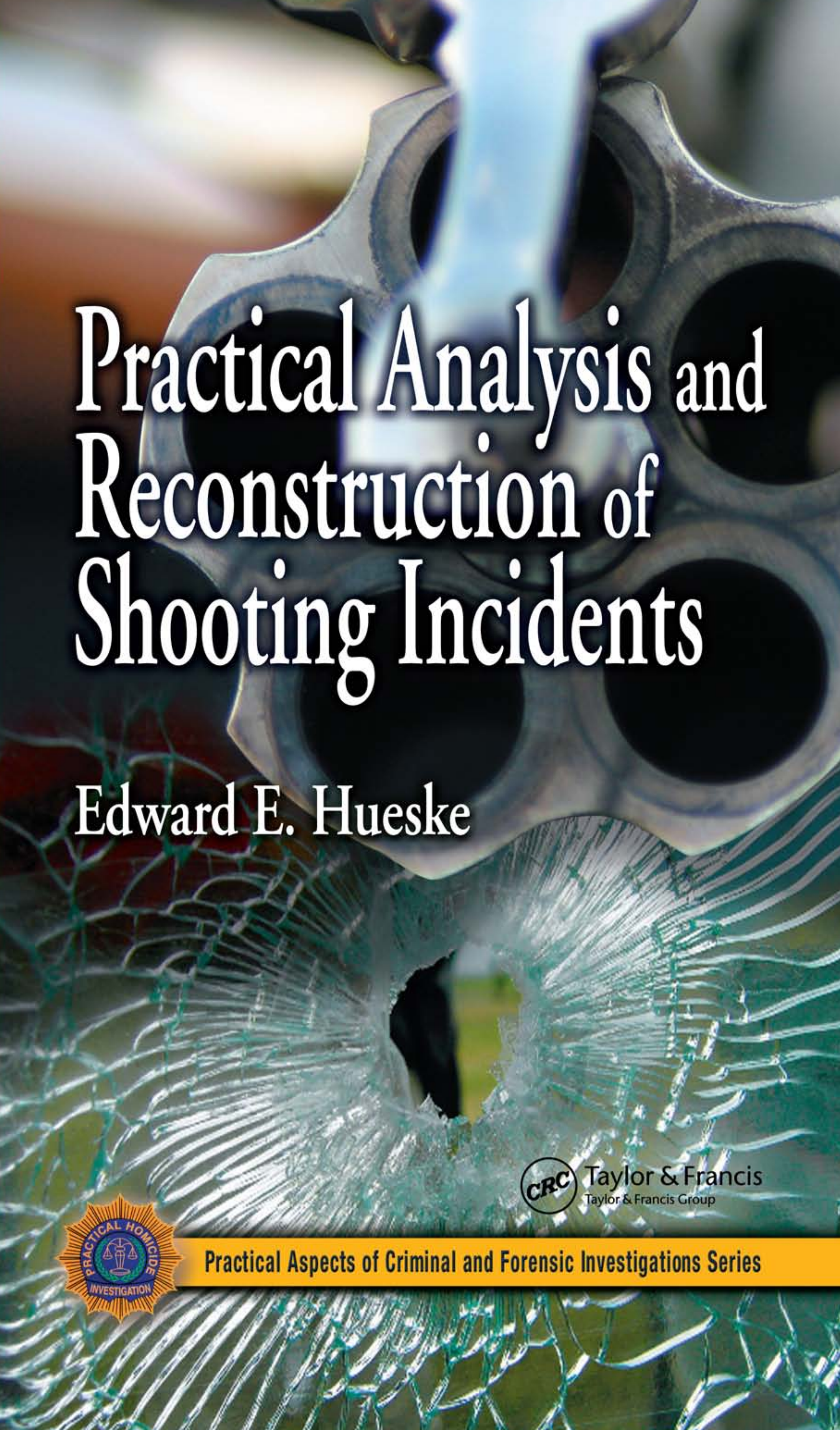

Practical Analysis and Reconstruction of Shooting Incidents

Edward E. Hueske

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Practical Aspects of Criminal and Forensic Investigations Series

Practical Analysis and Reconstruction of Shooting Incidents

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Preface

The goal of physical evidence preservation, collection, and examination is individualization — associating each piece of evidence with its responsible source. By so doing, the forensic scientist may be able to answer the questions about the who, what, when, where, how, and why of a crime. Firearms evidence in particular is in the somewhat unique category of physical evidence that has the potential to individualize its source. Thus, a bullet or cartridge case can be identified as having been fired from a particular weapon to the exclusion of all similar weapons.

While determining that a particular weapon was responsible for firing a fatal shot constitutes crucial evidence, the development of a probable scenario for the shooting is "where the rubber meets the road" in a criminal investigation. Without a theory of what took place in a shooting incident, the physical evidence is left open to broad speculation.

It is equally incumbent upon the investigator not to inflate the significance of what is present or read more into it than can be scientifically supported. This goes well beyond the "cup half-empty versus half-full" principle. For example, suppose a fired bullet cannot be positively identified as having been fired from a weapon. Describing it as "entirely consistent with" having been fired by the gun in question, while technically correct, pushes the window in a particular direction.

It is the responsibility of an individual involved in the analysis and reconstruction of a shooting incident or any other crime to properly represent the evidence within the limits of good science. The ability to do so is directly tied to education, training, and experience. While ignorance may be blissful, it can have disastrous effects when people's lives hang in the balance of an investigator's written report and testimony. Accordingly, the investigator should constantly question and test theories as they are proposed.

This text is intended to provide a basis from which the reader can develop and hone the skills necessary to analyze and reconstruct a shooting incident through practical experience. Knowledge without experience presents as many pitfalls as experience with no knowledge. Thus, the reader must recognize that careful study of the literature, individual observation, and experimentation combined with considerable direct field experience constitute the most likely formula for success in this discipline.

Acknowledgments

This book is dedicated to the many law enforcement professionals who have attended my shooting reconstruction classes over the years. Through their interest and participation in my classes, I have been motivated to continue to expand my own knowledge of the topic through experimentation, reading, and discussion. It is my sincere hope that this text will be of value to them in their ongoing efforts to discover who, what, when, where, and why at shooting scenes.

Among the numerous individuals who have provided encouragement and assistance with this project, three are deserving of special mention. They are James Gannalo, New York Police Department (retired), Dean Garrison, Grand Rapids Police Department, and Todd Garrison, Missouri State Police.

A special word of thanks is in order for two of my students in the criminal justice program at the University of North Texas. Jessica Jernigan spent many hours assisting in the manuscript preparation and Kyle Paulsen did an outstanding job recreating photographs that were otherwise unavailable.

Lastly, I am appreciative of the understanding displayed by my family whenever writing took precedence over family activities. That scenario was repeated many times throughout the process of putting this book together.

Author

Edward Hueske began his forensic career as a criminalist with the Fort Worth Police Crime Laboratory in 1974 where he first became interested in firearms examinations and shooting incident reconstruction. An avid shooter and gun collector, Ed continued to develop his skills in the discipline as he advanced to the position of assistant laboratory director. After leaving Fort Worth in 1983, Ed continued his law enforcement career in Arizona and Oklahoma crime laboratories before retiring from law enforcement in 1996 to establish Forensic Training and Consulting, LLC (FT&C). In 1999, he joined the faculty of the University of North Texas in Denton.

Ed continues to teach shooting incident reconstruction classes for police agencies, both domestically and abroad, through FT&C. He also regularly consults for the prosecution and the defense in civil and criminal cases, particularly in the area of shooting incident reconstruction. Ed teaches criminalistics at the University of North Texas in the department of criminal justice and helped establish a certificate program in criminalistics at the university.

Ed is a distinguished member of the Association of Firearm & Tool Mark Examiners (AFTE), a fellow of the American Academy of Forensic Sciences (AAFS), and an emeritus member of the Southwestern Association of Forensic Scientists (SWAFS) and the American Society of Crime Laboratory Directors (ASCLD). He is also a member of the International Association of Bloodstain Pattern Analysts (IABPA) and the Association for Crime Scene Reconstruction (ACSR).

When time permits, Ed can be found at the family ranch in West Texas working with his small herd of registered Texas Longhorn cattle. Other favorite outlets include bass fishing, working on antique automobiles, and skeet shooting.

Editor's Note

This textbook is part of a series entitled "Practical Aspects of Criminal and Forensic Investigation." This series was created by Vernon J. Geberth, New York City Police Department Lieutenant Commander (Retired), who is an author, educator, and consultant on homicide and forensic investigations.

This series has been designed to provide contemporary, comprehensive, and pragmatic information to the practitioner involved in criminal and forensic investigations by authors who are nationally recognized experts in their respective fields.

Illustrations

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Theory and Practice of Shooting Reconstruction

Shooting Reconstruction and the Scientific Method

Like all other forensic evidence, the evidence resulting from a shooting incident is evaluated according to the scientific method. Each and every piece of physical evidence, whether it is a fired bullet, a shot pellet pattern, a firearm, or a similar item, lends itself to this procedure of systematic evaluation. For each item, the particular question or problem must first be formulated, observations made, a hypothesis formulated, and tests conducted. Ultimately, the various pieces of the "puzzle" are put together into a coherent sequence that constitutes the theory of the shooting.

Scientific Method

- Identify the problem
- Make observations
- Develop a hypothesis
- Carry out tests
- Refine the hypothesis
- Develop a theory

For example, suppose we find a fired bullet lying on the floor near the body of a victim of a gunshot wound. Also lying nearby is a revolver. The obvious problem or question is "Did that revolver fire that bullet?" We observe that the weapon is 22 caliber. We also observe that the bullet appears to be 22 caliber. After properly documenting both items (taking photographs, videotaping, sketching and fixing locations through measurements) and taking appropriate precautions to preserve any trace evidence present, we pick up both items and are able to note that the bullet bears six lands/grooves with a right-hand twist. A look into the muzzle end of the weapon reveals that it too has six lands/grooves with a right-hand twist.

The next step is laboratory examination of the weapon and bullet to determine whether, in fact, the bullet was fired from the revolver. Based upon the laboratory results, we will form our hypothesis. In this instance, let us say the laboratory results excluded the revolver as having fired the bullet. However, the firearms examiner reported that the bullet's rifling characteristics included those of a Colt revolver.

Suppose we had found a Colt revolver factory instruction sheet in the residence. Based upon our observation and test results, our hypothesis would be modified and we would now propose that a Colt revolver may have been involved. A search of the decedent's files reveals a receipt from a local gun shop for a Colt revolver. We now form a theory that the bullet was probably fired from a Colt revolver belonging to the decedent. Thus, each piece of physical evidence is handled accordingly.

Ultimately, each piece of evidence and every aspect of a shooting incident will be subjected to this logical process of critical thinking and an all-encompassing theory developed. We must, however, always be open to new considerations as cases unfold. The biggest pitfall in criminal investigation is having tunnel vision. In the author's 30 years of crime scene and shooting incident reconstruction, there have been numerous cases in which investigators formed a hypothesis early on in the investigation and then proceeded to selectively collect the evidence and statements that supported this theory while rejecting facts and items that were at odds with their theory. This has occurred most often in cases where homicide versus suicide was the issue.

A resident in an upscale residential area called police after hearing what he perceived to be two gunshots shortly after midnight coming from the area of his next door neighbor's front yard. An officer was dispatched to the location. The officer shined his spotlight around the heavily foliated front yard of the reporting person's neighbor, a physician, but did not exit the patrol unit. Not observing anything, the officer left the area after checking off on the radio.

The following morning the reporting person arose and went outside to get his paper from his front yard. As he did so, he glanced over to his next door neighbor's yard and observed a body in the underbrush. Once again he called authorities to the scene; this time they exited their vehicles and found the doctor's body (Figure 1.1) clad in shorts and a T-shirt. He was wearing a pair of sandals. A single shot had entered the chest but did not exit. A World War II vintage Luger pistol (Figure 1.2) was found under the body. A most bizarre piece of evidence was also present: hanging onto the

Figure 1.1 Body at scene.

outside lip of a square concrete irrigation well (Figure 1.3) was a Walther 380 pistol with a piece of yard trimmer cord tied to the trigger guard. The other end of the cord was tied to some metal pieces from a vise, all of which extended down into the well (Figure 1.4).

Given the location of the Walther pistol on the lip of the well and the fact that the weights were tied to the trigger guard and hanging down inside the well, investigators surmised that this case was clearly a suicide and set out to prove it. In a clear case of tunnel vision, officers ignored evidence that tended to point away from suicide. For example, interviews of neighbors were structured so as to elicit responses favorable to the suicide theory. Rather than asking open-ended questions such as "How would you describe the victim's demeanor of late?" they asked questions such as "Have you ever seen the victim depressed?" A box of letters was found under the bed in the victim's master bedroom. With the exception of one letter dated a year earlier, all could have been categorized as love letters. The sole uncomplimentary letter was the only one collected.

Figure 1.2 Luger pistol.

Figure 1.3 Irrigation well (background).

The day after the doctor's death was reported on the news, an area restaurant owner contacted authorities and turned over a letter that he said the doctor had delivered the day before his death and asked that it be given to an employee who was not at work that day. Upon examining the letter, investigators noted that the letter alluded to money owed to the doctor and included what could be considered a very significant statement: "Your threats do not scare me, I expect you to come by and settle your debt this weekend." Was it possible the employee did so?

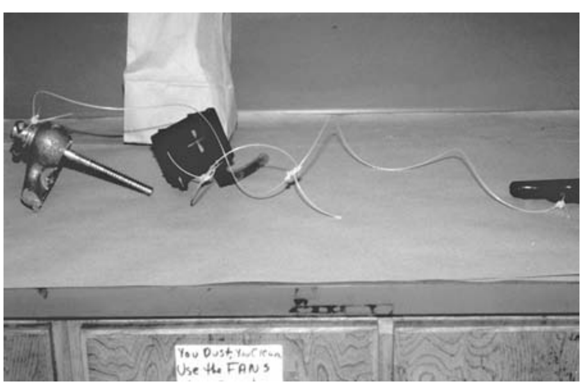


Figure 1.4 Walther pistol and weights.

Interestingly, the investigator reasoned that the intended recipient could not be a suspect because he never received the letter. That logic continues to defy understanding. Basically, the letter suggests a possible motive and definitely should have been investigated thoroughly. However, investigators had already concluded that the case was a suicide and did not want to be bothered with facts that pointed in any other direction.

Investigators spent a total of 2 hours at the crime scene, made no sketches or diagrams, recorded no videotape, and took a total of 9 Polaroid photographs. In keeping with the shoddy investigation, the victim's wife discovered a bullet hole through the exterior wall of the house after the officers left. The bullet had entered a bedroom, passed through a bifold door and came to rest in a basket of laundry inside a closet. Officers were again summoned to the house to collect the bullet and photograph the bullet hole. Investigators failed to determine the trajectory of the bullet through the front of the house. It was later established by an expert hired by the family that the trajectory indicated a shot originating approximately 20 feet from where the body was found.

The only laboratory examinations that the police agency requested were to establish which weapon fired the fatal bullet and which, if either of them, fired the bullet that entered the house. Ultimately, the fatal bullet was identified as having been fired from the 380 Walther. A check with The U.S. Bureau of Alcohol, Tobacco, and Firearms revealed that the Walther was registered to the doctor. A similar check of the Luger failed to identify its owner.

Because the Luger lay under the doctor's body after the shooting, the action became jammed with dried blood. The crime laboratory reported that the weapon was "unfireable as received" and, therefore, conducted no tests (other than eliminating the Walther) on the bullet found inside the bedroom. No further testing was requested and none was done. Because the case was ruled a self-inflicted gunshot wound, the investigating department was not required to maintain the evidence. With the exception of the two weapons, the evidence was all discarded. Thus, an independent examination was greatly hampered. The Luger was subsequently cleaned of blood and test fired. Without the bullet from the bedroom, it could only be speculated whether the Luger was responsible for the doctor's death. Ultimately, an unequivocal determination of suicide versus homicide could not be made. The predisposition of the investigators to declare the shooting a suicide resulted in only a superficial investigation and the overlooking of critical evidence.

One important item to remember in analyzing any crime scene is to remain open minded and constantly reassess the evidence. Basically, we recommend using inductive reasoning at the scene. We will ultimately shift from inductive to deductive reasoning as we formulate our theory of the shooting.

On-Scene Evidence: Evaluation and Documentation

Without a doubt, the most important activities related to shooting incident analysis and reconstruction take place at the scene. Trajectory determinations, for example, must be made at the scene. Likewise, the assessment of spatial relationships of items of physical evidence is best done at the scene. It is certainly possible to use scene photographs, videos, sketches, diagrams, and notes to make trajectory determinations but it is usually much simpler to do so at the scene.

Shooting incident reconstruction encompasses a wide variety of physical evidence types and, as a result, goes well beyond the concept of merely placing trajectory rods in bullet holes. The various types of physical evidence that must be considered when reconstructing a shooting include:

- Latent fingerprints
- Gunpowder particles
- Primer residue
- Ammunition components (cartridge cases, shot shells, shot cups, etc.)
- Footwear and tire tread impressions
- Bloodstain patterns
- Biological evidence
- Trace evidence

Items of physical evidence not collected at the scene during the initial investigation, such as gunpowder particles, glass particles and fibers, can seldom be recovered once a scene has been released due to chain-of-custody issues. Thus, it is critical to thoroughly evaluate and document a scene during the first phase of the investigation.

The more physical evidence, the more likely that a credible reconstruction of a shooting will be possible. Conversely, when little or no physical evidence remains, the chances of reconstructing a shooting approach zero. The Locard principle that dictates that entering and leaving a crime scene always results in something left behind and something removed is certainly true. It is up to the scene investigator to make sufficient effort to locate and identify such tell-tale items.

A sniper incident involving a long-range rifle shot through a car door takes place in an open, wooded area. The shot appears to have multiple possible points of origin. Placing a piece of tubing through the bullet hole in the driver's door and sighting through it allows an investigator to significantly reduce the range of possible points of origin.

The next step is a search, starting outside the car door and working outward toward the area visible through the tube. Ultimately, a fired 308 cartridge case is located some 500 yards to the north. In the same general area are found some footwear impressions and a cigarette butt. Also present nearby are tire impressions from an all-terrain vehicle (ATV) that lead away from the area. These ultimately lead to tire impressions indicating the ATV was apparently loaded into a truck.

The bullet recovered from the victim at autopsy is determined to be consistent in manufacturing characteristics and caliber with the cartridge case found at the scene. The bullet has not been damaged to the point that it cannot be compared to possible suspect weapons if they are located. Preliminary evaluation indicates that the rifling is consistent with a number of possible weapons, among them a Model 700 Remington bolt action. Marks left on the fired cartridge case are also consistent with a Model 700 Remington and several other weapons.

A tip from an individual who claims to have seen a pickup leaving the area with an ATV in the bed about the time of the shooting leads to a suspect. A search warrant is executed and a 308 caliber Model 700 Remington rifle with a telescopic sight, several rounds of ammunition, a pair of lug-sole hunting boots, an ATV, a partial carton of Marlboro cigarettes and a 4-wheel drive pickup are all seized.

Firearms examination confirms that the suspect's rifle fired both the cartridge case from the scene and the bullet recovered from the victim. The suspect's boots have sole designs consistent with the partial shoe impressions at the scene and both the ATV and the pickup tires are similar in size and tread design to the impressions in the area. DNA testing of the cigarette butt found near the fired cartridge case determines that the probability that someone other than the suspect was the donor is 1 in 12 billion. This shooting was reconstructed using a variety of forms of physical evidence. Had a thorough, careful search not been conducted, some or all of the evidence left at the crime scene might not have been found.

Bullet trajectories must be established at the scene and properly documented as will be explained in Chapter 4. Not doing this at the scene virtually eliminates the possibility of later determining trajectory. This information will be critical to the preparation of demonstrative evidence such as scale drawings and computer animations.

The collection of trace evidence, such as hairs, fibers, paint, and blood from around the margins of bullet holes in various objects can provide information as to intermediary targets that bullets first passed through. Failing to look for this evidence, documenting it, and collecting it at the scene would constitute a crucial error.

Gunpowder particles and primer residue can be deposited on any item in close proximity to the discharge of a firearm. Evidence of visible gunpowder particles can be found using a hand lens and a flashlight. It is important to evaluate the possibility that these residues exist at the scene, and such evidence can be present on suspects and witnesses.

Footprints and tire tread marks represent some of the most often overlooked physical evidence at crime scenes. Proper training is required so that investigators know how to locate, recognize and document this evidence. Doing so may be critical to placing a shooter and/or a victim in a particular location at the shooting scene.

It is common for blood to be shed at shooting scenes. Bloodstain patterns can provide information about the events of a shooting. If an investigator is not trained in bloodstain pattern analysis, he or she should at least have an understanding of the proper documentation of bloodstains at crime scenes.

The presence of latent fingerprints at shooting scenes can help establish a sequence of events. A bloody handprint, for example, usually establishes position *after* a shooting (assuming the bloody print was not in place before the shooting). Finding fingerprints on gun barrels and/or frames can help substantiate claims of struggles over weapons and subsequent unintentional firing. On the other hand, not finding identifiable fingerprints on weapons is a fairly common occurrence and the significance of the absence of fingerprints must be expressed with a great deal of caution. Experience has shown that, in fact, the probability of finding identifiable fingerprints on weapons is very low.

Off-Scene Evaluation and Investigation

Shooting reconstruction is facilitated by the results of various off-scene evaluation and investigation results. Certainly the results of laboratory examinations may provide much useful information. Additionally, the results of basic conduct of a criminal investigation of a shooting can provide essential pieces of the puzzle.

Witness statements, while subject to a variety of potential prejudices and shortcomings, must still be considered and evaluated. It well may be that credible information may be derived from these statements. This information is best assessed by weighing it against the physical evidence and determining whether it comports. Likewise, the information derived from interrogation of suspects must be carefully scrutinized and tested for fallibility against substantiated facts. It is not uncommon for suspects to give statements that are true to one degree or another: the truth, but not necessarily the whole truth, and nothing but the truth.

Telephone records obtained pursuant to subpoenas may provide time line information that is useful in the reconstruction of events at shootings. Knowing when incoming and outgoing calls were placed provides a way of verifying or refuting accounts of events leading up to and following shootings.

The brother of a suicidal man who was shot to death by a responding police officer stated that the decedent called him before the officer's arrival and that telephone contact had been maintained throughout the shooting. The man further stated that he was able to hear an officer's voice over the phone line during the shooting and never heard the officer refer to a gun in the decedent's hand. The police arrived at the scene in response to a call from the decedent's wife. During an earlier call from the decedent to his estranged wife, he voiced his intent to take his life. His wife subsequently called the authorities.

Telephone records were obtained and it was determined that the decedent called his estranged wife at approximately 3 p.m. on the day of the shooting. Their conversation lasted about 12 minutes. At 3:17 p.m. the decedent's wife placed a call to the police agency. Officers were dispatched to the scene at approximately 3:20 p.m. and arrived at 3:27 p.m. The shooting took place at approximately 3:35 p.m.

The decedent made a call to his brother at 3:19 p.m. The call lasted 17 minutes. This would put the shooting at some time prior to 3:36 p.m., assuming the connection was terminated at or shortly after the time of the shooting. Analysis of the various incoming and outgoing call times and the subsequent development of a time line tended to substantiate the statements made by the decedent's wife and brother. The question of whether the brother could have heard the officer's voice over the phone line throughout the shooting had to be resolved through reenactment.

Other documents that should be subpoenaed and evaluated include medical, business, bank, and insurance records. The purpose of examining such records, of course, is to determine apparent motives for a homicide or suicide.

In the case described earlier involving the doctor, it should be pointed out that the doctor was underinsured. His death benefit was only $250,000 and the policy had been in place for some time. Thus, no apparent financial motive could be related to his insurance policies. In effect, the doctor was worth more alive than dead. Thus, his wife was eliminated as a suspect on the basis of this fact and the lack of other motives. An examination of the doctor's personal medical records revealed that he suffered from heart disease diagnosed several years earlier. Again, no apparent health-related motives for suicide were revealed.

The family filed a writ of mandamus to challenge the ruling of self-inflicted injury in order to be able to collect the death benefit. The judge hearing the writ agreed that the case involved too many unanswered questions and said he could not completely rule out homicide. Accordingly, the cause of death was changed to undetermined.

Goal of Shooting Reconstruction

The goal of crime scene reconstruction in general is to answer *who*, *what*, *when*, *where*, *how*, and *why* questions. Shooting reconstruction is basically the same in this regard. There are, of course, specialized goals relating specifically to shooting incidents. Determinations of bullet trajectories, muzzle-to-target distance, ricochet crease and mark characteristics, and fired cartridge case locations, for example, combine to provide information about the positions of the shooter and victim. However, the investigator must consider that he will not typically have one particular scenario to the exclusion of all others.

Considering the virtually infinite number of different possible articulations of the human body, it is obviously unlikely that only one particular position of a body can explain how a shooting took place. As an illustration, suppose an individual is found lying on a living room floor with a through-and-through shot that entered the chest and exited the back at approximately the same level. Further consider that the exiting bullet passed through a wall and that a bloodstain in the area of the bullet hole is consistent with having resulted from a bullet. The bullet hole and bloodstain are approximately 36 inches above the floor. An overturned footstool is nearby.

Two possible scenarios immediately come to mind: (1) the victim was seated on the footstool with his back within a few feet of the wall when shot or (2) the victim was down on the floor on his knees when he was shot and the stool happened to be knocked over during the shooting. Without further information to direct us one way or another, it would be impossible to include one scenario and exclude the other. More often than not, multiple possible explanations may indicate how a shooting could have taken place.

Thus, we are required to evaluate all the possible alternative explanations. However, we can make some distinction between what is possible and what is probable. The goal of reconstructing a shooting is to establish a probable or likely sequence of events relating to the shooting, while recognizing that other explanations are possible. The only way to exactly define what took place at a shooting is to have been there and had an unobstructed view of all the events. Defining a "probable or most likely" sequence of events based on the physical evidence and the results of investigative efforts does not constitute "painting ourselves into a corner" when presented with positive proof that an event did not happen as we proposed.

