharged successively by the same firing mechanism.

Rifle
A firearm having rifling in the bore and designed to be fired from the shoulder.

Rifling
Helical grooves in the bore of a firearm barrel to impart rotary motion to a projectile.

Rifling Methods
Broach, Gang—A tool having a series of cutting edges of slightly increasing height used to cut the spiral grooves in a barrel. All grooves are cut with a single pass of the broach.

Broach, Single—A non-adjustable rifling cutter which cuts all of the grooves simultaneously, and is used in a series of increasing dimensions until the desired groove depth is achieved.

Button—A hardened metal plug with a rifled cross section configuration. It is pushed or pulled through a drilled and reamed barrel so as to cold form the spiral grooves to the desired depth and twist. When the carbide button was first introduced it was described as a "swaging process" or "swaged rifling."

Hook—A cutting tool that has a hook shape and only cuts one groove at a time.

Scrape—A cutting tool that cuts two opposing grooves at a time.

Swage—An internal mandrel with rifling configuration that forms rifling in the barrel by means of external hammering. Also known as "hammer forging."

Rimfire
See "cartridge, rimfire."

Shotgun
A smooth bore shoulder firearm designed to fire shotshells containing numerous pellets or sometimes a single projectile.

Shoulder
1. The act of placing a shotgun or a rifle to a shooter's shoulder to align the sights and fire at a target.
2. The sloping portion of a metallic cartridge case that connects the neck and the body of a bottleneck cartridge.
3. The square or angular step between two diameters on a barrel, pin, stud, or other part commonly used in firearms.

Striations
Contour variations, generally microscopic, on the surface of an object caused by a combination of force and motion where the motion is approximately parallel to the plane being marked. These marks can contain "class" and/or "individual characteristics."

Striker
A rod-like firing pin or a separate component that impinges on the firing pin.

Subclass Characteristics

Discernible surface features of an object that are more restrictive than "class characteristics" in that they are:

1. Produced incidental to manufacture.
2. Are significant in that they relate to a smaller group source (a subset of the class to which they belong).
3. Can arise from a source that changes over time. Examples would include: bunter marks, extrusion marks on pipe, etc.

Caution should be exercised in distinguishing subclass characteristics from "individual characteristics."

Theory of Identification as it Relates to toolmarks

- The theory of identification as it pertains to the comparison of toolmarks enables opinions of common origin to be made when the unique surface contours of two toolmarks are in "sufficient agreement."

- This "sufficient agreement" is related to the significant duplication of random toolmarks as evidenced by the correspondence of a pattern or combination of patterns of surface contours. Significance is determined by the comparative examination of two or more sets of surface contour patterns comprised of individual peaks, ridges and furrows. Specifically, the relative height or depth, width, curvature and spatial relationship of the individual peaks, ridges and furrows within one set of surface contours are defined and compared to the corresponding features in the second set of surface contours. Agreement is significant when it exceeds the best agreement demonstrated between toolmarks known to have been produced by different tools and is consistent with agreement demonstrated by toolmarks known to have been produced by the same tool. The statement that "sufficient agreement" exists between two toolmarks means that the agreement is of a quantity and quality that the likelihood another tool could have made the mark is so remote as to be considered a practical impossibility.

- Currently the interpretation of individualization/identification is subjective in nature, founded on scientific principles and based on the examiner's training and experience.

Tool

An object used to gain mechanical advantage. Also thought of as the harder of two objects that, when brought into contact with each other, results in the softer one being marked.

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