Defining a sequence as "probable or most likely" is not "waffling" or "hedging" but, rather, keeping our opinions within the realm of scientific reason. The cliché that states that it is "better to err on the side of caution" seems appropriate here and is particularly applicable when some pieces of the puzzle are missing.

An officer-involved shooting resulting in the death of a man prompts a civil suit against the officer and his department. The decedent was a local businessman returning home from his 40th birthday party late at night. He happened to be driving through an area that was under surveillance by an auto theft detail. When officers spotted the small pickup truck weaving down the road, they proceeded to follow it. When the man stopped at an intersection, plain clothes officers jumped out of their vehicles with guns drawn and demanded that the man exit his vehicle.

For unknown reasons, the man instead chose to pull away, accelerating across the intersection before negotiating a left turn at the top of a rather steep hill just past the intersection. It may be speculated that either he did not realize that the men were officers and thought he was about to be robbed or that he realized they were officers and wanted to avoid a DWI ticket (at autopsy his blood alcohol level was 0.12).

One of the officers who had been standing at the right rear of the import pickup, wound up in the pickup bed as it moved across the intersection. He stated that he lost his balance as the pickup "lurched forward" and, as a result, fell into the truck bed. The officer said he used his baton to break the back window and struck the man with the baton through the broken window in an effort to get the man to stop the truck. When that failed, the officer shot the man twice in the upper right back. According to the autopsy, both bullets had downward trajectories.

The man's vehicle came to rest at an angle in the middle of the street on an uphill grade approximately half a mile from the intersection where the original confrontation took place. When other officers arrived, the decedent was lying face down in the street a short distance from the truck. The back glass of the truck was broken. No blood was reportedly found inside the cab.

A shooting reconstruction was done. The question raised by the plaintiff's attorney was whether the decedent could have been shot while attempting to run from the vehicle after having stopped on the hillside. An officer standing in the back of the pickup could have accounted for the downward trajectories of the shots. The final position of the victim's vehicle in the street certainly raised some questions, as did the location of his body.

The officer maintained that he shot the man as the man sat in the driver's seat and drove erratically, causing the officer to fear that the man would roll the vehicle or crash it. The officer stated that he dragged the man out of the pickup cab and placed him in the street and handcuffed him after the vehicle finally came to a stop.

In attempting to reconstruct the shooting, a vital piece of evidence that certainly could have answered the question whether the officer's version of events was accurate was found to be missing: the victim's shirt. For some reason, the crime scene investigators did not recover the decedent's shirt. If the shirt had been available, the presence of gunshot residue would have confirmed the officer's statement concerning where the decedent was when the officer shot him.

On the other hand, if the shirt could have been tested and was found devoid of gunshot residue, the lack of residue would have suggested that the plaintiff's allegation that the officer fired as the man tried to run away was possible. The failure of the crime scene unit to collect the shirt left the police department open to another allegation: cover-up.

Because the trajectories of the bullets in the decedent could have been explained either by his having been shot while seated in the truck or while running from the vehicle and because the police had no shirt to test, the department was forced to pay a settlement. Fortunately for the department (and unfortunately for the widow), she had filed for divorce a few weeks before the shooting and thus her attorney could not seek damages for loss of future earnings.

Limitations of Shooting Reconstruction

Shooting reconstruction relies on the evaluation and analysis of the physical evidence as well as the results of the criminal investigation of the incident. A distinction will often be apparent as to what is "possible" versus what is "probable". On the other hand, it is usually not realistic to expect to be able to eliminate all the possibilities. Certain so-called possibilities can be taken beyond the realm of reason. For example, one could propose that Elvis might be a potential suspect in a shooting. Since most people have no direct knowledge of Elvis' death, he could still be alive. Possible? Perhaps, but in no way probable. Thus, we reach a point where we must draw a line as to what we are willing to include in what might better be referred to as realistic possibilities.

Every shooting will typically have certain aspects that give us direction as to what is probable versus merely possible. Suppose a man and a woman are both shot to death during a convenience store holdup. The question arises as to who was shot first, the man or the woman? In the absence of other facts, we might anticipate that the man would have posed a greater threat and, hence, would probably have been shot first.

As another example, suppose a shooting incident involves the firing of two shots, with one striking a man at the top of his head and the other striking the floor near the man's head. The shot striking the floor was further away than the shot to the top of the head. Which shot was most probably fired first? Again, experience and common sense would indicate that someone who fires a shot from a given distance and misses will likely move closer to the target before firing again. Thus, we would conclude that the missed shot was probably the first fired. Could the shots have been fired in the reverse order? Of course, but with only limited information, we can only opine which shot was probably fired first. The reverse order is then designated as possible rather than probable.

Reenactment as Part of Reconstructing Shooting Incidents

Sometimes it is necessary to carry out a reenactment of some aspect of a proposed theory of a shooting incident in order to test that particular aspect. We may have decided that the most probable scenario was a shot fired in a certain stance (say, kneeling) from a certain location. Rather than settling for speculation, the scientific method requires that we test our theory.

Reenactment can be accomplished in a variety of ways. The most familiar form of reenactment involves using individuals who are similar in stature to the individuals who were actually involved in the shooting. In addition to testing a particular theory of the shooting, reenactment can be used to produce demonstrative evidence for court presentation.

In selecting "actors" it is essential that the individuals duplicate the physical characteristics of the involved individuals as closely as possible. This means that a 6-foot tall, 180-pound, left-handed male would not be used to simulate the movements and position of a 5-foot, 7-inch, right-handed female in a shooting reenactment. This holds true both for testing a shooting incident theory and for the preparation of a demonstrative exhibit.

In an officer-involved shooting incident in which the officer fired through the windshield of a vehicle striking the driver, the question was raised as to where the officer was standing when the shot was fired. To attempt to answer this question, an outside expert was hired to perform a reconstruction. A trajectory rod was first placed through the bullet hole in the windshield of the car. Next the expert sat in the driver's seat of the vehicle and held one end of the trajectory rod to the right side of his face in the area where the victim sustained her wound.

The expert positioned an assistant outside the victim's vehicle in an effort to demonstrate the approximate position of the officer. This individual extended his arms out from his body to simulate the officer's shooting stance. A position in front of the vehicle was taken to ensure alignment, both vertically and horizontally, of the actor's extended arms and the trajectory rod that extended through the bullet hole in the windshield.

While this may sound like a reasonable approach to take in attempting to determine the officer's position, it had some serious shortcomings. The expert is a 6-foot, 2-inch tall, 260-pound male. The shooting victim was a 5-foot, 4-inch, 107-pound female.

The basis for establishing the position of the officer was, in large part, dependent upon the distance from the ground to the victim's bullet wound to the face. This, in turn, was dependent upon the victim's position inside the vehicle. The big difference in weight between the victim and the actor meant that the driver's seat was depressed quite differently when occupied by the victim. The difference in height of the two individuals further altered the proposed trajectory from the true one.

To further misrepresent the event, the individual who stood in front of the vehicle and purported to represent the officer was several inches shorter than the officer. All these differences combined to make the reenactment unreliable at best.

Another way to carry out or represent reenactment is through computerized animation. Various software programs now available allow the preparation of both 2- and 3-dimensional animations. Utilizing the physical data for the shooting scene and the participants allows the production of animations to scale. In this way, various perspectives can be viewed and tested for feasibility. Three-dimensional animations provide a means for a jury to view various perspectives and be able to develop a clear mental picture of the scenario proposed. For many jurors, reenactment is the key to understanding the particulars of a shooting.

As an example, a female was shot a total of 14 times from multiple distances and angles and sustained penetrating, perforating, and grazing wounds to the head, upper torso, and arms. By using a computerized 3-dimensional "mannequin" and "virtual trajectory rods" (Figure 1.5), the individual presenting the shooting reconstruction in court was able to show the jury the various shot directions, distances, and trajectories through the body. Without this demonstrative exhibit, the jurors would have been inundated with confusing verbiage such as "anterior to posterior" and "proximal to distal" and probably would have lacked any real understanding of the wounds and their significance.

The "poor man's computerized animation" may be produced using small-scale mannequins (Figure 1.6) and a camera. The mannequins are positioned as

Figure 1.5 Three-dimensional mannequins with virtual trajectory rods.

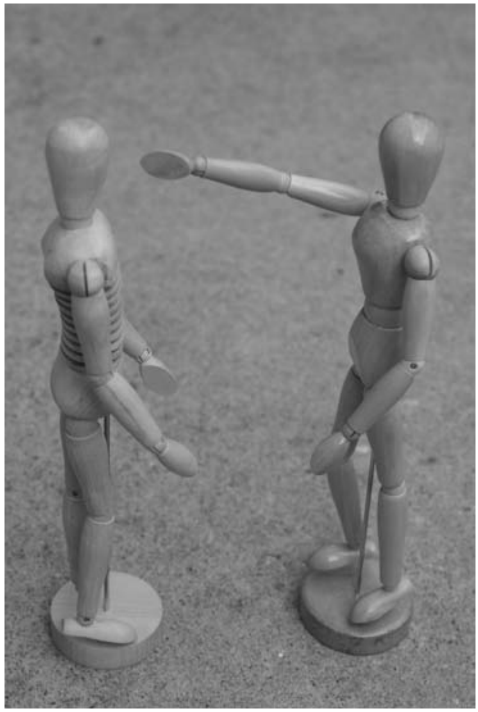


Figure 1.6 Small-scale wooden mannequins.

desired and photographs are taken from various perspectives. Miniature trajectory rods may be placed in the mannequins to show bullet paths. The images are then enlarged and mounted on poster board for presentation to the jury.

Another related form of demonstrative evidence for shooting reconstruction presentations is the scale model. This provides yet another means for a jury to be able to visualize a scene. By picking a suitable scale, such as 1:18, numerous items can be found at hobby and craft shops to add to the realism of a model. Items such as furniture, trees, shrubs and vehicles are all available for incorporation into a model. The model may range from a very basic building block-type representation to a very elaborate exact scale model incorporating all the features at a scene. The point, once again, is to provide a device that assists the jury in better understanding the reconstruction.

An officer-involved shooting is investigated to determine whether the officer was justified in discharging his weapon. According to the officer's statement, he was standing beside the driver's door requesting that the driver step out when the driver started the vehicle and turned the wheels toward the officer. The officer stated that he then attempted to move away from the vehicle

Figure 1.7 Scale model showing turning radius of truck (dark circle).

but, realizing that it was going to overtake him, began firing in an effort to "keep from being run over". The question that internal affairs wanted answered was whether the officer was ever actually in jeopardy of being struck by the vehicle.

To answer the question, a scale model was constructed on a 1:18 scale. This allowed the use of a plastic model truck that replicated the incident truck in every detail. Using measurements of the two buildings that the truck had been parked between and measurements of the general area, a scale model was constructed of foam board (Figure 1.7).

The curb-to-curb turning radius of the truck was determined from the manufacturer and verified through actual testing. A blue circular disc was cut to represent the turning radius and placed in the model. Once this was done, it became obvious that there was no way that the officer could have been struck by the vehicle unless he intentionally ran to the front of it. The scale model showed that the truck would have struck the building to the rear of the officer's position before it could have impacted the officer himself.

With any reenactment, certain body movements and articulations must be presumed to be legitimate. In the absence of evidence to the contrary, this usually does not present a problem. However, it is to be expected that objections on the grounds of hearsay may be made in an effort to prevent animations and other forms of reenactment from being admitted into court proceedings. Sometimes these objections are sustained, due mostly to the lack of proper foundation. It is incumbent upon the reconstructionist to qualify the reenactment with regard to assumptions that have been made and to properly explain the associated caveats.

Developing Time Lines

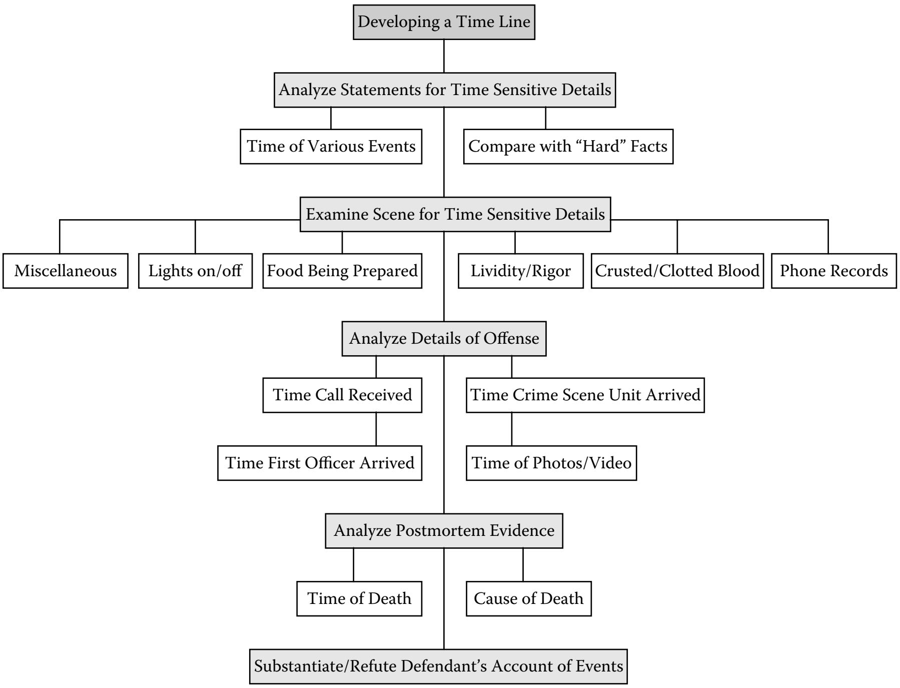
Part of the analysis of any crime is the development of a time line that includes all the pertinent details that can be related to times of occurrence. The time line is then used to test the veracity of witness and victim statements and evaluate various theories of the shooting. Some of the time line entries will involve specific times, like time of arrival at the scene, while others will involve approximations. Specific time indicators should include:

- Time call received at police agency
- Time of arrival of first officer
- Time of arrival of crime scene unit
- Times of taking photographs and videos
- Time scene investigation completed

Approximate time indicators might include:

- Lights: whether on or off
- Newspaper in front yard
- Mail in mailbox
- Food on stove or table
- Televisions and radios: whether on or off
- Pets: in or out of house
- Clothing worn: pajamas or street clothes
- Bath water temperature
- Dried blood stains
- Blood clots and/or crusts in blood pools
- Lividity (fixed and unfixed)
- Rigor mortis (partial and full)

When any of these indicators and a variety of others, are present, we can get some idea of the sequence of events in a shooting incident. For example, suppose an officer is dispatched to a shooting scene and finds dried blood stains near and on the body. Depending on when the call was received and when the officer arrived relative to when the shooting supposedly took place, the presence of dried blood at a scene may not fit the statements made by witnesses and/or suspects. A single drop of blood on, say, a table top, might require a half hour or more depending on temperature, humidity, and air currents to dry completely. If the time line indicates that significantly less time elapsed than what would be required for the blood to dry, the discrepancy will have to be resolved.



Structure 1-1 Steps in development of time line.

The development of a time line can provide clues that might otherwise have gone unnoticed. A time line can be vital in the analysis and reconstruction of a shooting incident by helping discern between various scenarios under consideration. Structure 1-1 summarizes the various considerations used to develop time lines.

In summary, shooting reconstruction involves using the physical evidence and other investigative results to develop a likely or probable sequence of events for the shooting. It is unlikely that one scenario will be developed to the exclusion of all others due to the many variables typically involved.

Exercises

1. You attempt to use your cell phone and find you are unable to power it up. Use the scientific method to develop a logical approach for determining what is wrong with the phone.

   Answer: A possible application might be as follows.

   State the problem: the phone does not power up.

Make observations (the phone worked fine yesterday; it was on a charger overnight).
Form a hypothesis (the battery is dead).
Carry out testing (try recharging the battery; it does not recharge; replace the battery with a new one; the phone powers up).
Form a theory (the battery was dead and needed replacement)

2. In the case of the doctor found shot to death in his front yard, what follow-up investigations should have been conducted concerning the Luger pistol?

   Answer: The residence should have been searched for any evidence (ammunition, documentation, holster) that the gun belonged to the doctor.
3. Concerning the trimmer cord and weights tied to the Walther pistol in the case of the doctor found shot to death in his front yard, what investigations would you have pursued in connection with trying to reconstruct the shooting?

   Answer: Attempt to determine their sources. Were they from the doctor's residence or from elsewhere? How was the trimmer cord cut and what kind of knots were used to tie it to the weights? Were tool marks present? Were surgical knots used?

4. Why was it important to establish the trajectory of the shot into the front of the doctor's house and relate it to the location of the doctor's body?

   Answer: To try to determine the feasibility that the doctor fired the shot and then shot himself in the chest.

5. In the sniper shooting, a piece of tubing was inserted into the bullet hole in order to visually determine the general area to be searched. What materials do you think might be used as viewing tubes?

   Answer: Drinking straws, steel, copper, or aluminum tubes.

6. Why is a tube of some sort necessary to determine the area to be searched? Why is a tube more effective than simply looking through a bullet hole?

   Answer: While it may sometimes be possible to look through bullet holes and get a reasonable idea of source locations, a piece of tubing inserted through entry and exit holes is likely to define more closely the possible area of origin.

7. In the officer-involved shooting in which the officer was standing alongside a pickup truck, why was it necessary to test the turning

radius of the truck when the manufacturer's information was available?

Answer: To ensure the pickup had not been subjected to modifications or model changes. Simply accepting manufacturer's specifications at face value would not have been good science.

8. How could knowing whether the lights were on at the scene of a shooting assist in its reconstruction?

   Answer: First, there could be issues of visibility. Furthermore, the time of day of the shooting might be suggested by the light status.

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Mathematics of Shooting Reconstruction

2

Trigonometry, Geometry, and Shooting Incident Analysis

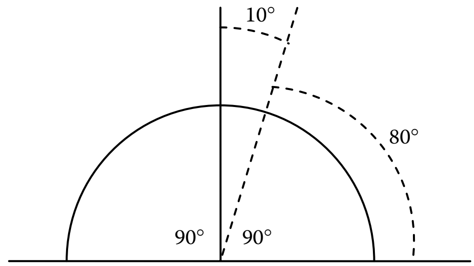
Trigonometry and geometry provide the mathematical bases for the solutions of many shooting incident problems. With this in mind, a review of some of the basic principles of trigonometry and geometry is in order. The word *trigonometry* simply means the measure of triangles. *Geometry* means earth measure.

Two angles, the sum of which is 90 degrees, are called complementary angles. Two angles whose sum is 180 degrees are known as supplementary angles. Structure 2-1 shows complementary and supplementary angles. When two lines meet perpendicularly to each other, two 90-degree right angles are created.

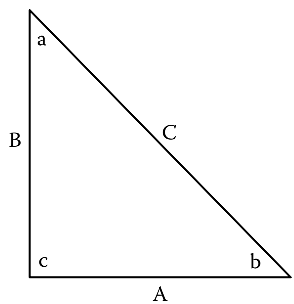
Triangles are three-sided figures containing three internal angles, the sum of which is 180 degrees as illustrated in Structure 2-2. In reconstructing a shooting, it is typical to use a certain type known as a right triangle, one angle of which is equal to 90 degrees. In Structure 2-3, the 90-degree angle in a right triangle is designated by a square.

If the sum of the angles of a triangle is 180 degrees and one of the angles spans 90 degrees, then the sum of the remaining angles will equal 90 degrees, as shown in Structure 2-4.

Pythagoras, a Greek philosopher and mathematician, studied right triangles and deduced the special relationships that exist between the sides of a right triangle. He found that the greater the angle, the longer the side opposite that angle. In a right triangle, the greatest angle is the right, or 90-degree, angle. Thus, the side opposite the right angle will be the longest and it is called the hypotenuse (Structure 2-5).

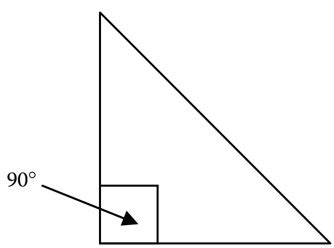


Structure 2-1



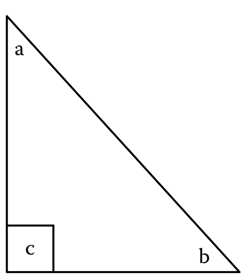
Sum of angles a + b + c = 180 degrees

Structure 2-2



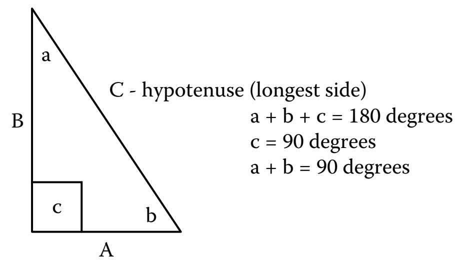
The 90 degree angle in a right triangle
is designated by a square

Structure 2-3



If a + b + c = 180 and c = 90,
then a + b = 90

Structure 2-4



Structure 2-5

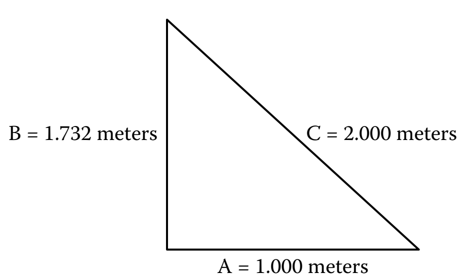
Pythagoras found that if one takes the length of the hypotenuse of any right triangle and multiplies it by itself ("squares" it), the product will equal the sum of each of the other two sides each multiplied by themselves. His discovery is known as the Pythagorean theorem and its formula is $C^2 = A^2 + B^2$. For example, suppose we have a triangle with the side lengths shown in Structure 2-6. According to the Pythagorean theorem, the length of the hypotenuse (C) squared is equal to the sum of the squares of the other two sides, that is, $C^2 = A^2 + B^2$. Thus, we would have

$$(2.00)^2 = (1.00)^2 + (1.732)^2$$

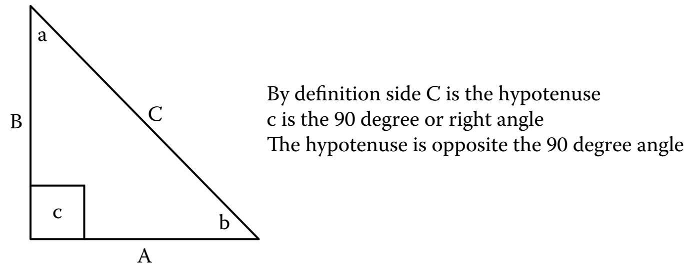
or

$$4.000 = 1.00 + 3.000$$

The relationships of the various sides and angles of right triangles are expressed in terms of a series of trigonometric functions that are very useful for solving various shooting reconstruction problems. Trigonometric functions are described in terms of the hypotenuse, which has already been defined, the side opposite the angle, and the side adjacent to it (Structure 2-7). Side C is the hypotenuse; c is the 90-degree or right angle; the hypotenuse is opposite



Structure 2-6



Structure 2-7

the 90-degree angle. For angles a and b, there will be an opposite side, an adjacent side, and the hypotenuse:

Angle	Adjacent Side	Opposite Side	Hypotenuse
a	B	A	C
b	A	B	C

Using these designations, we will work with three trigonometric functions known as the sine (abbreviated as sin), cosine (cos) and tangent (tan).

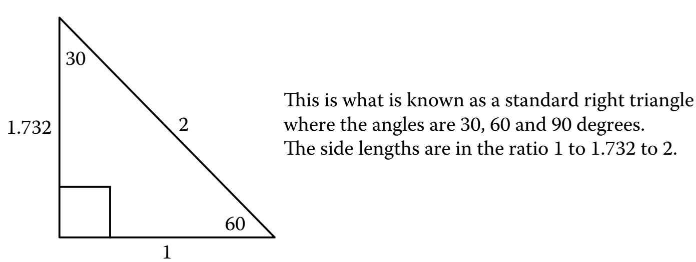
For each angle of a right triangle, these functions are defined in terms of their relationships to their respective opposite and adjacent sides and to the hypotenuse. Remember that the hypotenuse is always the side opposite the 90-degree angle. In writing mathematical formulas involving angles, Greek letter theta (Θ) is the symbol used to represent any angle.

Sin Θ = Length of opposite side/length of hypotenuse

Cos Θ = Length of adjacent side/length of hypotenuse

Tan Θ = Length of opposite side/length of adjacent side

For any right triangle, the relationships between the sides and angles are represented by these functions. By referring to the chart above, the designation of opposite and adjacent sides for a particular angle is apparent. Structure 2-8



Structure 2-8

shows a standard right triangle whose angles are 30, 60, and 90 degrees. The side lengths have a ratio of 1 to 1.732 to 2. Using our definitions and the given values for sides and angles, we determine the following:

Sin 30 degrees = Length of opposite side/length of hypotenuse
= 1/2 or 0.5

Sin 60 degrees = Length of opposite side/length of hypotenuse
= 1.732/2 or 0.866

Cos 30 degrees = Length of adjacent side/length of hypotenuse
= 1.732/2 or 0.866

Cos 60 degrees = Length of adjacent side/length of hypotenuse
= 1/2 or 0.5

Tan 30 degrees = Length of opposite side/length of adjacent side
= 1/1.732 or 0.577

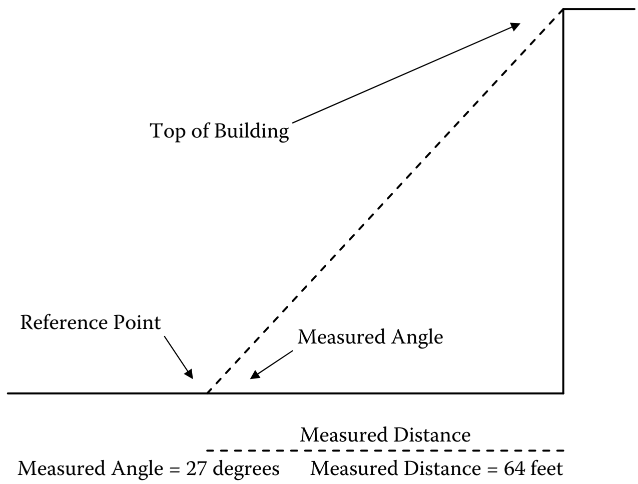
Tan 60 degrees = Length of opposite side/length of adjacent side
= 1.732/1 or 1.732

What relationships do you see between the sin, cos, and tan? Angles smaller than 90 degrees are called acute angles. A right triangle always has two acute angles. Remembering that the sum of the two acute angles is 90 degrees, these angles are termed complementary angles. Thus, the complement of 30 degrees is 60 degrees, the complement of 20 degrees is 70 degrees, and so on. Notice the relationship between the sin of an angle and the cos of its complement.

If you know the value of the sin of any angle, you also know the value of the cos of its complementary angle. Also note the relationship between the tan of an angle and the tan of its complementary angle. The relationship between the two is inverse. Thus, if you know the value of the tan of an angle, the tan of its complementary angle will be the reciprocal.

The Pythagorean theorem and the trigonometric functions are very useful in solving problems associated with shooting reconstructions. At a shooting scene, we can construct imaginary right triangles and use them to answer questions. For example, suppose we wish to determine the height of a building after shots were fired from its roof.

It is really unnecessary to call for sophisticated equipment, such as a surveyor's transit, to solve this problem. Using basic equipment that will be discussed in a later chapter, we can establish the angle of inclination from a reference point to the top of the building (Structure 2-9). The distance from the same reference point to the base of the building is then measured. With these two values, we can then calculate the height of the structure.



Structure 2-9

The measured angle equals 27 degrees and the measured distance is 64 feet. To solve for the height of the building, we use the tangent function because we know the length of the adjacent side of our imaginary triangle and we wish to determine the length of the opposite side. The formula to be used to solve for the height of the building is

Tan 27 degrees = Length of opposite side/length of adjacent side

Tan 27 degrees = Height of building/64 feet

Using a hand-held scientific calculator, we quickly determine that tan 27 degrees is 0.51. Substituting this value into our equation and rearranging it, we get

Height of Building = 0.51 × 64 feet

Height of Building = 32.6 feet

We can use this type of calculation to find the height of virtually any item or structure at a shooting scene. The only devices required are a scientific calculator, a tape measure, a tripod, an angle gauge and a laser. Equipment specifics will be discussed in Chapter 4.

In the infamous sniper incident at the University of Texas tower in the summer of 1966, Charles Whitman assembled a veritable arsenal and ascended to the top of the tower where he began picking off students on the ground. Whitman's initial weapon of choice was a Remington model 700 bolt action rifle in 6-mm caliber fitted with a telescopic sight. From his vantage point some 300 feet above the ground, Whitman was able to pick off students hundreds of yards from the base of the tower. As a student attending summer classes at the University of Texas, I clearly recall walking out of my dormitory on my way to organic chemistry class and hearing what I thought were firecrackers coming from the stadium. I soon realized that the sound was gunfire coming from the tower. The sound was bouncing off the stadium walls, making me think that the stadium was the source.

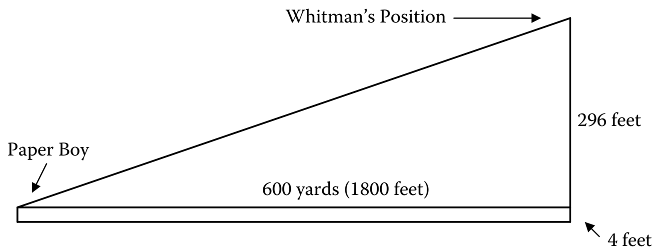
The scene that I witnessed upon reaching the mall of the University of Texas tower was incomprehensible: students were lying on the ground in pools of blood, students were falling as they were shot, and there was pandemonium everywhere. I noticed a Texas ranger crouched at the corner of a building shouldering a rifle. Periodically a shot would ring out as he fired up at the top of the tower. I crouched down a few feet behind him. He briefly turned back and glanced at me but said nothing as he turned his attention back to Whitman and the top of the tower.

The situation was totally out of control. Private citizens were soon returning fire as well. I personally witnessed a man in a service truck pull up near the location where the Texas Ranger and I were, grab a lever action rifle with no scope from behind the truck seat and begin firing toward the top of the tower. Given that the distance from his position to Whitman's location was probably at least 300 yards, trying to shoot without the benefit of a telescopic sight was reckless, to say the least.

After what seemed an eternity, although in reality was probably 20 minutes or so, a light aircraft could be seen heading toward the tower from off in the distance. The plane began to circle above the tower and automatic weapon fire could be heard. Members of the Texas Department of Public Safety apparently thought that attaining a position of higher ground would be the way to get to Whitman and end it. Once Whitman started returning fire, however, the aircraft departed.

The final resolution came when Austin police officers Martinez and McCoy ascended to the top of the tower via the same elevator that Whitman used and shot Whitman to death. This was an incredible act of bravery on the part of both men. Those of us who were positioned around the mall saw an arm waving a white handkerchief above the wall at the top of the tower. Not knowing what Martinez and McCoy had just done, we believed that Whitman was surrendering. For some unknown reason, we all rushed toward the tower. It was then that we learned the grisly details of Whitman's trip up the tower. Fourteen people were killed including Whitman, his wife, and his mother. Anywhere from 31 to 34 people were injured. The exact number was unclear because of questions about "friendly fire." Given the firing of high caliber rifles and automatic weapons upward from the ground and from above, it is amazing that more people were not struck by errant rounds.

It is despicable to compliment Whitman in any way, but his shooting skills were incredible. In one instance, a paper boy was shot off his bicycle while riding down the sidewalk some 600 yards from the base of the tower. We can use trigonometry to calculate a number of different aspects of that shot. For



Structure 2-10

example, suppose we wish to determine the minimum distance that the bullet had to travel. The path of a bullet, of course, is parabolic and not a straight line. This is why we are going to be determining the minimum distance as opposed to the actual. Based on the fact that the 6-mm Remington is a very flat shooting weapon that produces only an inch and a quarter bullet rise at 200 yards, we are able to make a pretty close approximation.

We begin by constructing an imaginary right triangle that incorporates the various distances that we have to work with (Structure 2-10). The paper boy was wounded approximately 4 feet above the ground as he sat on his bicycle. The height above ground of Whitman's position was approximately 300 feet. Therefore, the height of the right triangle is 300 feet minus 4 feet or 296 feet. For simplicity, we will ignore any differences in elevation for the paper boy's position relative to the tower.

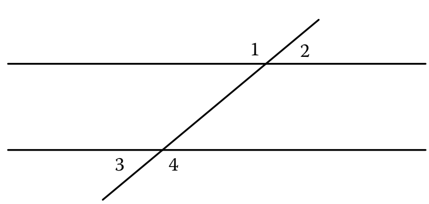
To calculate the minimum distance traveled by the fatal bullet, we use the Pythagorean theorem ($C^2 = A^2 + B^2$). In this example, the minimum bullet distance traveled is represented by the hypotenuse of the imaginary right triangle. Thus, our calculation is as follows:

$$C^2 = (296 \text{ feet})^2 + (1800 \text{ feet})^2$$

$$C^2 = 87616 + 3240000 = 3327616$$

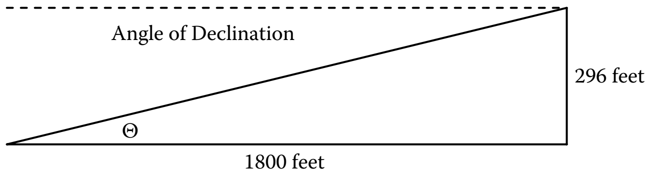
$$C = \text{square root of } 3327616 \text{ or } 1824 \text{ feet}$$

We can also calculate the angle of declination of the shot from Whitman's rifle by recalling that when two parallel lines are intersected by a diagonal, alternating angles are equal. In Structure 2-11, angles 1 and 3 are equal and



Thus, angles 1 & 3 are equal and angles 2 & 4 are equal

Structure 2-11



Structure 2-12

angles 2 and 4 are equal. We will use this information in calculating the base angle (Θ) of our imaginary right triangle and that angle will equal the angle of declination of the rifle (Structure 2-12). First we use the tangent function to solve for Θ which is equal to the angle of declination.

$$\text{Tan } \Theta = 296/1800$$

$$\text{Tan } \Theta = 0.164444$$

The angle Θ is then found by determining the arc tan or inverse tangent of 0.164444. This is easily accomplished using a scientific calculator. Looking at the key pad of a scientific calculator, you will note that above the keys for sin, cos, and tan is the symbol for the arc or inverse relationship (i.e., $\sin^{-1}$, $\cos^{-1}$ and $\tan^{-1}$). In the upper left hand corner of the key pad is a key marked "2nd" or "shift." By entering the numerical value, in this case 0.164444, depressing the 2nd or shift key, and then depressing the tan key we can determine the arc tan (inverse tan).

$$\text{Arc tan } 0.164444 = 9.3 \text{ degrees}$$

The above equation is a form of shorthand meaning, "The angle whose tangent is 0.164444 is 9.3 degrees." Thus, the angle of declination that Whitman used to shoot the paper boy off his bicycle was 9.3 degrees.

Calculation of Impact Angles

When a bullet or shot pellet penetrates a substrate, the angle of impact (interior angle between the bullet axis and the substrate) may be calculated by using the dimensions of the bullet or pellet hole. The shape of the hole provides us with information about the general impact angle. Bullets or pellets that penetrate substrates at or near 90 degrees generally produce round holes. Any angle of impact significantly smaller than 90 degrees results in an oval or oblong hole. The smaller the angle of impact, the longer the hole. In

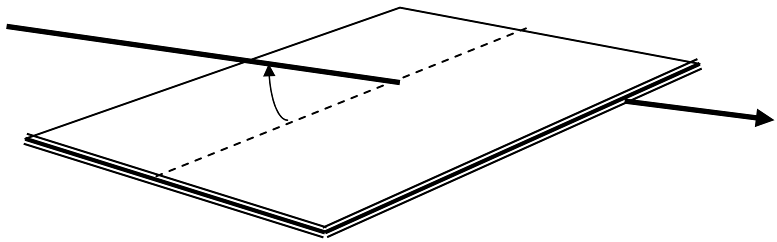


Figure 2.1 Angle of impact (interior angle between the substrate and axis of the impinging bullet).

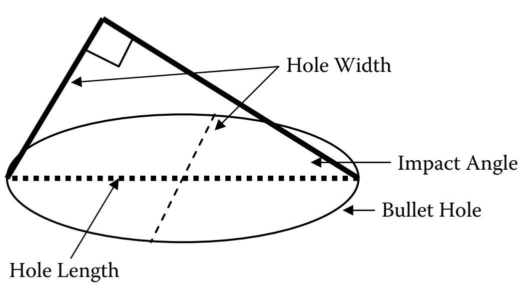
general, the width of the hole approximates the caliber (cross-sectional diameter) of the projectile. Naturally this will vary with bullet design and construction and substrate properties (texture, hardness, thickness, etc.). This principle is illustrated in Figure 2.1.

The width and length of the hole are, therefore, functions of the caliber and the impact angle, respectively. Once again we use trigonometry to derive the relationship of impact angle, hole width, and hole length (Structure 2-13).

Note that the hole length forms the hypotenuse of the right triangle that we have constructed and the side opposite the angle of impact is the same as the hole width. In case you are wondering why this is so, it is because we constructed our right triangle that way (it was not by mere coincidence). We use the sine function to express the relationship between the impact angle and the width and length of the bullet hole.

Sin of angle of impact = bullet hole width/bullet hole length

As an example, suppose that we measure the width of a bullet hole in a thin sheet of aluminum and determine the hole is 0.46 inch wide. We next measure the bullet hole length and find it to be 0.91 inch. The sine of the angle of impact (not the actual angle) is calculated as hole width divided by



Structure 2-13

hole length (0.46/0.92) which equals 0.50. To determine the actual angle, we must determine the inverse or arc sine of 0.50. That is, we must determine the value of the angle whose sin is 0.50 by using a scientific calculator. The sin value of 0.50 is entered, then the 2nd function or shift key is depressed, followed by the sin key. The value of the impact angle, in this case 30 degrees, appears in the window. In summary:

Step 1: Divide width by length (0.46/0.92 = 0.50).
Step 2: Depress the 2nd or shift key.
Step 3: Depress the sin key. The impact angle (30 degrees) appears in the window.

Note that if you depress the sin key while the 30 degree figure shows in the window, the 0.50 value reappears. This is the equivalent of "toggling" back and forth between the numerical value of the sin and the angle.

The value of the bullet hole width of 0.46 inch suggests the possibility of 45 caliber. It is unwise to speculate as to specific calibers, however, due to the fact that bullets may expand as they perforate substrates and produce slightly oversized holes. Soft substrates such as wood or cardboard will likely contract slightly following bullet passage. The margins of bullet holes in certain materials such as sheet rock or plywood will frequently be irregular, making accurate measurement difficult.

Angles of impact determined through calculation, like most other aspects of shooting reconstruction, are approximations, not absolutes, and should be considered as such. Since most shootings take place at close range, however, this does not constitute a major concern. If we are trying to establish a shooter position 500 or 1000 yards away using an impact angle we have calculated, a few degrees makes a more substantial difference. It then becomes necessary to consider a possible range of positions. Based upon repeated experiments with known shooting positions, one can typically expect fewer than 10 degrees of error (plus or minus) in the calculated value versus the actual value. More often than not, an error of no more than plus or minus 5 degrees is possible if the hole margins are well defined and the measurements are carefully and accurately made.

Shotgun pellet patterns can also be used to calculate approximate angles of impact by measuring the width and length of the pellet pattern perimeter. If buckshot is involved, the technique involves measuring the widths and lengths of individual buckshot holes. Birdshot, being much smaller in diameter, does not lend itself well to individual pellet measurement. This is illustrated in Figure 2.2. Additional considerations involving shot shell patterns are discussed in Chapter 6.

When a bullet or shot pellet impacts a surface, there will actually be two angles involving the axis of the projectile and the substrate. In addition to

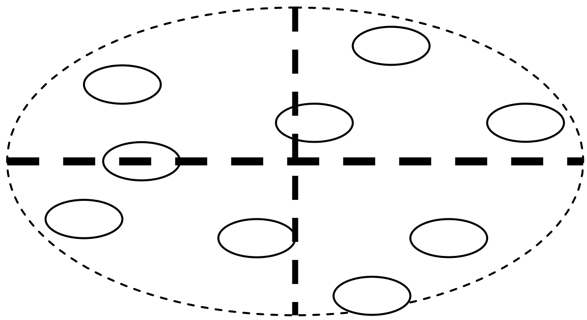


Figure 2.2 Shot pellet pattern impact angle determination (heavy dashed lines represent pattern width and length).

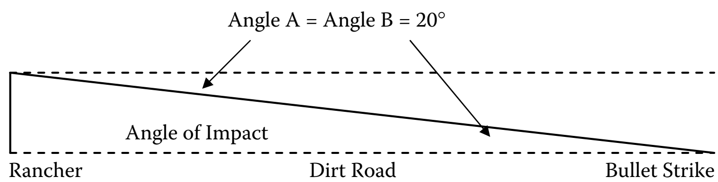
the angle of impact or interior angle we have been discussing, there is a lateral angle representing the angle of the projectile axis relative to the axis of the substrate. For an illustration and further explanation, readers are referred to Chapter 4.

A rancher is arrested following the shooting of a trespasser on his property. The rancher uses his land as a deer hunting preserve and it is surrounded by an 8-foot tall fence designed to keep his deer herd in. According to the rancher, he was walking along a dirt road within his fence line at dusk carrying a 25-06 caliber bolt action rifle with his right hand when he rounded a bend in the road and observed two males approximately 75 yards ahead. He stated that he yelled "stop," at which time one of the two males took off running. The other male whirled around with what the rancher perceived to be a handgun (it turned out to be a water jug). The rancher said that as he started to raise the rifle with his right hand, the weapon discharged and the apparent assailant fell to the ground with what was a bullet wound to the calf of his left leg.

The victim said he could only recall seeing a flash and feeling a burning sensation in his left leg. He stated he and his friend had merely been trying to take a short cut across the property. He admitted to climbing the fence to gain entry into the property.

The rancher maintained that he had not intentionally fired the gun but that he had his finger on the trigger as he instinctively raised the gun in response to the perceived threat from the trespasser. Because of a long history of area ranchers shooting trespassers, attempted murder charges were filed in an effort to "send a message."

The question to be answered was whether a ricochet could have accounted for the trespasser's injury. The wound was a perforating injury and the responsible bullet was never recovered. No photographs were taken of the wound and no detailed notes were made by the treating physician.

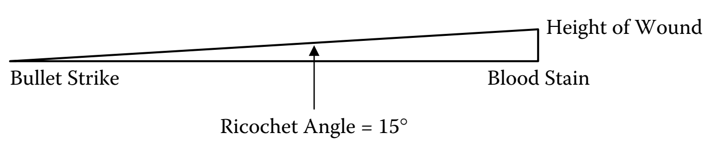


Structure 2-14

The reconstruction of the shooting began with an examination of the rifle and the determination that the trigger pull was only 1.5 pounds. Following this examination, a reenactment was carried out with a primed case (no powder charge or bullet present) in the chamber and the safety off. As described by the rancher, the weapon was held in the right hand with the muzzle toward the ground and the forefinger on the trigger. The idea was to test the hypothesis that the weight of the gun could have produced a discharge as the weapon was raised while the finger was kept on the trigger. This was determined to occur repeatedly. This testing was videotaped for documentation purposes. A visit to the scene of the incident was made for purposes of evaluating the terrain and taking measurements.

The terrain was relatively flat from the rancher's position toward the victim's position. The road consisted of soft mud. A possible bullet strike was located. The distances from the rancher's stated position to the bullet strike and also to the location of a blood stain were determined. Using the height of the rancher and his stated position, an approximate angle of impact with the ground was determined to be 20 degrees by constructing an imaginary right triangle and utilizing the fact that when parallel lines are intersected by a diagonal, alternating angles are equal (Structure 2-14). A similar imaginary right triangle was constructed using the position of the bullet strike mark, the position of the blood stain, and the distance of the victim's injury from the ground (Structure 2-15).

Based upon the examination of the weapon, the reenactment, and the reconstruction, it was determined that a ricochet was probable. The light trigger pull of the weapon was consistent with unintentional discharge, but the rancher's intentional firing of a warning shot that produced the ricochet could not be ruled out.



Structure 2-15

We can use measurements of bullet ricochet creases and marks to establish the approximate angle of impact in the same way. Using a variety of substrates, bullet calibers, and designs, the author has found that bullet ricochet marks and creases can be measured as to length and width and approximate impact angles can be determined. The key is to have a ricochet mark or crease that is symmetrical and thus conducive to length and width measurements. When the ricochet mark or crease is nonsymmetrical, estimations of length in particular are required. Obviously, when estimations are used, the results obtained will be somewhat less accurate. The technique for using a laser protractor to establish approximate shooter position using the calculated impact angle for a ricochet mark or crease will be discussed in Chapter 10. It is also useful to be able to calculate the x and y angles of impact.

Other Calculations

A number of other calculations are of value in shooting reconstructions. From time to time, the rate of fire of a weapon is a factor in determining whether a certain scenario is possible. Typically, where moving targets are involved, the question is whether it is possible to fire a particular number of shots within a certain time frame. The combination of rate of fire and time of target availability forms the basis for the determination of feasibility.

Rate of fire may be established through test firing, as will be discussed in a later section, or by referring to manufacturer's data when available. For semi-automatic weapons, such determinations are clearly subjective since one cannot precisely duplicate what a suspect can or cannot physically accomplish with regard to rate of fire of a weapon. It is, however, realistically possible to establish a maximum rate of fire and work with that.

Time of target availability can be derived from a variety of indicators. Vehicles are frequently involved in shootings and can serve as moving targets to be considered. Field of view and estimated speed offer the means for estimating target availability times. Suppose a vehicle was known to be traveling at 60 miles per hour when it was struck by two bullets that passed through the windshield and were not recovered. Also assume that the field of view is 50 feet. The first question to be answered is how long the vehicle presented itself as a target by converting the speed in miles per hour into feet per second. We do this because field of view is expressed in feet and rate of fire is typically expressed in rounds per second. Thus:

$$60 \text{ miles per hour} \times 5280 \text{ feet per mile} \times 1 \text{ hour}/60 \text{ minutes} \times 1 \text{ minute}/60 \text{ seconds} = 88 \text{ feet per second}$$

With a field of view of 50 feet, we divide by our speed in feet per second in order to determine the time the target is available:

$$50 \text{ feet}/88 \text{ feet per second} = 0.56 \text{ second}$$

The second question that must be answered is whether the weapon involved could have fired the two shots within the available time. If the weapon in question is capable of firing four shots per second, for example, we multiply the rate of fire by the time the target is available:

$$4 \text{ shots per second} \times 0.56 \text{ second} = 2.24 \text{ shots}$$

Thus, a total of two shots could have been fired. Had the result been a little less definitive, say, 1.75 shots, our conclusion would have been accordingly less definitive. Additional information would be required in order for a conclusion to be reached.

Three teenagers are riding around on a gravel road in a rural area at dusk. They are drinking beer and backfiring their Jeep by turning the ignition switch on and off. As they approach a residence along the road, they are unaware that the owner is standing in his front yard armed with a 22 caliber semiautomatic rifle. According to the owner, upon hearing what he thinks is a gunshot coming from the roadway, he "hits the deck" chest first while holding the rifle above the ground and "may have accidentally fired a shot" because his thumb was inside the trigger guard. A single fired 22 caliber cartridge case will later be recovered from the area where he claims he fell to the ground.

The driver of the Jeep received a fatal gunshot behind his left ear, slumped forward and crashed the Jeep into a parked vehicle on the side of the road a short distance away. The two passengers in the Jeep did not see or hear anything other than seeing the driver suddenly slump forward. Two additional bullet strikes to the Jeep were discovered. The question then became whether three shots could have been fired from the position of the shooter based on the "window of opportunity" presented by the Jeep as it moved across an opening in the underbrush in front of the residence. The weapon in this case was a Springfield Arms 22 long semi-automatic rifle. A series of test firings was carried out to determine that the rifle was capable of firing up to five shots per second.

An examination of the damage to the Jeep and the damage to the parked vehicle that was struck allowed the accident reconstruction unit to estimate the Jeep's speed at impact to be 25 miles per hour. Because the distance from the crash site to where the Jeep was likely first struck by gunfire was about two car lengths, it was assumed that the Jeep's speed just prior to the shooting was approximately 25 miles per hour as well. To calculate the feasibility that the shooter was able to fire three shots at the Jeep again requires calculating the time of target availability and relating it to the maximum rate of fire of the weapon:

25 miles per hour × 5280 feet per mile × 1 hour/60 minutes
× 1 minute/60 seconds = 36 feet per second

The field of view of the roadway from the shooter's position was approximately 50 feet:

50 feet divided by 36 feet per second = 1.38 seconds

Thus, 1.38 seconds is the time that the target was visible from the shooter's position. Using the rate of fire of the Springfield rifle, the feasibility of three shots having been fired may be determined:

5 shots per second × 1.38 seconds = 6.9 shots

Therefore, at least six shots could have been fired. Since the question was whether three shots could have been fired, it can be stated with confidence that the shooter had ample time to fire three shots.

Distorted Bullet Base Measurements

It is not uncommon to find bullets at shooting scenes during the course of a scene investigation. For purposes of reconstructing a shooting, it is important to be able to identify the source of each bullet located. The bullets recovered at shooting scenes are frequently distorted and/or fragmented, making caliber determination very difficult. Most distorted bullet bases take on somewhat of an oval shape. This can, of course, vary considerably from bullet to bullet but the estimation of caliber can be accomplished by measuring the long and short axes of the oval-shaped base. A "best fit" oval may be approximated when distortion results in a very irregular contour.

The formula for the calculation of the perimeter of an oval provides the means for calculating bullet diameter (caliber). The perimeter of an oval, P, is closely approximated using the formula:

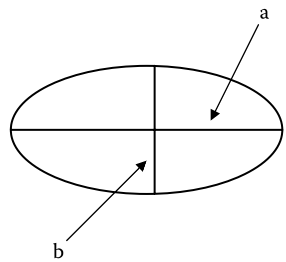
$$P \approx \pi\sqrt{2(a^2+b^2)-\frac{1}{2}(a-b)^2}$$

We know that the perimeter of a circle is found by multiplying the diameter (d) by a constant designated pi (π):

$$P = \pi d$$

From this we can derive the formula for the diameter of the circle represented by the oval:

$$\text{Diameter of circle (oval)} \approx \sqrt{2(a^2+b^2)-\frac{1}{2}(a-b)^2}$$



a = ½ long axis   b = ½ short axis

Structure 2-16

The "idealized" diameter of the oval equates to the caliber of the distorted bullet. The values of a and b are one half of the long axis and one half of the short axis, respectively (Structure 2-16).

A reasonable approximation of caliber for flattened (oval) bullets and bullet fragments may be calculated from the long and short axes of the bases. Jacketed bullets tend to yield results closer to the actual caliber than nonjacketed bullets. In any event, it must be remembered that the measured value obtained is an approximation only and should be treated as such.

In a recent shooting incident reconstructed by the author, one question concerned the number of shooters. A fired 40 Smith & Wesson (S&W) cartridge case, a flattened full metal jacketed bullet, and a distorted lead bullet fragment were found at the scene. No weapons were recovered and the victim had a through-and-through head shot. According to the autopsy report, the entry wound into the victim's head was circular and had a diameter of 0.25 inch. Examination of the bullet and bullet fragment revealed intact bases with an irregular contour for the lead fragment and an oval-shaped base for the jacketed bullet. Measurements were taken of the long and short axes of the bases of the bullet and the bullet fragment. A "best fit" oval was approximated for the lead fragment. Calculations yielded 36 caliber for the lead fragment and 40 caliber for the jacketed bullet.

Based upon the autopsy report, neither of these projectiles could have been responsible for the 0.25-inch entry wound. The jacketed bullet was consistent with the 40 S&W cartridge case found at the scene. The lead fragment was suggestive of 38 Special/357 Magnum ammunition. Thus, three different weapons were suggested by the ammunition components and the victim's entrance wound diameter (in the skull).

Other calculations are associated with shooting incident reconstruction. The bulk of these are associated with exterior ballistics. The calculations are accomplished using ballistics software and will be discussed in Chapter 15.

Exercises

1. A bullet hole is located in the aluminum siding of a mobile home. Measurements of the hole reveal a length of 0.63 inch and a width of 0.22 inch. What is the approximate angle of impact for the shot?

   Answer: 20 degrees. Solution:

   $$\text{Sin impact angle} = \text{width/length} = 0.22/0.63 = 0.3492$$

   $$\text{Impact angle} = \text{inverse (arc) sin } 0.3492 = 20.4 \text{ degrees}$$

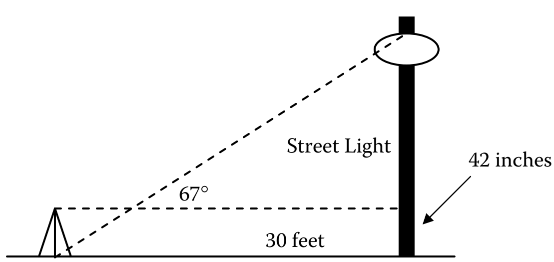
2. A shotgun blast into a vehicle door leaves an oblong pattern of nine holes. The overall pattern has a width of approximately 12 inches and a length of approximately 19 inches. What is the approximate angle of impact for the shot?

   Answer: 39 degrees. Solution:

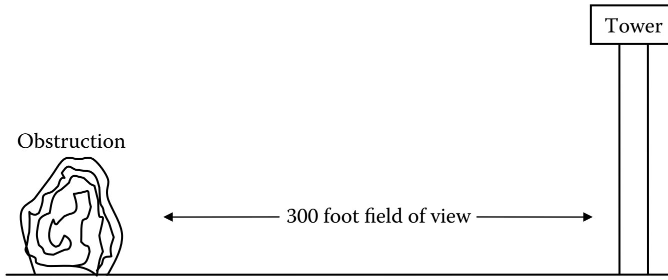
   $$\text{Sin impact angle} = \text{width/length} = 12/19 = 0.6316$$

   $$\text{Impact angle} = \text{inverse (arc) sin } 0.6316 = 39.2 \text{ degrees}$$

3. We wish to determine the height of a street light at the scene of a shooting incident. A tripod is set up as a point of reference. The tripod center is 30 feet from the base of the street light. The tripod is 42 inches high. An angle gauge is used to determine the upward angle from the plane of the top of the tripod to the top of the street light. This angle is 67 degrees. See Structure 2-17. How tall is the street light?



Structure 2-17



Structure 2-18

Answer: 27.6 feet. Solution:

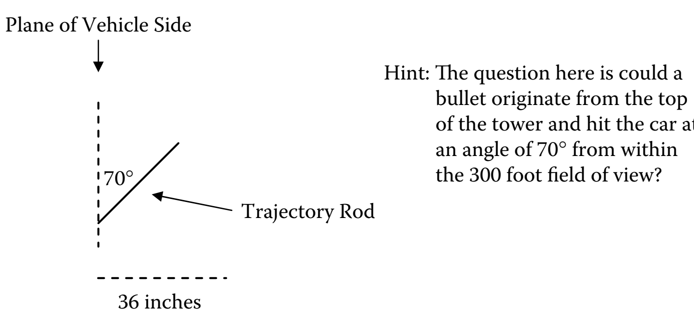
$$\text{Sin } 67 = X/30$$

$$X = 30\ (\sin 67)$$

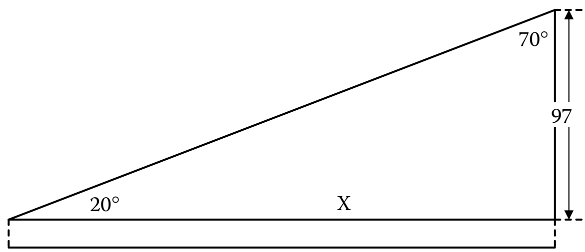
$$X = 30\ (0.92)$$

$$X = 27.6 \text{ feet}$$

4. A series of vehicle shootings takes place along a freeway. A suspect is arrested after having been seen near a water tower in the area. One of the vehicles has a bullet hole through the driver's door that is 36 inches above the ground. The angle of impact of the bullet is determined to be 70 degrees from the plane of the side of the vehicle downward. The tower is 100 feet tall. The field of view of the freeway from the top of the tower is 300 feet (Structure 2-18). Could the shot have been fired from the top of the tower? [Hint: The question is whether a bullet originating from the top of the tower could have hit a car at an angle of 70 degrees from within the 300-foot field of view. Structure 2-19 shows the plane of vehicle side.]



Structure 2-19



Structure 2-20

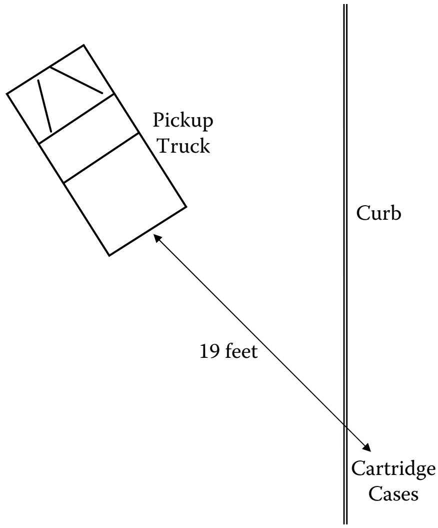
Answer: The shot would be possible. Solution: An imaginary right triangle is constructed; the length of the base is the unknown. In order for the shot to be possible (to be within the field of view), the base length must be less than or equal to 300 feet. The height of the triangle is 100 feet minus the distance of the bullet hole above the ground (assuming level terrain) or 97 feet (Structure 2-20).

$$\text{Tan 70 degrees} = X/97$$

$$X = \text{Tan 70 } (97)$$

$$X = 2.74\ (97) = 266 \text{ feet}$$

5. An officer jumps into the bed of a pickup truck just as the driver starts to flee after having been stopped for driving erratically. After repeatedly banging on the roof of the cab with his baton, the officer breaks out the rear glass of the pickup. He then strikes the driver with the baton through the broken window. Still unable to get the driver to stop the vehicle, the officer shoots the driver twice in the back. According to statements made by the officer to investigators after the shooting, the vehicle was moving forward at a high rate of speed when he fired the first shot. The officer stated that he waited "several seconds" and fired a second round after the first shot failed to get the driver to bring the vehicle to a stop. Two fired cartridge cases were found on the grass median next to the curb. The two cartridge cases were resting alongside each other at a distance of approximately 19 feet from the back of the pickup as it sat in the street (Structure 2-21). The family of the deceased driver filed a civil suit alleging that the officer shot the man after the man stopped the pickup and tried to flee on foot. In order to determine the validity of the officer's version of events, cartridge case ejection pattern testing was carried out on his weapon. It was found that, on the average, fired cartridge cases were ejected 19 feet to the right rear of the weapon. What do the positions of the fired cartridge cases tell you about how the shooting probably occurred?



Structure 2-21

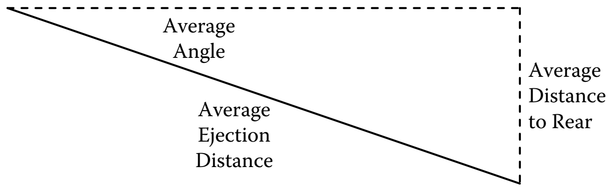
> Answer: To determine the significance, if any, of the cartridge case locations, we need additional information. The approximate speed of the vehicle at the time the shots were fired is critical here. Additionally, the grade of the street must be considered.

A reenactment was carried out and it was determined that the maximum speed of the vehicle at the point at which the shots were fired was approximately 25 miles per hour based on the fact that a sharp turn had to be negotiated just before the truck reached the area of the shooting. The street was inclined; this meant the fired cartridge cases would have had a tendency to bounce or roll after landing. The fact that they rested on the grass could simply be the result of having bounced there after striking the pavement. On the other hand, it is conceivable that they could have landed there directly from having been ejected from the officer's weapon. What must be considered is the fact that if the officer was firing as the vehicle moved forward at 25 miles per hour, the cartridge cases would have had a forward velocity component of 25 miles per hour as well. By virtue of the rearward ejection paths of the fired cartridge cases, they would have a rearward velocity component. The rearward velocity component can be approximated by determining the average time of flight and average distance of the ejected cartridge cases (Structure 2-22).

Using an average ejection angle of 23 degrees and an average ejection distance of 19 feet, we can calculate the average distance to the rear:

$$\text{Sin } 23 \text{ degrees} = X/19$$

$$0.3907 = X/19$$



Structure 2-22

Rearranging and solving for X:

$$X = 0.3907 \times 19 = 7.42 \text{ feet}$$

We must use the average time of flight for the ejected cartridge cases to determine the rearward velocity component. The average time of flight is determined to be 1 second and movement of 7.42 feet in 1 second gives us a rearward velocity of 7.42 feet per second. The forward component of 25 miles per hour must be converted to feet per second:

$$25 \text{ miles per hour} \times 5280 \text{ feet per mile} \times 1 \text{ hour/60 minutes} \times 1 \text{ minute/60 seconds} = 36 \text{ feet/second}$$

The net velocity for the cartridge case would be the difference between the forward component and the rearward component:

$$\text{Net velocity} = \text{forward velocity} - \text{rearward velocity}$$

$$\text{Net velocity} = 36 - 7.42 = 28.58 \text{ feet per second}$$

This means that if the shots were fired from the bed of the truck as it moved forward, the ejected cartridge cases would have landed forward of their location if fired from a stationary position. Since the cartridge cases were found beside each other and about 19 feet from the bed of the truck and since the ejected cartridge cases were projected to have landed about 19 feet away, it appears possible that the shots were fired after the vehicle came to a stop. On the other hand, if the shots were fired as the vehicle started around the corner, they could have landed in the grass where they were found. Thus, we are unable to determine whether the shots were fired when the vehicle was moving or after it stopped. Finding the two cartridge cases together rather than some distance apart appears to refute the officer's account of the shooting. However, the first shot could have been fired as the vehicle started around the corner and the second after it started up the hill, with the second ejected cartridge case bouncing or rolling down the hill and landing next to the first one.

Suggested Readings

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Hueske, E., Baker, C., Gharati, A. and Howard, T.J., Estimation of Caliber for Distorted Bullets, *SWAFS Journal,* 26, pp. 39–44, 2004.

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Firearms and Ammunition Components

3

In order to be able to reconstruct a shooting incident, it is extremely helpful to have at least a working knowledge of firearms and ammunition components. This chapter will provide a basic overview of the topic. The additional pursuit of information relating to firearms and ammunition can only add to an investigator's ability to decipher the information present at a shooting scene and to put it into proper perspective.

Firearms Categories and Nomenclature

This section is not intended to be an in-depth study of firearms designs and function, but is offered as a review of some of the fundamentals having direct application to shooting reconstruction. The reader is encouraged to seek out some of the many excellent references on the topic for more detailed information. Firearms fall into two broad categories: handguns and long guns. A handgun is designed to be held by and fired from a hand. A long gun is designed to be fired from the shoulder. There are, of course, exceptions that do not fall into these categories. For example, certain weapons are designed to be fired primarily from waist level while being gripped with both hands. Some handguns have detachable stocks that allow them to be fired from either the hand or the shoulder. Nevertheless, this broad classification is sufficient for our current purpose.

Handguns include pistols, revolvers, and single shot weapons such as Derringers. Derringers frequently have two barrels and can fire a total of two shots so the single shot description is really incorrect. Pistol and revolver actions are usually categorized as single action or double action. Single action weapons require cocking prior to pulling the trigger in order to fire. A double action weapon is cocked as the trigger is pulled, hence the double action description.

Semi-automatic weapons are perhaps better described as auto-loading. After firing an initial shot, they reload themselves. The recoil and gases produced force the breech bolt rearward, ejecting the fired cartridge case, then moving forward, stripping a live round from the magazine, seating it in the chamber and recocking the hammer in the process. The lever action and slide action are among the other types that perform the same functions but are manually actuated without relying on recoil or combustion gases to perform.

Fully automatic weapons are generally classified as machine or submachine guns. The distinction between the two types is simply that machine guns are chambered for rifle ammunition such as 308 caliber and submachine guns are chambered to fire pistol ammunition such as 9 mm.

Early handguns and long guns were produced with smooth bore barrels designed to fire lead balls of various diameters. With the advent of rifled barrels during the mid-1800s came great improvement in the accuracy of weapons. The rifling allowed the firing of conical shaped bullets or "mini-balls" (Figure 3.1). The rifling produces spin stabilization of a bullet in flight.

Rifling may be described as a series of helical grooves in the inner surface of a gun barrel with either a right twist or left twist direction. The raised areas between the grooves are known as lands. The rifling process is carried out using a variety of techniques. The two basic categories are classified as cut rifling and hammer forged (polygonal) rifling. With cut rifling, a cutting

Figure 3.1 Civil War Era mini-ball.

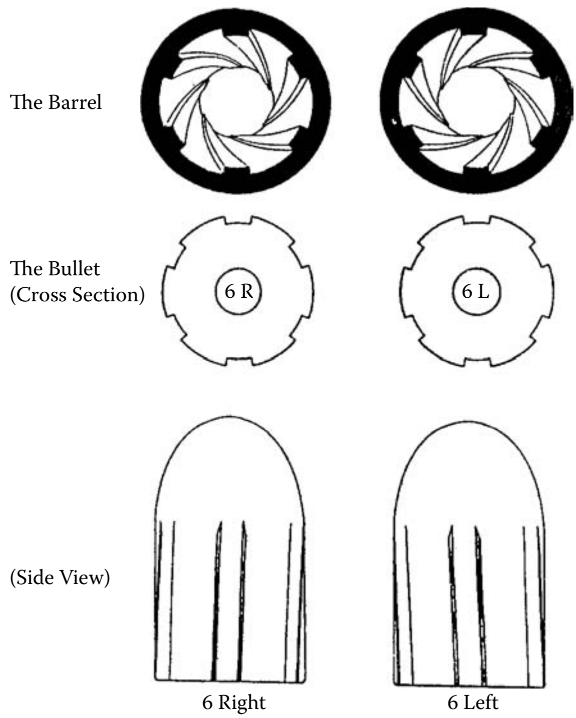

Figure 3.2 Cut rifling.

device of one design or another is used to create the helical grooves (Figure 3.2). Polygonal rifling is created through the use of a mandrel that is inserted into the barrel and hammered to form the rifling (Figure 3.3). Traditional cut rifling and polygonal rifling are distinguishable by the squared-off edges of the grooves and lands on cut rifling as opposed to the rounded edges of

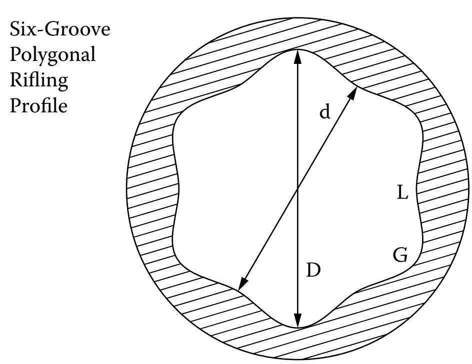

Figure 3.3 Polygonal rifling.

polygonal rifling. Most modern police weapons, such as the Glock, Sig Sauer and Heckler & Koch, have polygonal rifling. This is of more interest to a firearms examiner than a field investigator.

The important issue from the standpoint of field investigation and on-scene shooting reconstruction is that the investigator be able to visually examine a gun barrel and determine the number of lands and grooves and the direction of twist. The reason is that fired bullets and suspect weapons are frequently found at shooting scenes. Instead of having to wait for examination of the evidence by the firearms unit and then waiting to receive the report of findings days or weeks later, it is of investigative value to be able to make an immediate determination as to the possibility or impossibility that a bullet found at a scene was fired from a weapon found at a scene.

To determine the general rifling characteristics of a bullet, one simply needs to hold the bullet parallel to the ground and look straight down at it. If the rifling cants to the left when viewed in this manner, the bullet has left twist and has a right twist if it cants to the right. The next step is to determine the number of lands and grooves by counting as the bullet is rotated. This is shown in Figure 3.4. This task can be somewhat difficult if the rifling is damaged and/or poorly defined. Certainly, if a bullet is bloody or other trace evidence adheres to it, this type handling and examination should not be attempted at the scene and may have to be reserved for the firearms unit.

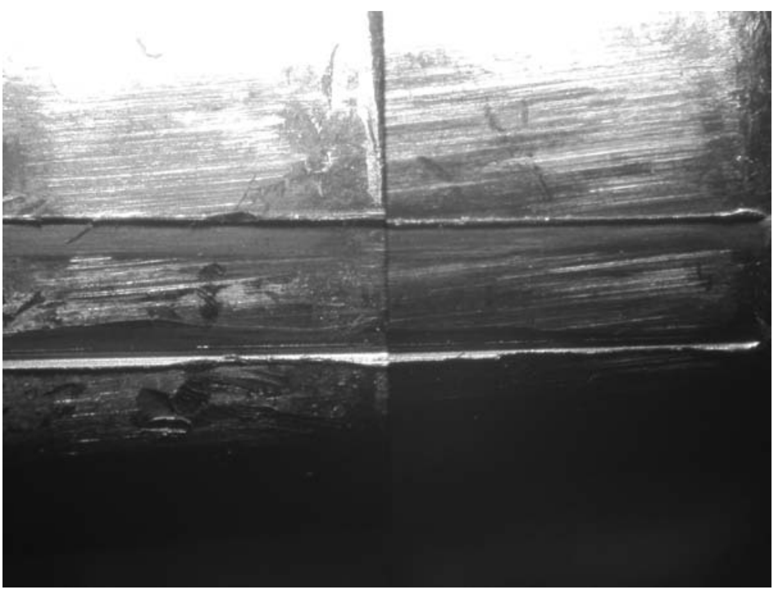

Figure 3.4 Bullet rifling marks.

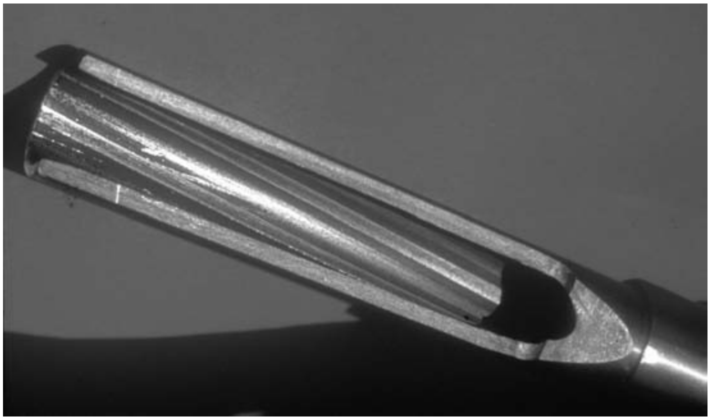

Figure 3.5 Barrel rifling (left twist).

The general rifling characteristics of a gun barrel are fairly easily determined by looking into the muzzle of the weapon. Obviously, the gun should have first been photographed in place, made safe (unloaded and loading status properly documented) and trace evidence considerations (latent prints, hairs, fibers, blood, etc.) should have been addressed before the gun was picked up and handled. If one looks into the muzzle of a barrel at an oblique angle (fewer than 90 degrees), it is usually possible to see and count the number of lands and grooves. By looking down at the muzzle from the top of the barrel, the direction of twist can be determined by noting whether the rifling cants to the right or left. This can be seen in Figure 3.5.

This allows a field investigator to quickly and easily include or exclude a weapon as having fired a bullet when the circumstances at the scene permit the examination and the situation has some urgency from an investigative standpoint. Of course, the evidence would ultimately be submitted to the firearms unit for complete examination and confirmation of the preliminary observations.

An investigator arrives at a crime scene to find a body lying on a floor inside a residence, the apparent victim of a gunshot wound to the head. There is a snub nose 38 revolver lying alongside the body. Further examination of the scene results in the location of a fired bullet on the floor just under the skirt of a sofa in the same room.

Once the scene has been properly documented by measuring evidence locations, incorporating them into a sketch of the scene, taking appropriate photographs, and videotaping the scene, the investigator prepares to collect the evidence. As the bullet is collected, the investigator observes that it bears eight lands and grooves with a right twist direction. Upon carefully picking up the revolver so as to avoid touching any smooth areas likely to have latent prints, the investigator uses a scribe to score a line onto the cylinder on both sides of the top strap. Once this is done, the investigator carefully opens the cylinder latch and swings out the cylinder. The contents of each chamber in the cylinder are recorded and the items removed and placed into containers for submission to the crime lab. Continuing to handle the weapon so as not to obliterate or damage possible latent prints, the investigator looks into the muzzle of the revolver and determines that it has six lands and grooves. By looking from above the front sight down to the bottom edge of the muzzle, the investigator notes that the rifling cants to the left.

It is clear from the investigator's examination of the bullet (eight lands and grooves with a right twist) and the revolver (six lands and grooves with a left twist) that the bullet found at the scene could not have been fired from the revolver. Does this mean that the victim was shot with another gun? Not necessarily, since it must first be established that the victim has a perforating (through-and-through) wound to the head and that the bullet found is consistent with the bullet holes in the skull. If the victim's skull has no exit hole, it would be expected that a bullet would be recovered at autopsy. In that case, the firearms examiner would have to compare the bullet found at the scene with the one found during autopsy to determine whether only one gun was involved.

In any event, it is important for the investigator to know that the revolver and the bullet found at the scene are not related and it is most important to know this while still at the scene. In this way, the investigator can immediately begin to consider other scenarios and look for corroborating evidence. This can help avoid one of the pitfalls of having many years of experience and "having seen this many times before": a rush to judgment. It is not uncommon in the absence of obvious contradictions to make an assessment as to the type of event on the basis of general appearances only. This seems to happen most frequently in cases where suicide appears to be a consideration.

When a revolver is fired, a deposition of soot will appear on the cylinder face around the chamber involved. This is particularly evident if the weapon was clean prior to the firing, but it is usually recognizable even on dirty weapons. These deposits are known as halos or cylinder flares (Figure 3.6). Note that the last chamber to have been fired should have a cylinder flare that overlaps those on either side.

The cylinder of a revolver can rotate clockwise or counter-clockwise (as viewed from the back of the weapon). The rotation direction can be easily determined by merely noting the shapes of the notches in the side of the cylinder rather than by having to work the action. This is especially helpful when multiple shots have been fired from a revolver and different brands of

Figure 3.6 Cylinder flare or halo.

ammunition were used. The cylinder notches are typically in what is suggestive of an arrow head shape. The "point" of the arrow head shows the direction of rotation of the cylinder. This can be seen in Figure 3.7.

By combining the cylinder flare information with the cylinder rotation direction and the loading status of a revolver, frequently one can determine what the sequence of shots was and whether the cylinder was opened and

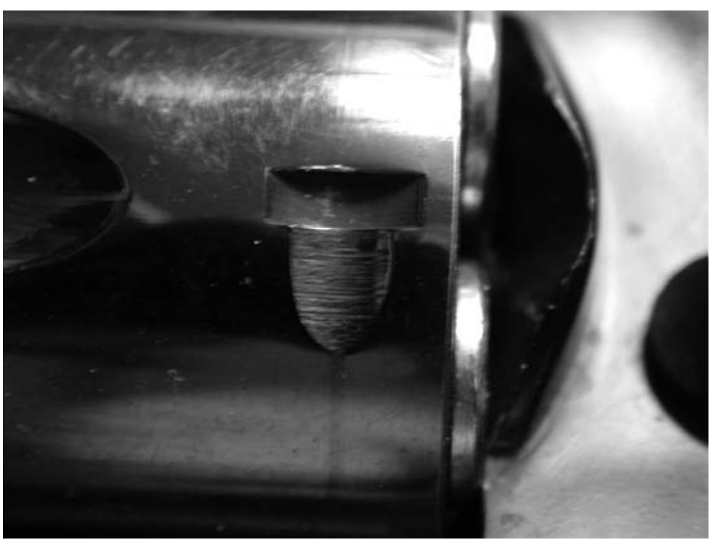

Figure 3.7 Cylinder notch.

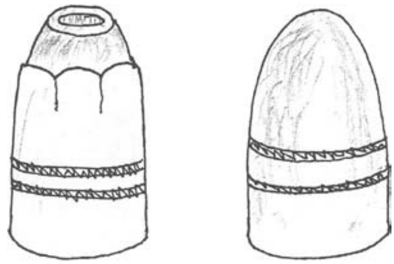

Figure 3.8 Remington–Peters bullet (left) and Winchester bullet (right).

the weapon reloaded during a shooting. Similarly, the staging of a shooting incident can sometimes be ascertained through examination of these characteristics.

A revolver is recovered from a suspect following a shooting outside a police station during shift change. The suspect was reportedly disgruntled over having received multiple traffic citations from different officers within the same day and decided to vent his frustrations by waiting in the police station parking lot for officers arriving and departing at shift change time. Two officers were subsequently shot by the suspect before he could be wrestled to the ground and disarmed. The two bullets recovered from the wounded officers were different in design (Figure 3.8).

When the revolver was examined, the investigator noted that the cylinder notches indicated that the revolver cylinder rotated clockwise. After marking the location of the cylinder by making a mark on each side of the top strap, the investigator opened the cylinder and observed that a fired Winchester cartridge case had been under the hammer and a fired Remington–Peters cartridge case was in the chamber immediately to the right. A visual check of the cylinder face revealed that the chamber with the Winchester cartridge case had a cylinder flare that overlapped the flares on either side. It was further observed that the chamber with the Remington–Peters cartridge case had what appeared to be a recent cylinder flare as well. Once the cylinder contents were recorded and the contents removed and packaged as evidence, the investigator also noted powder particles and soot residue inside the two chambers.

It was evident to the investigator, after examining the revolver, that only two shots had been fired and that the cylinder position had not changed following the second shot. It also appeared to the investigator that it was likely that the firearms examiner would be able to determine which of the officers had been shot first. During the shooting, no one had really been sure which officer was hit first.

After examining the weapon, the fired cartridge cases, and the bullets, the firearms examiner was able to conclude that the suspect's revolver did, in fact, fire the two bullets that struck the officers. The bullet with the scalloped jacket was identified as consistent with Remington–Peters ammunition and the other bullet with Winchester ammunition. The firearms examiner noted that, based upon cylinder flares and cylinder rotation direction, the Remington–Peters round would have been fired first and, thus, confirmed the field investigator's belief that the sequence of shots could have been ascertained from the weapon condition and the ammunition evidence.

Ammunition Components

As with the previous section, this section is in no way intended to be a complete reference on the subject but is to serve as a review of basic principles. The reader is again encouraged to seek out other references for more complete information. The basic unit of handgun and rifle ammunition is the cartridge. As shown in Figure 3.9, the cartridge consists of a case, a powder charge and a bullet. The general public commonly describes the entire unit as a bullet. Thus, it is not uncommon for attorneys at trial to refer to cartridges as bullets and for the jury to picture a cartridge when the bullet term is used. It is up to the shooting reconstruction expert to make sure that the term *bullet* is used properly in reports and subsequent testimony and that all interested persons understand what is meant.

Figure 3.9 Cartridge.

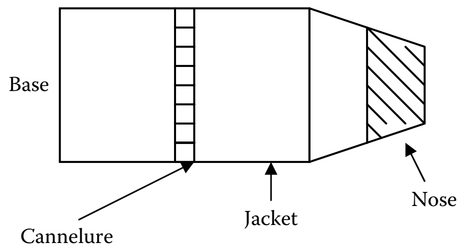

Figure 3.10 Bullet nomenclature.

Thanks to the huge number of different bullet designs and configurations, fired bullets recovered from victims and inanimate objects can often be easily distinguished from one another and their manufacturers identified. A bullet may consist primarily of lead or copper or may have a lead core with a copper jacket or a thin electroplated coating of copper. Figure 3.10 depicts an example of a semi-jacketed bullet with a partial copper jacket and a lead core.

The cartridge case also contains a priming mixture that consists of a shock-sensitive explosive, such as lead styphnate, that ignites the powder charge following impact by the firing pin or striker. Two basic designs are used for placing the priming mixture in the cartridge case: rim fire and center fire. The rim fire design incorporates the priming mixture in the annular rim of the cartridge case as shown in Figure 3.11. The 22 caliber cartridges used

Figure 3.11 Rim fire cartridge case.

Figure 3.12 Center fire cartridge case.

in short, long, and long rifle configurations are the most commonly encountered rim fire types.

The center fire design has a primer pocket in the cartridge case base that seats the primer. The primer consists of a metal cup containing the priming mixture. Rim fire cartridge cases cannot be reprimed and are not reloadable. Center fire cartridge cases are reloadable. Figure 3.12 shows a center fire cartridge case design.

The basic unit of shotgun ammunition is the shot shell consisting of a paper or plastic tube with a brass base. This type of shell may also be entirely constructed of plastic. Shot shells are center fire types but differ from other cartridges in that they have a device called a battery cup that supports the primer cup. A shot shell contains a powder charge and shot pellets. A paper or plastic wad or plastic shot cup separates the shot from the powder charge. Shot is classified as *bird shot* or *buck shot*, depending on the intended target (birds or deer and other large animals, respectively). The shot varies in size from 12 to 000. Table 3.1 presents a comparison of shot sizes. A shot shell may also contain a single projectile called a slug. These various components are shown in Figure 3.13. Detailed discussions of how these various ammunition components factor into the reconstructions of shooting incidents follow in later chapters.

In a more esoteric arena are devices that allow the firing of a bullet smaller than the actual weapon caliber. The sabot is probably the simplest of these devices. A sabot consists of a polymer cup whose outside diameter is the same as the caliber of the weapon to be used. The sabot fits into the cartridge

Table 3.1 Shot Size (Pellet Diameter) Comparisons

	Bird Shot Size									
	12	9	8 1/2	8	7 1/2	6	5	4	2	BB
Inches	0.05	0.08	0.085	0.90	0.95	0.11	0.12	0.13	0.15	0.18
Millimeters	1.27	2.30	2.16	2.29	2.40	2.79	3.05	3.30	3.81	4.57

	Buck Shot Size						
	No. 4	No. 3	No. 2	No. 1	No. 0	No. 00	No. 000
Inches	0.24	0.25	0.27	0.30	0.32	0.33	0.36
Millimeters	6.10	6.35	6.86	7.62	8.13	8.38	9.14

case in the same manner as a bullet. The cavity of the sabot accommodates a smaller bullet than the caliber of the weapon. Figure 3.14 illustrates a sabot designed to enable a 30 caliber weapon to be able to fire a 223 caliber bullet. The rifling of the barrel creates an impression on the sabot during discharge. The bullet exits the barrel, the sabot separates, and the bullet, devoid of rifling, continues on to its target. It would be a rare occurrence indeed to find a sabot at a shooting scene, particularly an outdoor scene where a sabot would be very difficult to find.

Occasionally, bullets and barrels are not of corresponding dimensions and one is slightly undersized relative to the other. The result can be a fired bullet that lacks evidence of rifling impressions even though it passed through a rifled barrel.

The bullet in Figure 3.15 was fired through a Browning Hi-Power 9-mm barrel. The case involved a through-and-through shot to a German tourist

A B

Figure 3.13 Shotgun slug (A) and size 00 buckshot (B).

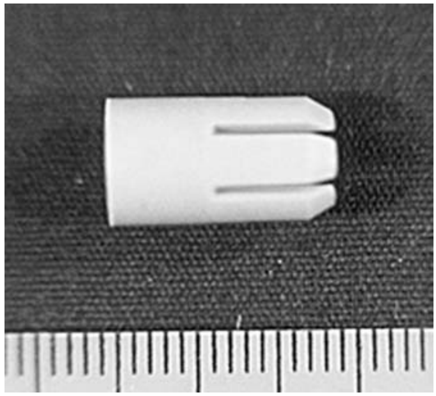

Figure 3.14 Sabot.

at the Grand Canyon. The cast lead bullet exited and was found lodged in a paper container of powdered drink mix. A 9-mm Browning Hi-Power pistol was recovered from the suspect, an avid hand loader. Although the use of lead bullets in semi-automatics is generally discouraged, they will work if they have enough tin content to make them harder than normal. Harder bullets encounter fewer problems feeding from the magazine into the chamber.

The suspect's weapon was fired with jacketed ammunition and engraved the bullets as expected. In examining the evidence bullet, it was noted that a lubricating groove was devoid of lubricant. Other similar bullets in the suspect's

Figure 3.15 Fired bullet with no rifling impressions.

reloading supplies had blue colored grease in their grooves. This clearly indicated that the bullet in evidence had actually been fired. Otherwise, grease would still be present in the groove. But why were no rifling marks present?

To answer this question, hand loads were constructed using bullets from the suspect. When these hand loads were fired in the suspect's Browning pistol, the bullets were found to be absent of any rifling just like the evidence bullet. The unfired bullet diameter was determined by measurement with a pair of calipers. The internal barrel cross-sectional diameter was also measured. From these two measurements it became apparent that the bullets were several thousandths of an inch smaller in diameter than the bore of the barrel. The question was why?

Further investigation revealed that the American bullets worked fine in American-made 9-mm pistols. European 9-mm barrels have bores that are slightly over-sized as compared to American-made weapons. Thus, the cast lead bullets were slipping inside the bore of the Browning and were not engraved by the rifling. Interestingly, the author encountered another case involving a 9-mm Browning Hi-Power and cast lead bullets a few years later. As in the earlier case, the bullet bore no rifling marks. This time, however, the answer was already known. In shooting reconstruction, unusual and unique situations appear frequently. The examples presented thus far cover only a few of the many unusual aspects of shooting reconstruction that might be encountered. By applying the scientific method, the answers to most of the questions that arise can be found.

Scene Documentation of Weapons

It is extremely important to properly document the configuration of a weapon when it is found at a scene. Proper documentation includes photographs, written notes, and loading diagrams. The written notes are especially important because photographs do not always show details of particular interest or they may not turn out (a good reason to use digital imaging). Consider the weapon shown in Figure 3.16. What would you note about the weapon if you observed it lying on the floor at a shooting scene?

If you observed and noted that the slide safety is off, the hammer is fully cocked, and the magazine is not fully seated, you are on the right track. These and other similar aspects of weapons may be significant considerations in a shooting reconstruction. In this particular example, the fact that the magazine is not fully seated raises the question as to how the shooting could have taken place. Was the shooter in the process of reloading (removing an empty magazine or reinserting a fully loaded magazine) when the gun was dropped? Did the magazine get into this configuration as a result of being dropped? Is there another reason why the magazine is not fully seated?

Figure 3.16 Weapon at crime scene.

What would you note about the configuration of the weapon in Figure 3.17? What possible explanations reveal why the slide is locked back? What additional information would provide the answer? The slide is designed to lock back once the last round has been fired. If one or more rounds are found in the magazine, the slide had to have been manually locked back. Here again the questions as to when and why this was done must be considered. This type

Figure 3.17 Second weapon at scene.

of information may have no real significance with regard to circumstances and events of the shooting. On the other hand, the lock-back may be very pertinent. In any event, it must first be recognized and then properly documented.

The contents of revolver cylinders, hand gun, and long gun magazines must be recorded. Likewise, the chamber contents should be documented. It is a good idea to use a standard form and complete one for each weapon at a scene as it is unloaded. As previously discussed, knowing the cylinder rotation and the loading status of a revolver can sometimes allow determination of shooting sequence. Figure 3.18 is a sample loading diagram. The positions of safeties, decockers, and hammers should be recorded. The presence of visible trace evidence should also be noted, along with any damage to the weapon.

The loading status of the magazine of a weapon can provide information about the number of shots fired. This can be compared to the number of fired cartridge cases and bullets recovered. Such information can be useful in resolving questions as to how many shots were fired by the different persons involved in a shooting incident. "Shot accounting" is an important part of shooting reconstruction, particularly when multiple shooters are involved.

Six officers were involved in a border incident in which a man drove around the barriers at the border crossing to enter the United States from Mexico. As the man drove his vehicle through the crossing, one of the officers fired shots at the vehicle. The man turned the vehicle around and began driving back toward Mexico. As he once again sped toward the barriers at the crossing, six officers began firing on his approaching vehicle and continued firing as he sped by them. A rain of bullets failed to hit the driver but struck the vehicle causing it to come to a stop short of the Mexican side of the crossing. The man then jumped out of the vehicle and began to run toward the border. Two more shots rang out, striking him in the back and killing him. A total of 42 fired cartridge cases were found on the roadway at the crossing.

The investigators began by collecting the fired cartridge cases and the weapons from each of the six officers. Since many of the fired bullets missed their targets, the fired cartridge cases provided the most reliable way to determine the total number of shots fired. The number of shots fired by each officer required firearms examination of the cartridge case markings and comparison to test fires from each officer's weapon. As an additional check, the loading status of each weapon (contents of chamber and magazine) was determined. Since the standard procedure for each officer was to always have a round in the chamber and a full magazine, the total number of shots fired by each officer could theoretically be determined by subtracting the number of rounds remaining in each weapon from the total magazine capacity plus one (the round in the chamber). This, of course, presumes that each officer followed the procedure and began with a fully loaded weapon. It further presumes no reloading during the shooting.

Scene Documentation of Firearm

Date________________ Location____

Case #________________ Time collected_______ Collected by__________________

Type____________ Make______________ Model_____________ S/N_____________

Caliber/gauge________Finish____

Type/position of safeties____

Visible damage/alteration____

Trace Evidence (type/location)____

Other observations____

Loading status (brand/live or fired):

Chamber(s)____

Cylinder (capacity/contents – also complete diagram below)___________________

____

Magazine (capacity/contents)____

Revolver cylinder: Draw in chambers & indicate cylinder rotation direction,
chamber contents (headstamp/fired or unfired) and presence of halos on face

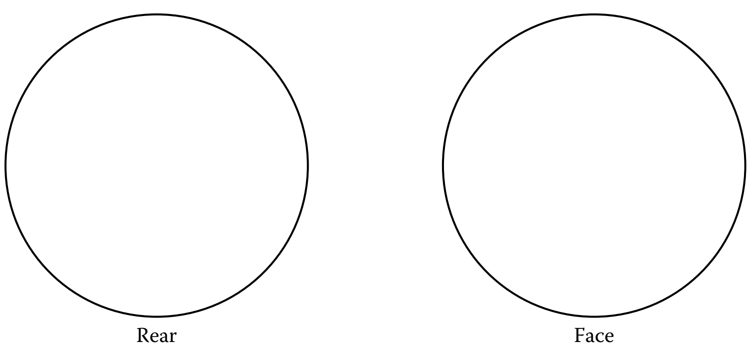

Figure 3.18 Sample loading diagram.

In the event that one or more fired cartridge cases were not found, the count would have been thrown off and there might not have been any way to determine whether fewer shots were actually fired and whether less-than-maximum loading was responsible. Nonetheless, determining the loading statuses of all firearms involved was the appropriate step to take. A discrepancy between the loading status of the weapons and the number of fired cartridge cases was discovered and could not be resolved. This added to the problems generated by the circumstances of the shooting in general and probably was a factor in an out-of-court settlement of a suit filed by the family of the deceased.

Exercises

1. A revolver is recovered at the scene of an alleged suicide. The cylinder of the weapon is determined to rotate counter-clockwise. There is a fired cartridge case under the hammer and a fired cartridge case in the chamber to the immediate right.

   What does this suggest?

   Answer: The counterclockwise rotation direction of the cylinder means that, if the two fired cartridge cases were fired sequentially, the fired cartridge case should be to the left and not right of the one under the hammer. This suggests that the weapon either was not fired sequentially or the cylinder was opened, rotated by one chamber and then replaced.

2. What could be used to determine whether the two fired cartridge cases found in the revolver in Problem 1 were sequentially fired?

   Answer: Cylinder flares on the face of the cylinder, if present, could answer the question. The last cartridge fired should have produced a cylinder flare that overlaps cylinder flares on either side.

3. Several shot pellets are recovered from a wall and are determined to have an average diameter of approximately 8.4 mm. What shot size is indicated?

   Answer: 00 Buck shot.

4. A suspect is apprehended with a handgun containing live rounds and fired cartridge cases. In examining the victim's shirt, ball powder particles are observed around a bullet hole in the victim's chest. What simple examination can be conducted here that might tend to implicate the suspect?

   Answer: Assuming all the ammunition with the gun is of the same brand, an examination of one of the live rounds should be conducted to determine what type powder (ball, flattened ball, or flake) is present. The presence of ball powder would indicate that the gun and ammunition may implicate the suspect.

5. What possible explanations could there be for the failure of the powder in the suspect's weapon to match the powder on the victim?

   Answer: We have the wrong suspect or the weapon was reloaded between the time of the shooting and the examination of the ammunition.

6. What do 38 Special and 357 Magnum cartridges have in common?

   Answer: They both use bullets of the same caliber (cross-sectional diameter): 0.357 inch.

7. What is a sub-caliber device?

   Answer: A device that allows a weapon to fire a smaller caliber bullet than it is designed to fire (e.g., 223 in a 30 caliber weapon).

8. A bullet found at a crime scene has no rifling impressions but other evidence indicates that it was fired. What possible explanations could account for this?

   Answer:

   The bullet was fired in a slightly oversized barrel.
   The bullet was fired in a barrel with worn rifling.
   The bullet was fired in a barrel with no rifling.
   A sabot was used to fire the bullet.

9. A plastic shot cup is found at the scene of a shooting involving a shotgun. A measurement of the shot cup diameter shows it to be approximately 0.8 inch. What gauge shotgun was involved?

   Answer: The bore diameter of a 12-gauge shotgun is approximately 0.78 inch; thus, the shot cup is consistent with 12 gauge.

10. The slide of a semi-automatic handgun at a shooting scene is observed to be locked back. What does this indicate?

    Answer: Either the last round was fired or the slide was manually locked back (as indicated by rounds remaining in the magazine).

Suggested Readings

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4

Shooting Reconstruction Equipment and Use

Documentation of Bullet Holes at Shooting Scenes

Proper documentation of bullet holes at shooting scenes should involve a series of steps as follows:

1. **Exmine the area around the bullet hole and the margins of the hole for trace evidence (blood, hair, fiber, tissue, glass, paint, gunpowder, etc.).** If present, document photographically and collect as appropriate (refer to Chapter 8 for instructions on how to collect gunpowder particles). It is best to collect the object containing a bullet hole or part of the object; include trace evidence whenever possible and document the evidence properly with photographs, measurements, and sketches. This permits collection and/or examination to be pursued at the crime laboratory under more ideal conditions.
2. **Measure the bullet hole and record the dimensions.** Be careful not to disrupt any trace evidence in and around the bullet hole while determining its dimensions. If the hole appears circular, a quick check of hole width in two directions should be made to verify this. Bullet holes resulting from impacts at fewer than 90 degrees will typically have ovoid shapes. A pair of calipers allows quick, accurate measurements to be taken. It must be remembered that in many situations a bullet hole will be slightly larger than the bullet diameter (caliber) due to bullet expansion upon impact. The bullet hole may be significantly larger than the bullet diameter and irregular in shape due to

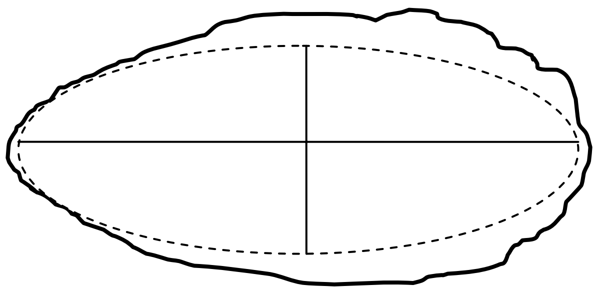


Figure 4.1 Approximating best-fit oval.

stretching or tearing of the substrate. This is frequently seen in vehicle body panels. In these cases, the "best-fit oval" must be approximated and utilized for obtaining measurements on which to base calculations of impact angles (Figure 4.1).

3. **Fix the position of the bullet hole by establishing the x and y linear coordinates.** This is standard crime scene procedure for documenting location based upon fixed objects at the scene. For example, suppose the bullet hole is in an interior wall of a building. The height above the floor constitutes the y coordinate and the distance to the nearest intersecting wall could serve as the x coordinate. For a vehicle, it is useful to relate all bullet holes to a common point of reference. In that way measurements of distances between holes can be easily calculated. The plane of the front (or rear) of a vehicle frequently provides a convenient point of reference.
4. **Determine the x and y angular coordinates of the bullet hole.** There are two angular components for each trajectory associated with a bullet hole. Figure 4.2 illustrates these angular components or coordinates. The angular components are determined by inserting trajectory rods into the holes and measuring the angles (as explained in the next section covering trajectory rods) or by calculating from the hole dimensions and the hole axis. Figure 4.3 illustrates the calculation of x and y angles.

The assignment of x and y axes for a substrate surrounding a bullet hole is purely arbitrary. What is important is that the investigator takes notes and makes sketches to designate what is labelled the x axis and what is labelled the y axis. For example, suppose a bullet hole in a vertical wall is to be documented. The logical approach would be to establish the vertical direction as y and the horizontal direction as x (standard graphical orientation). In this example, the smaller of the two vertical y angles would be defined as the angle of impact while the smaller of the two horizontal x angles would be defined as the lateral

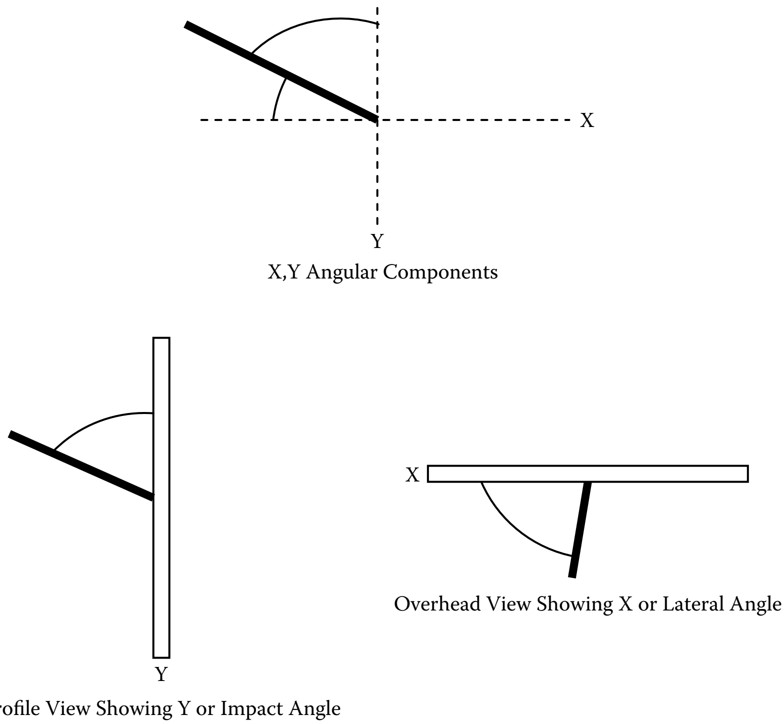


Figure 4.2 Angular components of trajectory.

angle (refer to Figure 4.2). However, the x and y designations can just as easily be assigned in the opposite order without problems as long as the reversal is appropriately recorded in the investigator's notes. Suppose that the surface surrounding the bullet hole happens to be horizontal rather than vertical or is neither horizontal nor vertical but obliquely oriented. What then? Again, the investigator decides how to designate the orientations of the axes. In general, the impact angle is the minimum or smaller angle between the axis of the impinging bullet and the surface, and the lateral angle is the minimum angle between

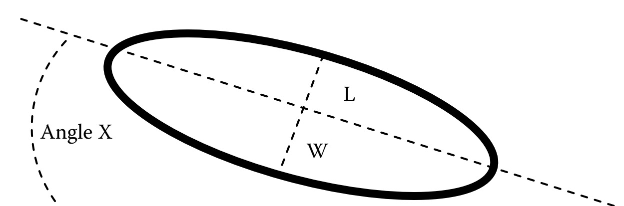


Figure 4.3 Determination of X and Y angles. Angle X is measured between the bisector of the hole and a reference plane. Angle Y equals the arc sine of W/L.

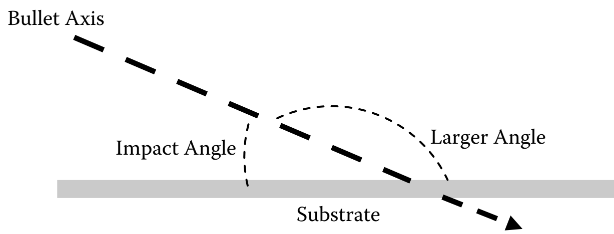


Figure 4.4 Angle of impact (smaller angle between substrate and bullet trajectory axis).

the axis of the impinging bullet trajectory and either side. Figure 4.4 and Figure 4.5 illustrate these angles.

The measurement and documentation of these two angles are essential components of compiling bullet hole data at shooting scenes. By properly measuring and recording these angles, the investigator will be able to prepare scale drawings to assist in the analysis of the shooting incident and present them to a jury as demonstrative evidence. Two perspectives should be evaluated for purposes of establishing whether a particular shooter position is possible or impossible.

5. **Give certain issues special consideration when documenting bullet holes.** Special consideration is required when bullet holes are found in elastic media such as plastic vehicle components, tires, and all types of glass. These situations are discussed in more detail in Chapter 9. As to elastic media, the equivalent of an abrasion ring typically appears around the margins of a bullet hole. The hole will be smaller than the bullet diameter due to the elasticity of the media (analogous to bullet holes in skin). Plastic vehicle components often show concave areas around bullet holes. Measuring the diameter of the outer perimeter of the visible defect (abrasion or concave area) will allow the minimum possible caliber to be determined.

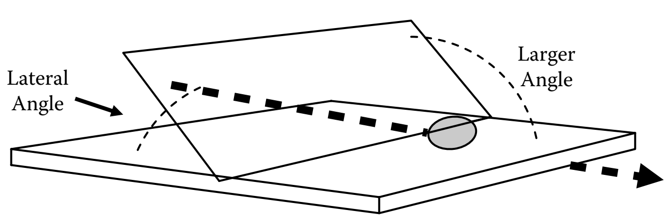


Figure 4.5 Lateral angle (smaller side-to-side angle of trajectory axis).

With regard to bullet holes in glass, it is important to document the presence of beveling on the exit side around a hole margin. It is also important to note and document the fracture pattern around the hole (see Chapter 9 for an explanation of bullet holes in glass). Special considerations for the documentation and analysis of shots fired into vehicles are discussed in Chapter 13.

Trajectory Rods and Use at Shooting Scenes

Trajectory rods are useful for the determination of bullet trajectories in the reconstruction of shooting incidents. Investigators find it useful to have a variety of different rods available because of the varying conditions and materials found at crime scenes. It is important to understand the special techniques associated with trajectory rod use. Trajectory rods are placed through bullet holes to help a shooting scene investigator establish the approximate shooter position and also to assist in determining the points of impacts of bullets passing through various objects (Figure 4.6).

The impact angles (both interior and lateral) can be calculated using trajectory rods. This technique is particularly useful when bullets pass through doors or walls. By marking the trajectory rod at the entry surface and also at the exit surface, the distance the bullet traveled through the object may be measured. This distance then forms the hypotenuse of an imaginary

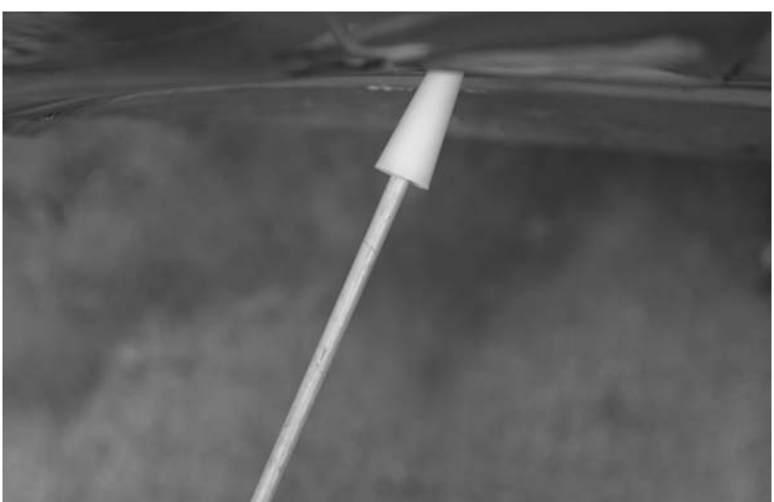
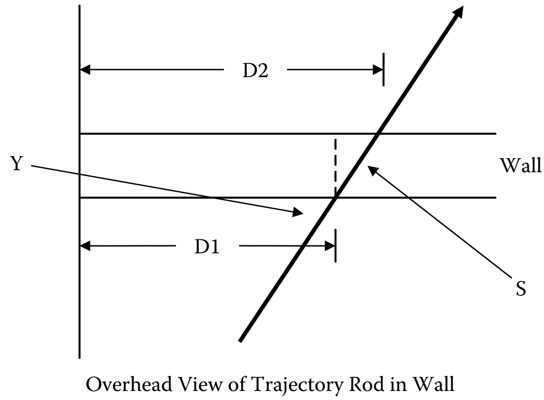


Figure 4.6 Trajectory rod placement.



D1 = horizontal distance to entry hole

D2 = horizontal distance

S = distance bullet traveled through wall (length of rod within wall surfaces)

Y = horizontal impact angle

Example:

D1 = 33.5 inches D2 = 36 inches S = 5 inches

cos Y = (D2 – D1)/S

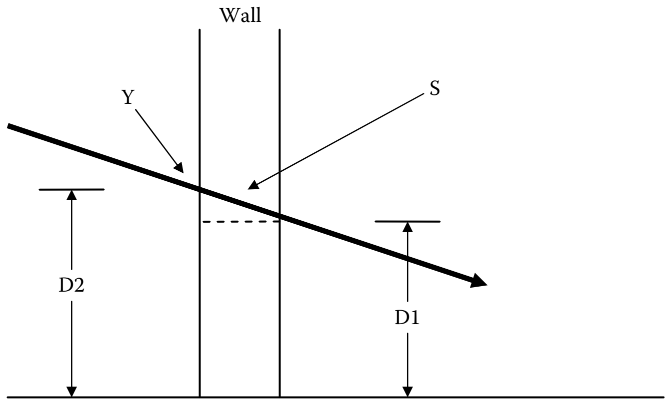
cos Y = (36 – 33.5)/5 = 2.5/5 = 0.5

arc cos 0.5 = 60 degrees

Figure 4.7(a) Determining horizontal angle of impact. Overhead view of trajectory rod in wall. D1 = horizontal distance to entry hole. D2 = horizontal distance. S = distance bullet traveled through wall (length of rod within wall surfaces). Y = horizontal impact angle. D1 = 33.5 inches. D2 = 36 inches. S = 5 inches. Cos Y = (D2 – D1)/S. Cos Y = 36 – 33.5 /5 = 2.5/5 = 0.5. Arc cos 0.5 = 60 degrees.

right triangle used to calculate the associated angle desired as illustrated in Figure 4.7. An assortment of types and sizes of trajectory rods is useful at a shooting scene so that an investigator is prepared to work with a wide variety of media. The addition of various accessories to trajectory rods, such as specialized tips and lasers, greatly expands their utility.

An understanding of the correct placement of trajectory rods is essential to arriving at meaningful results. Proper documentation of trajectory rod placement involves determining two angular coordinates and two linear coordinates as already discussed. It is important for the investigator to realize,



Side View of Trajectory Rod in Wall

D1 = vertical distance to exit hole

D2 = vertical distance to entry hole

S = distance bullet traveled through wall (length of rod within wall surfaces)

Y = vertical impact angle

Example:

D1 = 48 inches   D2 = 50 inches   S = 5 inches

cos Y = (D2 – D1)/S

cos Y = (50 – 48)/5 = 2/5 = 0.4

arc cos 0.4 = 66 degrees

Figure 4.7(b) Determining vertical angle of impact. Side view of trajectory rod in wall. D1 vertical distance to exit hole. D2 = vertical distance to entry hole. S = Distance bullet traveled through wall (length of rod within wall surfaces). Y = vertical impact angle. D1 = 48 inches. D2 = 50 inches. S = 5 inches. Cos Y = (D2 – D1)/S. Cos Y = (50 – 48)/ 5 = 2/5 = 0.4. Arc cos 0.4 = 66 degrees.

however, that the use of trajectory rods to help establish shooter position is not an exact science. Thus, the results obtained must be viewed as approximations. Locating additional substantiating evidence, such as fired cartridge cases and trace evidence, can give added weight to a trajectory rod determination. The use of trajectory rods to approximate shooter position is a well established technique. However, it is essential that the investigator have a clear understanding of both the capabilities and the limitations of the rods and also know something about the associated use of lasers and mathematical calculations.

Bullet Hole Basics

Before attempting to use trajectory rods at a crime scene, some bullet hole basics must be understood.

- Bullets striking at or near 90 degrees produce virtually round holes.
- Bullets striking at angles below 90 degrees tend to produce oval holes.
- The lower the angle of impact, the longer the bullet hole.

Angle of impact is mathematically related to the width and length of a bullet hole by the formula:

Sin of angle of impact = width/length

- Bullets tend to expand upon impact such that the hole diameter (width) produced will typically be slightly larger than the bullet cross-sectional diameter (caliber).
- The more unyielding a target, the greater the difference between hole diameter and actual bullet cross-sectional diameter (unexpanded).

In materials such as wood and sheet metal, the entry side of an oval bullet hole will typically have a visible shoulder while the exit side will not.

- Bullet holes in double-walled objects such as car doors will often have large, irregular exit holes due to expansion and the exiting of fragments from internal supports and mechanisms.

Figure 4.8, Figure 4.9, and Figure 4.10 illustrate some of the characteristics of bullet holes that can be expected.

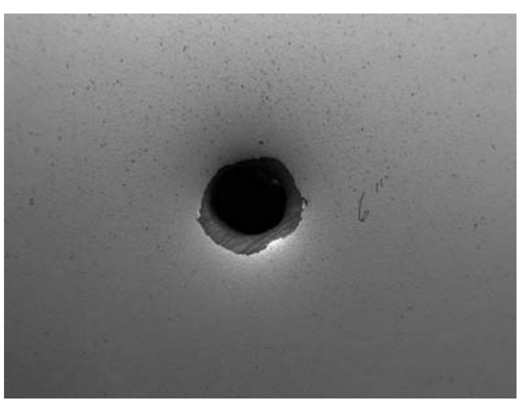


Figure 4.8 Ninety-degree bullet impact (round hole).

Figure 4.9 Angular bullet impact in glass.

Types of Trajectory Rods

A wide variety of items may be used as trajectory rods in addition to commercially available types. Different circumstances dictate which types of rods are best. Among the different possibilities are:

- Wooden dowels of diameters ranging from approximately 0.22 to 0.50 inch
- Plastic-coated steel rods with screw-in connector studs produced commercially for this purpose
- Colored fiberglass rods
- Tent poles (fiberglass with metal connectors)

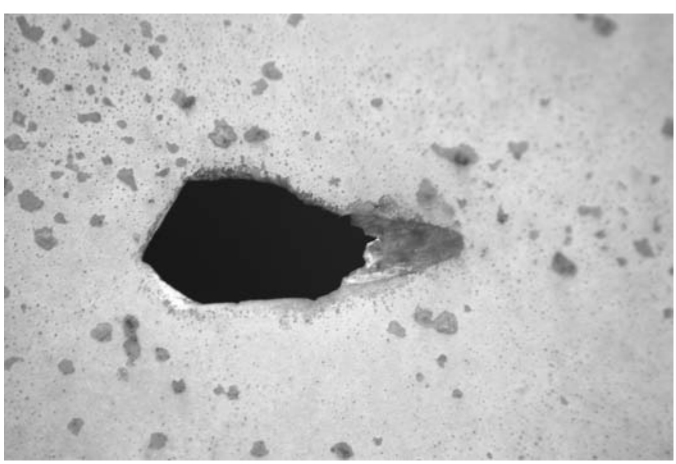


Figure 4.10 Shoulder at entry side of hole in metal.

Figure 4.11 Assortment of trajectory rods in holder.

- Aluminum tubes (arrow shafts work well as do gun cleaning rods)
- Steel tubes (auto brake lines are made in different diameters and can be cut to any length)

A handy holder for the trajectory rods can be easily made from a piece of PVC pipe by gluing a cap to one end and using another cap for a slip-on fit at the other end (Figure 4.11).

Trajectory Rod Accessories

A number of useful accessories are available (Figure 4.12) and include:

- Centering cones (allow smaller diameter rods to work in larger diameter holes).
- Connectors (allow rods to be joined together).
- Tips for attaching strings (gun cleaning patch holders work well).
- Pointed tips (assist in passing rods through objects such as car seat backs).

Other Required Equipment

A number of other items are necessary for use with trajectory rods in establishing probable bullet paths. This equipment includes:

- Zero base trajectory protractor (for angle determination; Figure 4.13)
- Laser protractor

Figure 4.12 Trajectory rod accessories.

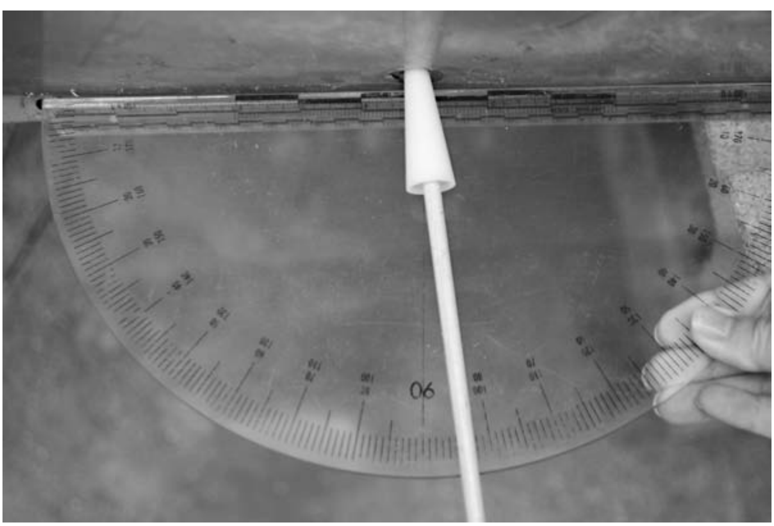


Figure 4.13 Zero base protractor (full).

- Laser with protractor rod attachment capability
- Hand-held scientific calculator (with sine, cosine, and tangent functions)
- Plumb bob and string
- Piece of white foam board approximately 8 $^1/_2$ by 11 inches
- Elastic string (white and black)

A zero base protractor differs from typical protractors in that its base is the point of origin for angle measurement (the base is zero degrees). Standard protractors have their base lines slightly above the actual protractor bases. Using other than zero-base protractors results in error in the measurement of trajectory angles. The zero-base protractors specifically designed for trajectory analysis are larger and easier to read than standard protractors. They also have L-shaped profiles that make them easier to use on flat surfaces although this feature makes them unsuitable for use on irregular surfaces. This can be remedied by switching to an angle gauge or using a plumb line held out away from the surface as discussed in the section on uneven, curved surfaces that follows.

A useful companion to the full (180-degree) zero-base protractor is the half-size (90-degree) version. The half-size protractor is useful for measuring in close quarters where obstacles prevent use of the full-size protractor. These protractors are shown in Figure 4.13 and Figure 4.14.

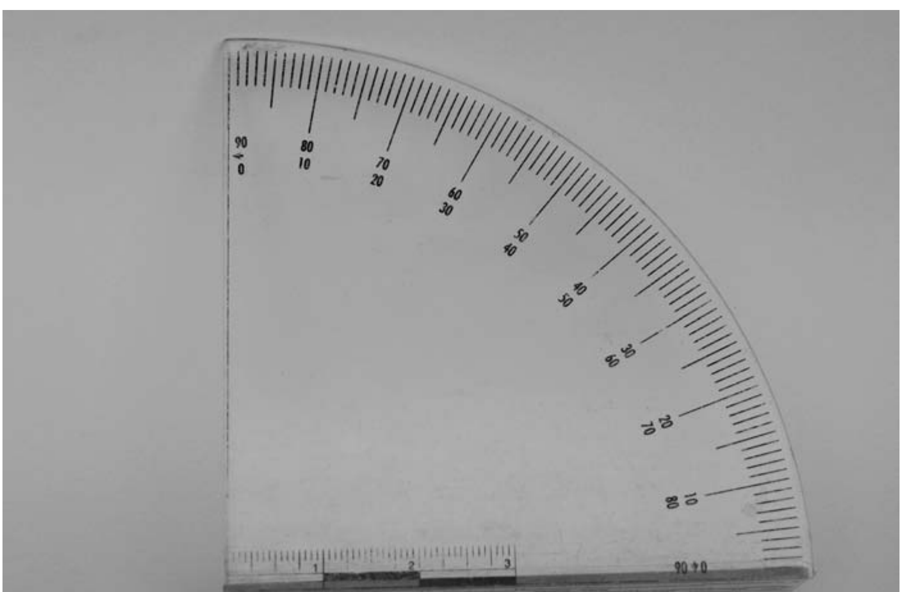


Figure 4.14 Zero base protractor (half).

Substrate Considerations

Different substrates present various considerations when using trajectory rods:

- Plywood and other laminates produce splintering and irregular exit edges.
- Sheet metal can produce over-sized, irregular entry holes.
- Tempered glass can produce irregular holes.
- Upholstered furniture and car seats can obscure bullet holes.
- Rubber tires can produce tiny holes with certain ammunition (i.e., 22 round-nose lead).
- Structural walls and car doors often contain inner obstacles that alter bullet paths.

Proper Trajectory Rod Placement

Different conditions require different techniques. If a shoulder is present on the entry side of a bullet hole and centering cones are not used, the trajectory rod should be pressed against the shoulder to obtain the most accurate trajectory estimate. If holes are large and/or irregular, centering the rods will give the best trajectory estimate. This may be accomplished by using centering cones, physically holding them or using two strips of tape across the hole in an X pattern to create a support for the rod at the center of the hole.

Uneven, Curved Surfaces

Car body panels often have irregular contours that make the measurement of trajectory rod angles difficult when using a trajectory protractor. To solve this problem, a plumb bob is attached to a string and suspended alongside the body panel and next to the rod. The protractor is then lined up with the base along the plumb bob string and the angle of the trajectory rod in the vertical plane is measured. In this way, multiple bullet holes in body panels are all measured with respect to the same reference (the plumb line) in the vertical plane (Figure 4.15). As an alternative, an angle gauge may be used for vertical angle measurements (Figure 4.16).

An electronic, digital angle gauge can also be used. These gauges are available at hardware and building supply stores. One such device, the Smart Tool™, is shown in Figure 4.17. These gauges have the advantage of being easily read and show up better in photographs.

Neither the mechanical angle gauge nor the electronic version works in the horizontal plane. Therefore, the use of a zero-base protractor is the only solution. Horizontal angles require a particularly steady hand on the protractor if the surface is uneven in this plane since the plumb line only works vertically.

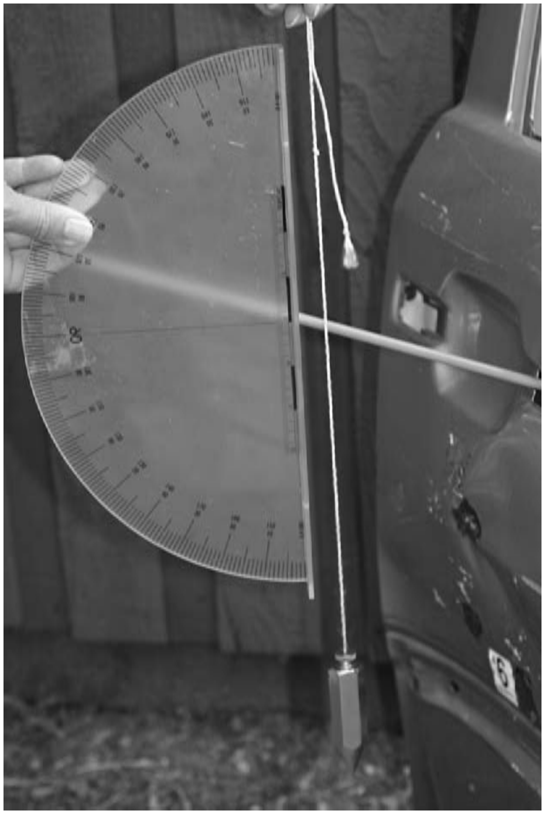


Figure 4.15 Using a plumb line as a point of reference.

Figure 4.16 Using an angle gauge.

Figure 4.17 Smart Tool™ angle measuring device.

Rod Extension via Laser

A laser can "extend" a trajectory rod out to 100 yards or more if needed. Attaching a laser to the end of the trajectory rod allows for quick evaluation of maximum shooter position. Using a white target, such as a piece of foam board, allows a laser dot to be followed up in a range of conditions of bright sunlight (otherwise it may be extremely difficult to see).

Use of Lasers without Trajectory Rods

For bullet holes through single-walled materials such as aluminum siding, it is necessary to use the mathematical relationship of angle of impact, hole width, and length to calculate the impact angle. Once this is done, a laser protractor is set to the appropriate angle, lined up with the bullet hole axis and the trajectory examined via the laser beam (virtual trajectory rod). The hole axis may be marked on the substrate surface, if feasible, as shown in Figure 4.18. Then the laser protractor is positioned as shown in Figure 4.19.

Proper Examination and Documentation

It is important to properly examine all bullet holes for the presence of trace evidence (blood, hair, fibers, and tissue) prior to insertion of trajectory rods. Any trace evidence found must be photographed in place and/or collected.

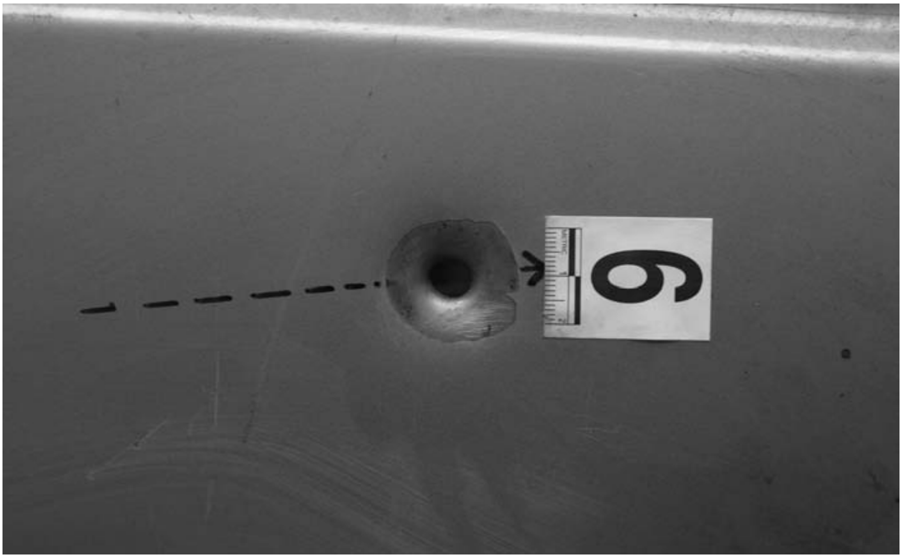


Figure 4.18 Marking hole axis.

Figure 4.19 Positioning laser protractor.

Proper documentation of trajectory rod position includes photographing and/or recording two angular components and two-dimensional components as previously described.

Key Points to Remember

- Trajectory rod placement requires an understanding of the dynamics of bullet hole production.
- Trajectory determination can be aided through the use of lasers.
- The established trajectory will be only an approximation.

In the author's experience performing numerous test firings into a wide variety of substrates commonly found at shooting scenes, trajectory rods fitted with lasers give reasonable approximations of shot trajectories when care is taken in their placement. Since most shootings take place at distances of only a few yards, the fact that true bullet trajectories are not straight lines is of no real consequence. At extended distances, the investigator must take into account the true elliptical trajectories of bullets in flight by using appropriate ballistics software as will be discussed in Chapter 14.

The sole purpose of trajectory rods, whether real or virtual, is to establish a path along which the shooter could have been positioned. This will mean that the shot could, theoretically, have been fired anywhere between the point of impact of the bullet out to the point at which the line of sight terminates. This is illustrated in Figure 4.20.

The use of trajectory rods alone can seldom fix a shooter position exactly. To do so requires additional evidence such as footwear impressions, fired cartridge cases, cigarette butts, or trace evidence. A combination of bullet trajectory and physical evidence can often limit the possible number of shooter positions considerably. For example, if we establish a probable general bullet trajectory and also have several fired cartridge cases from the scene, we have the ability to propose a probable shooter location. We begin by determining the ejection pattern characteristics for the weapon and ammunition. Knowing the direction of the shot, we can determine approximately

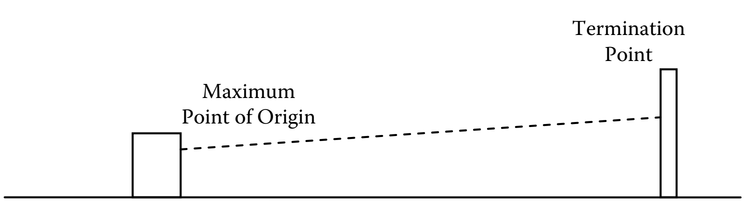


Figure 4.20 Possible shooter positions (between maximum point of origin and point of termination) based on trajectory.

where along the trajectory path the shooter was positioned. This technique also requires knowledge about shooter height and shooting stance or making assumptions about those facts.

Tripod-Mounted Lasers

It is very useful to be able to mount a laser on a tripod when reconstructing events surrounding shootings. A tripod-mounted laser in combination with an angle gauge can become what might be called "the poor man's transit." The combination allows calculation of many useful angles and distances to assist in shooting reconstruction. The tripod-mounted laser and angle gauge are shown in Figure 4.21.

Suppose a bullet hole is found in the upper area of a multistory building. A tripod-mounted laser provides a quick and simple way of establishing the height of the bullet hole above the ground. The tripod is placed at a convenient position in front of the building. The laser is set parallel to the ground and the laser dot on the building is measured for its height from the ground.

Figure 4.21 Tripod-mounted laser.

Figure 4.22 Laser level.

The distance of the laser from the building is measured. The laser is then rotated upward until the dot is directly on the bullet hole. The angle of the laser on the angle gauge is then read. From this data, the height of the bullet hole above the ground can be calculated.

A variety of laser levels are available at building supply and hardware stores. A particular useful type incorporates a leveling table that allows 360-degree rotation and can be used to determine lateral angles. By constructing a simple bracket and drilling a hole through the laser level, vertical rotation of the laser can be combined with horizontal rotation. This is illustrated in Figure 4.22, Figure 4.23, and Figure 4.24. The result is a very useful device for shooting reconstruction. An alternative to fabricating and drilling is to place a laser protractor into a universal leveling table as shown in Figure 4.25.

Potential Role for Tripod-Mounted Laser at Texas Tower Shooting

Although compact, high intensity lasers were not available in the 1960s, a tripod-mounted laser would have been very useful in documenting some of the shots fired by Charles Whitman during the sniper incident at the University of Texas tower in the late 1960s. Many shots were fired at

Figure 4.23 Leveling table.

Figure 4.24 Laser level modified for vertical rotation.

Figure 4.25 Laser protractor placed into universal leveling table.

Whitman from the ground upward by police officers and private citizens. The author was attending a summer session at the time and clearly remembers the impacts of bullets on the face of the clock at the top of the tower. Setting up a tripod-mounted laser on the ground below the tower would have allowed the heights of bullet impact marks near the top of the tower to be determined. Because the site was more than 300 feet above the ground, other methods of measuring would have been more difficult to carry out. Similarly, a laser set up to approximate Whitman's field of view could have been used to determine downward angles for specific shots where victim locations were known.

Total Data Stations

The ultimate piece of equipment for shooting incident reconstruction is the total data station. This device allows the acquisition of relative distance and position data from physical evidence and the subsequent downloading of the data into a computer software program for generation of a scale drawing.

The total data station utilizes infrared light to accurately determine measurements from an established reference position. Total data stations can generate diagrams of buildings and vehicles and also create general crime scene diagrams. Because they cost in the neighborhood of $16,000, they are out of reach for many small police departments. Larger departments typically have this equipment and use it for both vehicle accident reconstruction and crime scenes.

Chronographs

Chronographs are used to determine muzzle velocities, velocities after passing through intermediary targets, velocities after ricochet, and various other projectile-related velocities. The use of a chronograph to determine the velocity of a bullet after it passed through a vehicle seat back is illustrated in Figure 4.26. A chronograph measures velocities via a series of "screens" through which bullets pass. As a bullet passes through the first screen, a beam of light is broken. After the bullet passes through the final screen, a microchip calculates the elapsed time and converts it into feet per second.

Figure 4.26 Use of chronograph to determine velocity of bullet after passing through seat back.

Use of Chronograph to Solve a Case

The author was involved in a case in which an individual replaced the receiver cover of an AKS 7.62 × 39 semiautomatic rifle with an aftermarket receiver cover designed to accommodate a telescopic sight. The aftermarket receiver cover was made of cast iron; the original was made of stamped steel. The owner took the rifle to a shooting range in order to sight it in with the new telescopic sight. He purchased a case of Chinese-made ammunition to use for sighting it in and hunting. After successfully firing several rounds, a malfunction resulted in the front part of the aftermarket receiver cover flipping upward, carrying the telescopic sight along with it. The upward motion of the receiver cover and scope made the cover appear as though it was hinged at the rear. This motion caused the eyepiece of the scope to literally scoop the shooter's eye out. The receiver cover was cracked in the process.

A search of the immediate area by investigators located a fired cartridge case with a deformed mouth. Instead of the bottleneck shape that should have been present, the mouth of the cartridge case was bulged out (see Figure 4.27). The head of the cartridge case was deformed and a portion was missing from the rim (see Figure 4.28).

The question was whether the receiver cover was at fault. The focus was placed upon the cover, of course, because it was a non-factory add-on. However, the receiver cover manufacturer was quick to point out that the company never experienced a single failure among thousands of such items

Figure 4.27 Deformed 7.62 × 39 cartridge case mouth.

Figure 4.28 Deformed 7.62 × 39 cartridge case head.

and noted that its cover exceeded the factory version in tensile strength even though it was a cast product.

The damage to the receiver cover and the deformed cartridge case found at the scene indicated excessive pressure was involved. The focus of attention then became the ammunition. The question was whether the rounds were consistent in powder charge, bullet seating and crimping, primer seating, and cartridge case construction. The answer to most of these questions lay in test firing representative samples from the case the victim purchased. Even moderate discrepancies would have been revealed as muzzle velocity variations. This was clearly a situation for chronograph testing.

Three cartridges were selected from each box of 20 rounds contained in the case of 500 rounds. Comparison firing was conducted with the ammunition purchased by the victim and with several rounds of U.S.- and Russian-manufactured ammunition. For each group of three rounds, the chronograph determined the high, low, and average muzzle velocities and calculated the standard deviation. This allowed the shooter to ascertain how similar the loads were and whether any "hot" loads might have produced higher-than-normal pressure.

As a result of the testing with a chronograph, the author was able to eliminate the ammunition as the source of the malfunction. Ultimately, the culprit was determined to be internal residual cosmolene (heavy grease applied to inhibit rust during shipping). The cosmolene caused the gas piston to stick and caused the weapon to fire out of battery. Because the bolt was not fully locked up, it moved rearward with such force that the receiver cover was fractured and flipped up at the front, injuring the shooter.

Specialized Equipment for Shooting Reconstruction

A number of specialized fixtures are useful for solving shooting reconstruction problems. Some are commercially available but most are the products of "backyard ingenuity." With regard to commercial products, gun rests and gun holders come to mind immediately. Machine rests for hand guns and long guns have been available for many years and are well known to gunsmiths. Using a machine rest and a mechanical trigger release allows a hand gun or long gun to be sighted in without having to deal with the human factors involved in holding and firing a weapon.

It is not uncommon for the accuracy of a weapon to be an issue in a shooting incident. The question of whether a shot was intentional can be narrowed down to the weapon itself and how it was sighted in. This is particularly true when a weapon has a telescopic sight. The use of a machine rest is a requirement in such cases. This topic will be examined in more detail in Chapter 7.

A cardinal rule in shooting reconstruction is that theories must be subjected to physical testing. It is never adequate to rely on theoretical information without ever testing it. Thus, if an angle of impact, for example, is calculated by measuring the width and length of a hole, the angle must be verified by test firing the same weapon and ammunition used in the shooting into the same substrate.

When setting up a target for impact angle verification, it is usually simpler to maintain the weapon in a rest at 90 degrees to the front edge of the target base and then rotate the target to the desired angle rather than trying to adjust the angular orientation of the weapon to a fixed target. An example of a machine rest and target table with a rotating face is shown in Figure 4.30. The base of the target table consists of steel pipe to which a piece of 2×12 inch board has been bolted to serve as a mounting table for a target holder. The target holder is constructed of 2×4 inch boards glued and screwed together in a U shape. The bottom piece has a $\frac{1}{4}$-inch hole drilled in the center as does the mounting table. A $\frac{1}{4}$-inch bolt through the respective holes holds these parts of the apparatus together. A wing nut fastens the bolt at the bottom. Loosening the wing nut permits rotation of the target holder as desired. The table top should be marked off in degrees to simplify angle settings. This device can accommodate fairly large targets (Figure 4.30).

As an alternative, when smaller target media are involved, a universal leveling table secured to a solid base can be used. Since the leveling base can be rotated 360 degrees, it is possible to set test impact angles. The fact that the leveling base has small, vise-like jaws allows easy mounting of appropriate targets, as seen in Figure 4.23. To avoid target movement upon bullet impact, a frame must be used around the target since the leveling table jaws secure it only at the base. With a little ingenuity, the appropriate fixture for a particular job can be constructed.

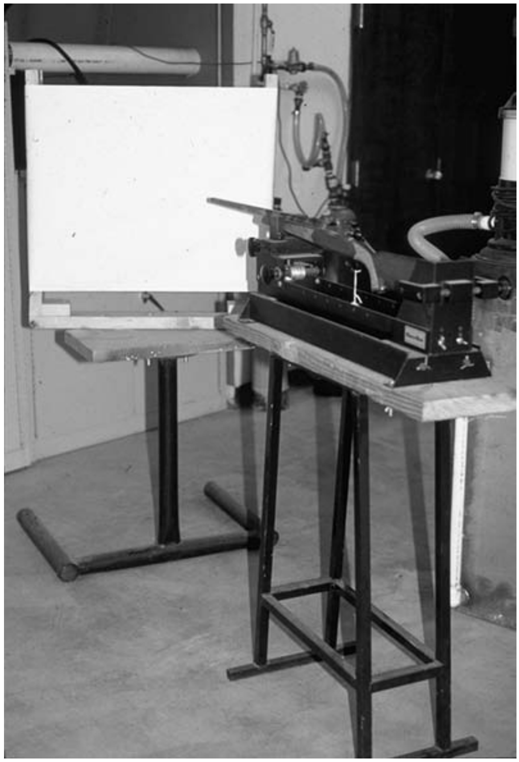


Figure 4.29 Machine rest and adjustable angle target.

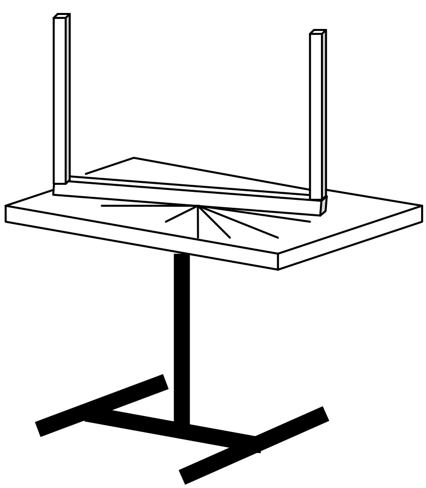


Figure 4.30 Device for impact angle determination.

Shooting Reconstruction Using a Special Fixture

A number of years ago, the author worked on the reconstruction of a shooting incident in which a bullet passed through the rocker molding below the driver's door of a vehicle in which the driver was shot to death. It was critical to the case to establish the trajectory of the bullet that passed through the rocker molding. The vehicle was traveling along a roadway when the shooting took place. Since roads are sloped from the center to both sides for drainage, the position of the vehicle on the roadway could have resulted in a slight difference in trajectory. The bullet trajectory needed to be established as accurately as possible in order to determine whether the defendant's version of events could be corroborated.

The first thought was to reenact the shooting by taking the vehicle back to the scene. However, the vehicle was no longer running and the thought of moving it by hand did not seem practical because temperatures were in the nineties at the time. Because the rocker molding was removable, the decision was made to construct a fixture that would support the molding at the same distance above the ground as its distance from the ground when it was installed on the vehicle, then use a laser to determine trajectory.

The first effort at constructing a fixture resembled a four-poster bed frame. The idea was to have the outer dimensions of the frame equivalent to the outer perimeter of the vehicle to allow visualization of spatial orientation. The molding was attached to one side of the rectangle. Since the crime scene was some distance away, the fixture had to be easily disassembled for transport and this resulted in a rather rickety setup. Ultimately, the frame device was scrapped in favor of a much simpler and more easily moved fixture.

The newer fixture consisted simply of a saw horse that supported the rocker molding by using C clamps and pieces of 1 × 2 inch wood. Small pylons were used to indicate the points where each tire touched the ground. This gave a visual indication of the spatial orientation of the vehicle. The device was entirely portable and easily moved about on the roadway at the scene for testing the effect on trajectory of various possible positions. A laser was placed behind the rocker molding and projected through a piece of steel tubing inserted into the bullet hole. Figure 4.31 illustrates the fixture used at the shooting scene.

The fixture allowed the author to determine that the shot was fired near the ground and not from an upright (i.e., standing) position. It should be pointed out that this conclusion contradicted a reconstruction by another expert who tied a string to the end of a trajectory rod inserted into the molding while it was still attached to the vehicle. Because the distance of the shot was approximately 50 feet, the difficulty of maintaining a string in

Figure 4.31 Special fixture for trajectory determination.

exact alignment with the rod should have been apparent. The results obtained with a string rather than a laser reflect that.

Exercises

1. Which one of the following can be used as a trajectory rod?
   a. Fiberglass tent pole
   b. Steel rod
   c. Wooden dowel
   d. All of the above

2. Which one of the following is used when trajectory rods are placed into oversized holes?
   a. Pointed end
   b. Connector
   c. String connector
   d. Centering cone

3. A bullet hole through automobile sheet metal is often:
   a. Smaller than the bullet
   b. Larger than the bullet
   c. About the same size as the bullet
   d. Indeterminate

4. The angle of impact for a bullet hole:
   a. May be measured only with a protractor
   b. Can be calculated only by measuring
   c. Can be measured either with a protractor or calculated
   d. Cannot be determined

5. Trajectory rods work best with:
   a. Double-walled materials
   b. Thin sheet metal
   c. Glass
   d. Almost any material

6. Laser protractors are often used with:
   a. Double-walled materials
   b. Thin sheet metal
   c. Glass
   d. Wood

7. Trajectory rods are used to:
   a. Approximate a shooter's position
   b. Pinpoint exact shooter position
   c. Locate bullets
   d. Find trace evidence

8. The area where a bullet first passes through sheet metal at an angle smaller than 90 degrees is known as the:
   a. Foot
   b. Face
   c. Shoulder
   d. Eye

9. Trajectory rod diameter:
   a. Is unimportant
   b. Must be exactly the same as the hole diameter
   c. Should usually include an assortment of different diameters from 0.22 up to 0.50 inch
   d. Must be about 0.25 inch

10. When making angular determinations from irregular contours such as car doors, it is best to:
    a. Approximate
    b. Use an angle gauge
    c. Use a plumb bob
    d. Use a zero base protractor

11. As bullet impact angle gets smaller, the bullet hole tends to:
    a. Stay the same
    b. Become longer
    c. Become shorter
    d. Become wider
12. A trajectory rod placed through a bullet path will have:
    a. Two angular components
    b. One angular component
    c. Three angular components
    d. No angular components
13. A trajectory rod placed through a bullet path will have:
    a. Two dimensional components
    b. Three dimensional components
    c. One dimensional component
    d. No dimensional component
14. Bullet holes striking a surface at about 90 degrees tend to produce holes that are:
    a. Irregular
    b. Elliptical
    c. Circular
    d. Oblong
15. Bullet holes produced by impacts at less than 90 degrees tend to be:
    a. Round
    b. Oblong
    c. Irregular
    d. Square
16. The trigonometric function that relates impact angle to the width and length of a bullet hole is the:
    a. Cosine
    b. Tangent
    c. Sine
    d. Pythagorean theorem
17. The angle of impact of a bullet hole is found by determining:
    a. The arc sin of width/length
    b. The tan of width/length
    c. The arc cos of length/width
    d. The cos of width/length

18. The margins of a bullet hole should be examined for:
    a. Blood
    b. Hair
    c. Fibers
    d. All of the above

19. Using a plumb bob to measure angles allows:
    a. The use of only one hand
    b. The opportunity to photograph
    c. A common point of reference
    d. One person to complete the work

20. The use of a laser protractor is important when:
    a. Thin, single-walled material is involved
    b. A hole is oversized
    c. A double wall is involved
    d. The bullet cannot be found

Answers: 1-d, 2-d, 3-b, 4-c, 5-a, 6-b, 7-a, 8-c, 9-c, 10-c, 11-b, 12-a, 13-a, 14-c, 15-b, 16-c, 17-a, 18-d, 19-c, 20-a.

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5

Cartridge Case Ejection Pattern Testing

Testing Considerations

Under the right conditions, cartridge case locations can provide useful information about the probable position(s) of a shooter. A number of variables are associated with how a particular weapon ejects fired cartridge cases. These variables include:

- Weapon design
- Weapon condition
- Ammunition type
- Position weapon is held in when fired
- Movement of weapon during firing
- How tightly weapon is held during firing
- Type of terrain where shooting occurred
- Presence of obstacles at scene

What must be determined in a shooting incident involving ejected cartridge cases is how many of these variables are unknown and the effect, if any, of not having information about those variables. For example, if fired cartridge cases are found at a shooting scene and no gun is recovered, no meaningful results can be obtained by carrying out cartridge case ejection testing with a weapon selected at random. Although it may be possible from the markings left on the cartridge cases to predict a possible weapon, tests must be carried out using the particular weapon and similar ammunition (from the same lot if possible).

Weapon design determines general cartridge case ejection characteristics (rearward, to the right, forward, straight up, etc.). Unless the specific weapon that fired the cartridge cases can be identified, the ejection characteristics cannot be stated to any degree of certainty. Certainly physical evidence may support only one general ejection characteristic, but those situations tend to be rare at shooting scenes.

The importance of using the same weapon used in the shooting for testing cannot be over-emphasized. For example, variations in cleanliness and amount of lubrication of the incident weapon and the weapon used for ejection pattern testing can produce decided differences in cartridge case ejection even to the extent of resulting in failure to eject. Likewise, different pressures for recoil springs and magazine follower springs as found in different weapons of the same make and model can affect ejection.

Naturally, an argument might be made about possible differences in operability due to wear and tear when a significant amount of time has passed between a shooting and obtaining the suspect weapon. Nonetheless, using the same weapon for test firing is the appropriate practice. If a legitimate question exists about the cleanliness and lubrication of the weapon at the time of shooting versus its condition when received for test firing, it can be test fired as received, and retested after cleaning and lubrication and before comparing the results. Sometimes weapons with broken or missing parts are received. It is then necessary to repair the weapon or replace the parts in order to render it fireable. If the part or parts required could in any way affect cartridge case ejection, an appropriate disclaimer must be included in any subsequent report or testimony relating to the ejection pattern results.

Ammunition types can produce significantly different ejection patterns. There is a big difference, for example, in the ejection characteristics for a weapon firing standard loads versus the higher velocity +P and +P+ loads due to the increases in pressure associated with these loads. Even similar loads from the same manufacturer can contain different powder types. The best practice is to use some of the same ammunition recovered with the weapon, if any is present. If not, and it is possible to determine the lot number from which the incident ammunition came, ammunition from the same lot is appropriate. If only the brand of ammunition is known, it is essential to ascertain the style and weight of bullet involved in order to acquire similar factory loads. It is a good idea to pull a bullet from a round so that a determination of powder type may be made and compared to any powder from the victim and/or scene if available. In that way one can establish that the same type powder involved in the incident was also used for test firing.

Hand loads present a unique set of concerns. First and foremost, it must be established that the hand loads are consistent in powder charges, bullets and primers. This can be determined by disassembling several loads if a sufficient number are available. They can always be re-assembled and fired if required. Test firing and chronographing a few rounds (if available) can also provide the answer. Of course, if the ejection pattern developed through test firing is fairly consistent, the answer is self-evident: the loads are similar in make-up.

The position in which the weapon was when the shots were fired can produce a drastic effect on cartridge case ejection pattern. The so-called "gangsta" style of holding a weapon sideways while firing produces an altogether different pattern and/or location than a weapon held in the traditional manner when fired. Likewise, firing while a weapon is pointed downward produces results decidedly different from firing with the barrel more or less parallel to the ground. The bottom line is that when verifiable information as to how a weapon was held during a shooting exists, it must be factored into the testing. This is most likely to be the case in officer-involved shootings where an officer can provide details as to his or her shooting stance. In any event, weapon position is a definite consideration.

A Case Where Cartridge Case Location Raised a Serious Question

The author was involved in a case in which the question of how the shooting occurred was raised. According to one version (that of the surviving shooter), the decedent was upright and lunged at the shooter who then shot the decedent in the chest. The decedent was said to have fallen to the ground, turning as he fell, and winding up on his back. The question raised was whether the shooter could have been standing at the decedent's head as he lay on the ground on his back, thus negating the self-defense aspect.

A single fired cartridge case was found to the decedent's right as he lay on the ground. The weapon and ammunition like that used in the shooting were obtained for use in test firing. The weapon was found to eject fired cartridge cases to the right rear of the shooter when the gun barrel was held parallel to the ground. The ground was relatively flat and covered with leaves. If it is assumed that the cartridge case location was pristine and representative of the actual point where it came to rest, the shooter could not have been facing the decedent as he claimed.

On determination of the general ejection pattern characteristics, test firings were conducted with the gun barrel pointed downward toward the ground. The gunshot residue pattern on the decedent's shirt indicated a muzzle-to-target distance of 12 to 24 inches. Using a distance of 18 inches from the muzzle to the ground, the cartridge cases were found to land in the same general area with respect to an imaginary body on the ground, as occurred at the scene.

Based upon cartridge case location at the scene, the conclusion was that the shot was more likely fired while the decedent was on the ground rather than standing upright. Of course, this statement is contingent on the fact that neither the cartridge case nor the decedent at the scene was moved. Several individuals responding to the scene could corroborate the position of the decedent but only the crime scene investigator who found the fired cartridge case could speak about its position. Therefore, the disclaimer concerning the cartridge case location had to precede all discussion concerning its significance.

If a weapon is moved about as it is fired and/or the shooter changes position, cartridge case locations will be affected accordingly. The usefulness of cartridge case locations under these conditions can be limited unless bullet strikes can be used to relate to the cartridge case locations. For example, assume we have a weapon that ejects rearward and to the right when held in the usual manner and with the barrel approximately parallel to the ground; two shots are fired in directions approximately 90 degrees apart and the fired cartridge cases remain where they first hit the ground. Using the weapon and ammunition recovered from the suspect, we establish an average ejection pattern of 20 degrees rearward from the plane of the breech face of the weapon at a distance of 5 feet. If we have no information as to where the bullets struck, the locations of the two fired cartridge cases could indicate a shooter in any position 360 degrees around the cartridge cases as shown in Figure 5.1.

On the other hand, if we have bullet strikes and/or holes at the scene to which we can relate the cartridge case locations, we can approximate the shooter positions using the average ejection angle and distance we determine

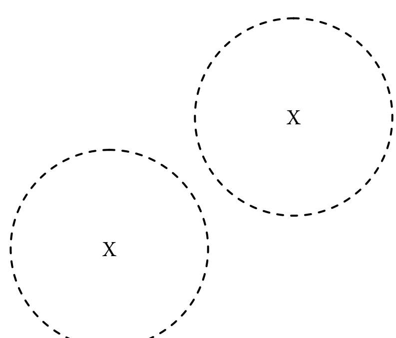


Figure 5.1 Possible shooter positions based on cartridge case location (X) and average ejection distance.

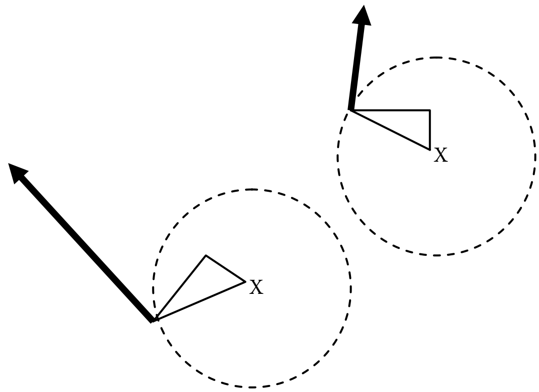


Figure 5.2 Approximate shooter positions based on locations of fired cartridge cases, bullet holes at scene, and average ejection angle and distance (assuming the weapon was fired from a certain height above ground and from an upright position).

through test firing. This is represented in Figure 5.2 in which the arrows represent the bullet trajectories and the right triangles are based upon a hypotenuse that corresponds to the average distances cartridge cases are ejected at an average angle from the plane of the breech face.

Obviously, if we are dealing with shots fired from positions that are relatively close together and/or the cartridge case locations are not representative of their actual points of coming to rest, we cannot do anything beyond making a very general statement regarding their significance; for example, "The cartridge cases were all generally located on the east side of the room, indicating a shooter toward the west side of the room."

When shots are fired and significant changes in position are involved, such as from moving vehicles, the situation becomes more complex. The ejected cartridge case locations will be dependent upon the velocities of the cartridge cases to a large degree. For example, if shots are fired from a weapon that ejects forward and the shots are fired in the direction of travel, the ejected cartridge case velocity will be the sum of the forward velocities of the vehicle and the cartridge case itself. In other words, if the vehicle is traveling forward at 55 miles per hour and the cartridge cases are ejected at 10 miles per hour, the net forward velocity is 65 miles per hour. This means that the cartridge cases will travel much farther down range than the results of static testing would predict. This scenario is illustrated in Figure 5.3. Additional considerations would include appreciable winds and cartridge case shape (a bottleneck cartridge case would have less tendency to roll than a standard cylindrical cartridge case, for example).

Admittedly, the previous example is somewhat of an oversimplification for purposes of explaining the concepts involved. A more realistic scenario

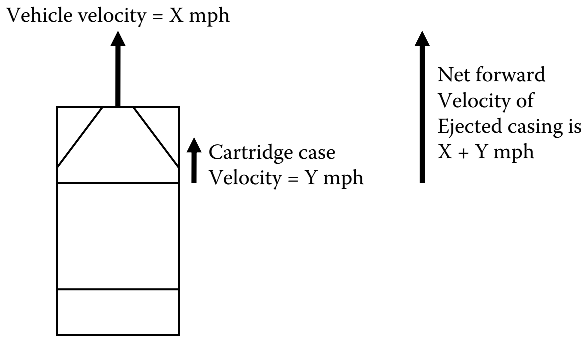


Figure 5.3 Net ejected cartridge case velocity.

would involve a weapon fired from a moving vehicle. The weapon is fired toward the side with a rearward and to-the-right ejection pattern as the vehicle moves forward. Solution of this type problem requires vector analysis. Information about how the weapon was positioned and the directionality of the shots is essential. If the forward vehicle velocity is known or can be estimated, the only remaining issue is the rearward velocity component of the ejected cartridge cases. It may be possible, in some cases, to determine cartridge case ejection velocity with a chronograph. The trick is getting the ejected cartridge cases to go through the chronograph screens. Admittedly this is a bit of a stretch from a practical standpoint, but if we can estimate the cartridge case ejection velocity, the approximate point at which the shots were fired can then be determined. The rearward velocity component is solved using trigonometry as shown in Figure 5.4.

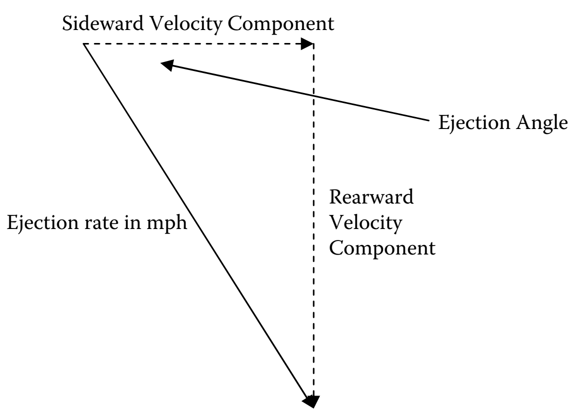


Figure 5.4 Rearward velocity component.

In any reconstruction involving cartridge case locations, substrate conditions are extremely important. There is clearly a big difference in the relevance of fired cartridge case locations to shooter position when changes in substrate type and texture and grades or inclines are involved. Thus, end results for cartridge cases ejected onto flat, grassy ground and those ejected on a steep incline of concrete are likely to show significant variation. The key aspect of using cartridge case location in any scenario is to carry out testing under similar circumstances. As noted in the earlier discussion of the use of cartridge case ejection velocity components, the value of the theoretical information that can be obtained from such calculations pales in comparison to the results of tests designed to simulate the circumstances of the shooting as nearly as possible. Simulation is sometimes impossible because of the conditions that would have to be duplicated. In those cases, testing can still provide information that can be useful in reconstructing the shooting.

How tightly a semi-automatic handgun is gripped can, in some instances, affect the recoil action of the weapon. An extremely light grip can, for example, cause the weapon to fail to eject. However, ascertaining how tightly a weapon might have been held during a shooting is obviously beyond the realm of possibility in nearly every shooting reconstruction. The net result is that a "standard" grip is applied when carrying out test firing.

The presence of various obstacles at a shooting scene (chairs, tables, vehicles, other individuals, etc.) changes everything with regard to ejected cartridge case location and predicting shooter position. The movements of various people within a scene can alter cartridge case locations and must be considered. This is especially important as the number of cartridge cases gets smaller. Thus, if only one cartridge case is present in a shooting scene, extreme caution must be exercised in applying a great deal of significance to its location. On the other hand, even what appears to be a pattern may have another explanation.

In one case involving an officer, seven cartridge cases from the officer's weapon were found on the street between the officer's car and the curb. The car was approximately 3 feet from the curb. The officer's recollection was that all the shots were fired from the area between the car and the curb. He did not recall moving during the shooting. The wounds to the defendant were such that the officer had to change positions during the shooting. The cartridge cases seemed to support the officer's recollection of events.

Test firing and cartridge case location analysis showed that what actually must have happened is that four shots were fired from the officer's original position and the remaining three shots were fired from the opposite side of the vehicle. The fired cartridge cases from the second position undoubtedly landed on the rooftop of the vehicle and then bounced off onto the street in the same area as the cartridge cases from the first position.

Methodology

The determination of cartridge case ejection patterns requires the following:

- Incident weapon
- Ammunition like that used (preferably from the same lot) in adequate quantity (at least a full magazine)
- Terrain similar to that at the shooting
- Tripod
- Two 100 foot steel tapes
- Plastic markers
- Information as to how the gun was positioned during the shooting

The tripod is used to establish a known point from which to fire. In officer-involved shootings, the officer is usually able to provide information as to his or her position when the shots were fired. Using this information, a tripod is set up to the appropriate height in the test area. The test area should conform to the terrain at the shooting scene. Otherwise, if only general patterning is being determined, a sand pit provides a surface for which little or no cartridge case bounce upon impact will be encountered.

The weapon is loaded with a full magazine and positioned using the tripod as a support that allows reproducibility of the height from which the weapon was fired. A steel tape placed on the ground provides a convenient baseline. The baseline is set up so that it is in line with the plane of the breech face of the weapon. A second steel tape is laid perpendicular to the first. This provides an easy way to reference X and Y position coordinates for each fired cartridge case. As each shot is fired, a marker is placed next to the final resting place of the cartridge case. The setup is illustrated in Figure 5.5. As an

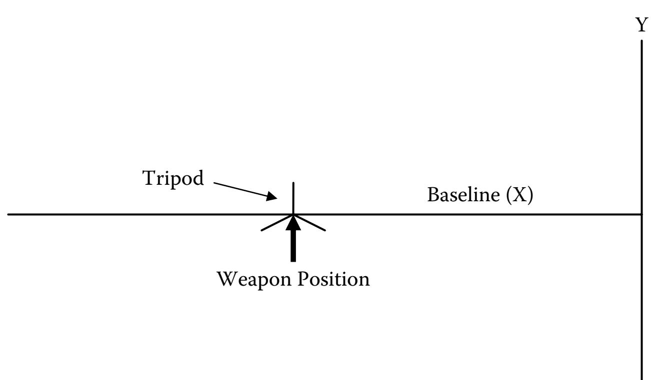


Figure 5.5 Cartridge case ejection pattern testing setup.

Shot #	X Coordinate (inches)	Y Coordinate (inches)
1	24	22
2	20	21
3	18	23
4	20	22
4	22	17
5	19	24
6	20	18
7	17	20
8	21	19
9	16	17
10	20	24

example, suppose this setup was used to test fire a 25 auto pistol and that the above data were collected for the 10 rounds fired.

The cartridge case ejection pattern is expressed in terms of the average angle to the rear (for this example) at whatever the average distance is found to be. This can be represented by a right triangle, the dimensions of which are shown in Figure 5.6.

The values for average X and average Y are determined by adding the respective columns in the table above and dividing by 10 (total number of entries):

$$\text{Average X} = 217/10 = 21.7 \text{ inches}$$

$$\text{Average Y} = 227/10 = 22.7 \text{ inches}$$

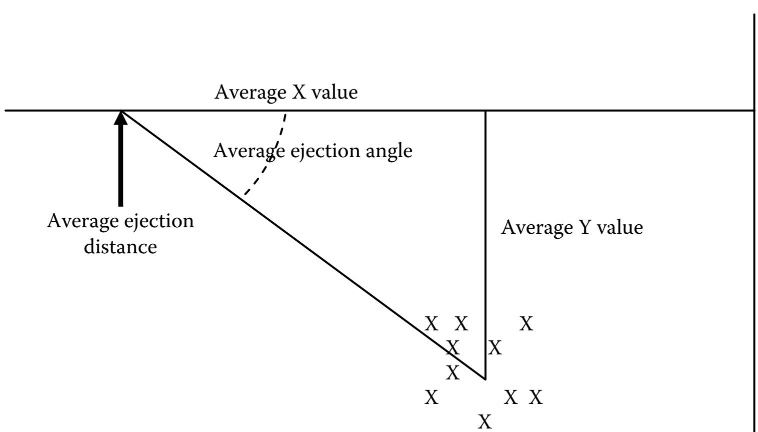


Figure 5.6 Ejection characteristic determination.

We can then solve for the average ejection distance using the Pythagorean theorem:

$$C^2 = A^2 + B^2$$

where A = average X, B = average Y, and C = the average ejection distance. Substituting terms, we get:

$$C^2 = (21.7)^2 + (22.7)^2$$

$$C^2 = 470.89 + 515.29 = 986.18$$

$$C = \text{square root of } 986.18 = 31.4 \text{ inches}$$

This means the average ejection distance is 31.4 inches. The average ejection angle can be found by taking the values for the sides of the right triangle and using one of the trigonometric functions. The sine is a convenient function to use in this example. We recall that the sine (sin) of any angle is the ratio of the length of the side opposite the angle divided by the length of the hypotenuse (the side opposite the 90-degree angle). In this case, the length of the side opposite is 22.7 inches and the length of the hypotenuse is 31.4 inches as calculated above. This means the sin of the average ejection angle = 22.7/31.4 = 0.7229. The average ejection angle is the inverse sin of 0.7229 or 46.3 degrees. The average ejection pattern then is rearward and to the right at an average angle of 46 degrees from the plane of the breech face at an average distance of approximately 31 inches.

Interpretation of Results

How do we apply this information to the cartridge case locations at a shooting scene? The answer is that we compare the average ejection characteristics to the actual locations at the scene to determine whether they are reasonably close. If not, we must explain the reason. Possible explanations include relocation of cartridge cases and shooter movement.

In summary, in order to be able to use cartridge case locations to help reconstruct shootings, we must first know that they can be relied upon. Knowing that, we must have an idea of directionality for the shots involved. We then must carry out test firing that duplicates every aspect of the incident as closely as possible. Finally, we must be careful as to how much significance we give to our findings due to the many unknowns that may be involved.

We have limited this discussion to semi-automatic weapons. It could just as easily be applied to fully automatic weapons. An added problem related to slide action weapons, bolt action, lever action, and other manually operated actions is the issue of not knowing just how vigorously the action might have been operated. This too can be tested by using soft, medium, and hard approaches or simply by using a moderate amount of force when working the action. Of course, positioning is of major concern as the action of the weapon is worked because position can directly affect where the fired cartridge cases will land.

Problems

1. A weapon is fired from the bed of a pickup truck toward the rear as the pickup travels down a dirt road at approximately 25 miles per hour. The weapon is an SKS 7.62 × 39 rifle that ejects forward. Under these conditions, will the ejected cartridge cases tend to end up closer to the point of firing or farther away?

   Answer: We must know how fast the ejected cartridge cases exited the weapon to arrive at a definite answer. The net velocity would be the difference between the forward velocity of the pickup (25 mph) and the rearward velocity of the cartridge cases exiting the weapon as it is fired to the rear.

2. At a shooting scene two separate groups of fired cartridge cases are found on the ground. It is established that they were all fired from the same weapon. What would be required in order to help reconstruct the shooting?

   Answer: Some idea of the bullet trajectories and the results of ejection pattern testing of the weapon.

3. During a shooting, several fired cartridge cases wind up on the floor inside a bar that contains numerous tables and chairs. What information can the fired cartridge case locations provide?

   Answer: Little or none due to the fact that the obstacles (chairs and tables) present would have resulted in the ejected cartridge cases striking them and bouncing off in unpredictable directions.

4. Cartridge case ejection testing shows that a particular weapon ejects the cases approximately 3 feet to the right rear of the shooter. Six cartridge cases are found within approximately 12 inches of each other. What possible position(s) could the shooter have assumed?

   Answer: Without knowing anything about the bullet trajectories, the shots could have been fired anywhere within approximately 3 feet of the center of mass of the group of fired cartridge cases.

5. Use the cartridge case position coordinates to determine the average ejection distance and average ejection angle from the plane of the breech face based on the following table.

Shot 1	X = 37 inches	Y = 30 inches
Shot 2	X = 30 inches	Y = 34 inches
Shot 3	X = 32 inches	Y = 20 inches
Shot 4	X = 29 inches	Y = 33 inches
Shot 5	X = 42 inches	Y = 29 inches
Shot 6	X = 36 inches	Y = 34 inches

Answer: First determine the average X value by adding the X coordinates and dividing the total by 6. Then do the same for the Y coordinates. This yields 34.3 inches for X and 30.0 inches for Y. Next use the Pythagorean theorem to solve for the average ejection distance (hypotenuse of the imaginary right triangle formed from the shooter's position to the center of mass of the cartridge cases). See Structure 5-1.

$$(\text{Average ejection distance})^2 = (\text{Average X})^2 + (\text{Average Y})^2 = (34.3)^2 + (30.0)^2$$

$$(\text{Average ejection distance})^2 = 1176.49 + 900.00 = 2076.49$$

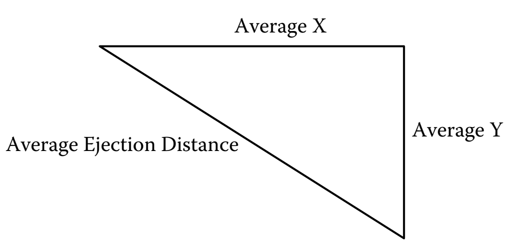
Average ejection distance = square root of 2076.49 = 45.46 inches

The average ejection angle is found by using the sin function and the values for average Y and average ejection distance:

Sin average ejection angle = average Y distance/average ejection distance

Sin average ejection angle = 30/45.46 = 0.6599

Average ejection angle = arc sin of 0.6599 = 41 degrees



Structure 5.1

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Shot Pattern Analysis and Testing

6

Smooth bore weapons were the very first types of firearms ever produced and they persist to this day, albeit in highly refined forms. Shotguns are widely used in sport shooting (trap and skeet) as well as hunting. They are made in a wide variety of configurations and designs, the most common of which are single and double barrel (over-and-under and side-by-side) types. The subject of this chapter is not shotgun operation and design, per se. It will cover the end result of the discharges of shot shells, that is, the shot pattern and its significance in shooting reconstructions involving shotguns.

The pellets fired from shotguns are of two broad categories based upon their intended targets: buckshot and bird shot. As previously discussed, buckshot pellets are designed for hunting deer and other medium to large game animals. Bird shot is designed for use on game birds ranging from quail to geese and turkeys (see Table 3.1). Law enforcement agencies that issue shotguns to their officers typically use 00 size buckshot loads. The most commonly used 00 load used in law enforcement consists of 9 pellets; 00 loads with 12 pellets are also used but not as frequently.

The Drug Enforcement Administration (DEA) has done a lot of research in order to refine the patterns produced by shotguns their agents are issued. As part of the agency's research, it found that the use of eight 00 pellets per load improves the patterns obtained. This was demonstrated to the author recently at the DEA firing range in Quantico, Virginia. It appears that use of eight pellets instead of nine produces fewer "fliers" (pellets that strike well outside the area where the majority strike). This is likely due to less pellet-to-pellet impact upon discharge and the subsequent reduction in pellet distortion. Distorted pellets are less aerodynamic and thus tend to travel erratically. Figure 6.1 depicts deformations resulting from inter-pellet collisions. The pellets were recovered from a water tank into which they were fired.

Figure 6.1 Deformation of size 00 buckshot.

When the shot pellets exit the shell upon discharge, they are close together in a column. During the course of their travel down the barrel, inter-pellet collisions occur. Upon exiting the muzzle, the pellets begin to move apart. They continue to move apart with distance, assuming a conical distribution. Ultimately, of course, the effects of gravity and air friction bring the pellets to ground.

A plastic or paper disk known as a wad or plastic shot cup (Figure 6.2) separates the powder charge from the shot within a shot shell. They travel with sufficient velocity to penetrate human tissue at close range in and of themselves. At close range, the wads often penetrate wounds and are recovered at autopsy. An officer in one of the author's shooting reconstruction classes described being hit by a shot cup at about 20 feet and said the shot cup penetrated his side. It is not uncommon for the impacts of shot cups to produce dents in vehicle body panels upon impacts at close range.

In numerous test firings with 12-gauge, 00 buckshot at shooting ranges, the author observed that shot cups and wads travel in fairly straight paths and can travel as much as 40 yards down range. Locating shot cups and wads in the field can be a challenge, however. If located, they can provide information as to gauge and manufacture. A word of caution must be given with regard to 12 gauge versus 16 gauge shot cups and wads. In some cases, 16-gauge shot cups or wads were used in 12-gauge shot shells by a manufacturer due to shortage of 12 gauge components. Thus, finding a 16-gauge shot cup or wad at a scene is not an absolute indication of the use of a 16-gauge shotgun. The reverse situation, using a 12-gauge shot cup or wad in a 16-gauge shot shell, is not feasible.

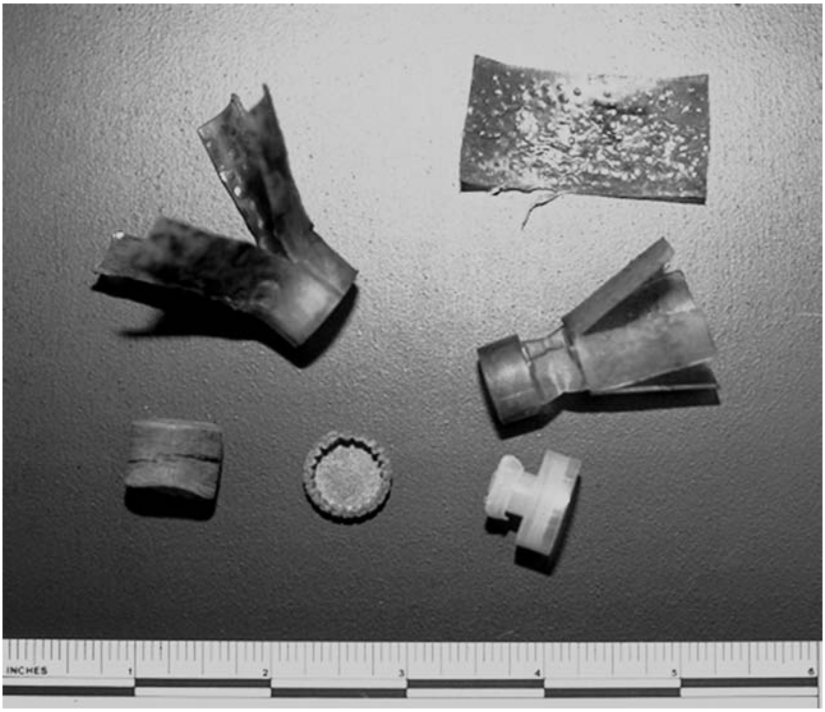

Figure 6.2 Shot shell wads and shot cups.

Approximating Muzzle-to-Target Distance

When a more or less complete pellet pattern is present on a substrate, a rough rule of thumb may be used to approximate the muzzle-to-target distance: for each inch of pellet pattern spread add approximately one yard of muzzle-to-target distance.

In other words, if we find a somewhat circular pattern of pellet holes in a door, wall, or other object, we can measure the diameter of the pellet pattern and use the 1-inch-to-1-yard rule to approximate the shooter position. However, it cannot be emphasized enough that this is only a very rough approximation that is useful for the purpose of narrowing the field of search for additional evidence of shooter position (i.e., fired shot shells, footwear impressions, trace evidence, etc.) at the scene. The reason that this rule of thumb is only a generalization is apparent when we consider all the variables associated with the diameter of a shot pellet pattern other than muzzle-to-target distance. These variables include:

Gauge
Choke
Barrel length
Pellet size

"Gauge" is an old English designation for bore diameter. It specifies the number of lead shot of that particular diameter to the pound. Accordingly, a 12-gauge shotgun barrel has a bore diameter such that 12 lead shot of that diameter would weigh 1 pound. Likewise, a 20-gauge shotgun has a bore diameter that equates to 20 lead shot to the pound. That means, of course, that the bore of a 20 gauge is significantly smaller than that of a 12 gauge. The difference in muzzle bore diameter changes the pattern produced at a given distance.

While many police riot shotguns have barrels that lack built-in constructions or "chokes," many shotguns have chokes that alter the patterns produced at given distances relative to weapons without choke (cylinder bore). A choke increases the effective distance of the pellets by keeping them together longer (i.e., decreasing the rate of spread over distance).

Barrel length can affect pellet patterns as well. We would not expect exactly the same diameter pellet pattern for a 36-inch barrel versus a 26-inch barrel, for example. Likewise, a severely shortened barrel would exhibit a different pattern as compared to the unaltered version.

Pellet size has a significant effect on the pattern obtained. One obvious explanation is that the smaller the pellet size, the greater the effect exerted by air friction. In the course of numerous range tests, the author has found that 00 buckshot approximates the 1-inch-to-1-yard rule of thumb fairly well in most instances. On the other hand, birdshot can vary fairly significantly from the 1-inch-to-1-yard rule.

This discussion has focused on straight on shots (90-degree impacts). What about shots fired from other angles? When a shotgun is fired at an angle significantly smaller than 90 degrees, the pattern typically approximates an oval in shape and the short axis of the oval is used to approximate muzzle-to-target distance based on the 1-inch-to-1-yard rule.

Although shotguns, by definition, are smooth bore weapons, barrels with rifling are available for firing slugs. The presence of rifling drastically alters pellet patterns. Figure 6.3 and Figure 6.4 show shots fired at the same distance using the same loads and same barrel lengths. Figure 6.3 shows a smooth bore; Figure 6.4 depicts a rifled bore.

The conclusion to be drawn from this discussion is, once again, that the 1-inch-to-1-yard rule is strictly an aid for an investigator to use at a scene to aid the search for other evidence of shooter position. The real answer to approximating shooter position comes from carrying out test firing the weapon and similar ammunition into material similar to the target material.

Another general rule of thumb is that all shotguns tend to produce circular holes out to about 2 feet of muzzle-to-target distance, circular holes with irregular margins between 1 and 3 feet, and circular holes with irregular margins and individual pellet holes at about 3 feet. Hole specifications must be verified through testing for each specific set of circumstances and the rule is useful only for general investigative purposes.

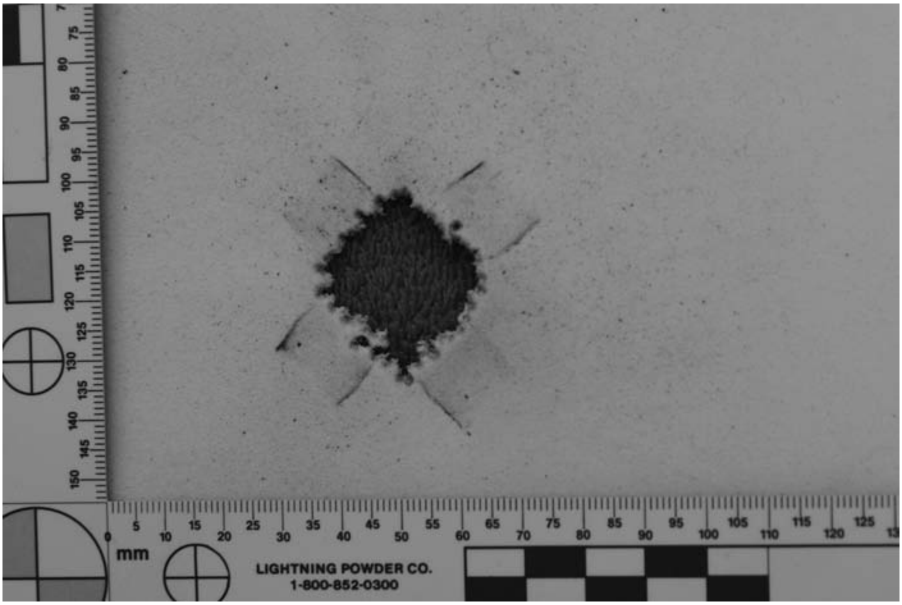

Figure 6.3 Shot with smooth bore.

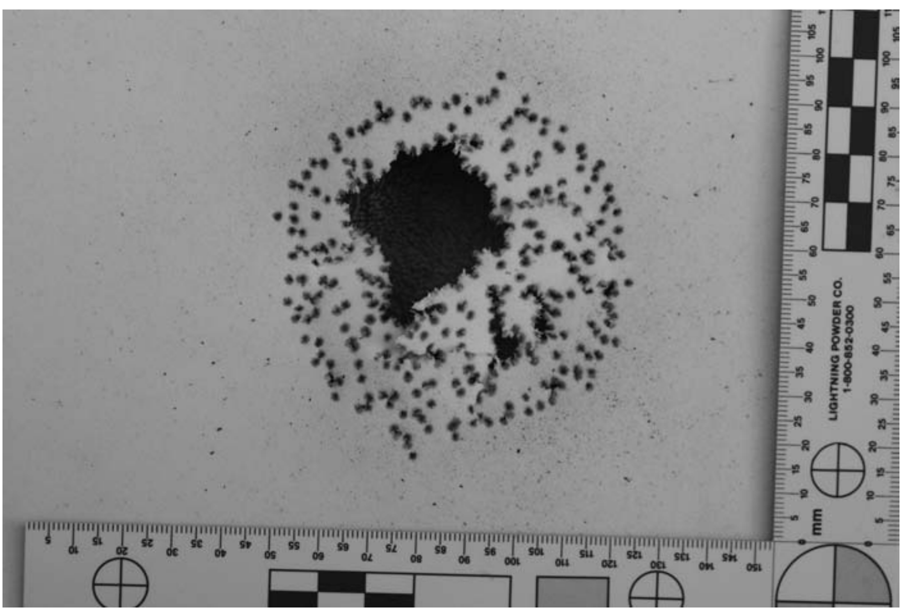

Figure 6.4 Shot with rifled bore.

An additional consideration related to approximating shot distance on the basis of pellet pattern spread relates to intermediary targets. When pellets first impact an intermediary target, the pattern "opens up." Greater shot distance than the actual distance may be estimated if the intermediary target effect is not taken into consideration. Testing must be carried out in order to assess the actual effect on pattern size for a given intermediary target.

Angle of Impact Estimation

The angle of impact for a shot pellet pattern may be determined from the axes of the overall pellet pattern. In many instances, an oval incorporating pellet impacts can usually be approximated. Sometimes fliers can be ignored. Using the short and long axes and the sin relationship, the angle of impact can be calculated as previously discussed. If a very erratic pattern is produced, other methods can be used to compare patterns. These include drawing rectangles instead of ovals around the patterns. When 00 buckshot or similar size shot has been used, the individual pellet strikes can be examined. The technique involves calculating the angles of impact for each of three different pellet holes or marks and averaging them to check the result from the overall pattern analysis.

In summary, using the short axis and the 1-inch-to-1-yard rule of thumb, we approximate the muzzle-to-target distance. By using the width-to-length ratio of the overall pattern (and/or individual pellets), we can determine the angle of impact. The combination, along with other physical evidence, allows the approximation of shooter position.

Test Firing

In carrying out shotgun pattern testing, as with any such testing, it is important to duplicate the circumstances of the shooting as nearly as possible. This means using the same shotgun with similar ammunition (same lot if possible) and the same substrate unless general patterning only is desired. A minimum of two shots should be fired from each distance to establish reproducibility.

When only general pattern testing is desired or when gunshot residue deposition (soot and/or powder stippling) is the concern, several suitable media can be used. The author has used foam board (white poster board enclosing a piece of styrofoam) as a test medium for many years. The only problem encountered is when very close range shots (closer than about 12 inches) are desired. At close range, the muzzle blast has a tendency to break apart the foam board.

During a gunshot residue analysis class the author taught in San Diego in 2003, Lance Martini of the San Diego County Sheriff's Department introduced the author to the use of Craft Paper™ as a test medium. It is a synthetic material available in sheets from hobby suppliers and craft stores. It can easily withstand muzzle blasts at near-contact distance. The Craft Paper was used for the images shown in Figure 6.1 and Figure 6.2. Shots were fired from a 12-gauge shotgun at a muzzle-to-target distance of 4 inches.

Shot Pellet Pattern Indicates Homicide

An Idaho sheriff's detective contacted the author several years ago and requested a review of a case involving a shotgun death that had been ruled a suicide. The victim was found in his basement with a shotgun blast to the chest and a second shot to the left shoulder. Both shots were similar in that they consisted of large, circular holes with several individual pellet holes around the margins.

A shotgun was found lying on top of a large box and a bicycle fork was lying on top of it with one of the axle ends against the trigger. The obvious implication was that the bicycle fork had been used to fire the weapon. However, the scene raised a number of issues. First, the shotgun could only have been held by the barrel when it was fired. Otherwise, the recoil would have caused it to fall off the box. An examination of the top of the bicycle fork and the gun barrel failed to reveal the presence of fingerprints.

More troubling, however, were the appearances of the two wounds. Both the chest wound and the wound to the left shoulder consisted of circular holes with individual pellet entries around the margins. This pattern typically appears at a muzzle-to-target distance of about 4 feet. The presence of two wounds was not a major concern because suicides do involve multiple shots from time to time. On the other hand, the locations of the wounds did not make a lot of sense considering the shotgun had to remain on top of the box for the duration of two shots.

The determination whether the shooting was a homicide or suicide required test firing of the shotgun to establish the muzzle-to-target distance as closely as possible. Foam board was used as a test medium. The first shot was fired at the distance of 4 feet as suggested by the wound appearances. Ultimately, it was determined that the approximate muzzle to target distance was 6 feet. Even with the use of a bicycle fork to depress the trigger, there was no way the decedent could have shot himself with the muzzle of a shotgun 6 feet from his chest and shoulder. The case was then reopened as a homicide.

Graphical Analysis

Rather than trying to duplicate the pattern found at a crime scene, it is usually simpler to test fire at a minimum of three distances (two shots at each distance) and prepare a graph of the results. The graph can then be used to determine

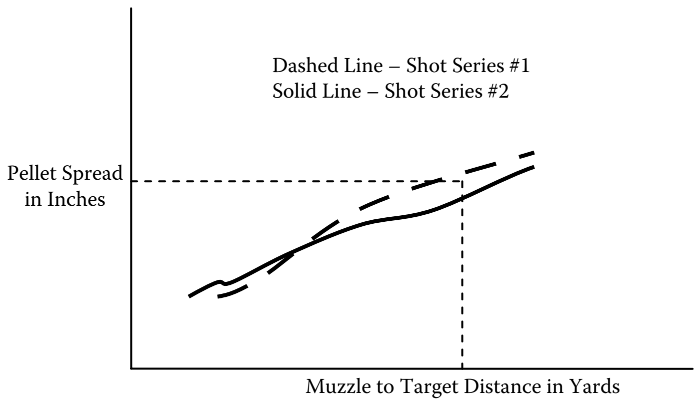

Figure 6.5 Graphic representation of shot pellet pattern.

the muzzle-to-target distance for the pattern in question. Figure 6.5 depicts an example of graphical representation. The light dashed lines represent how the graph is used to determine distance for a particular pellet pattern or estimate pellet pattern for a given distance.

Shot Shell Buffer and Distance Estimation

Certain brands and types of shot shells contain a white granular material known as buffer (Figure 6.6). Shot shell buffers are available in a number of different morphologies and may consist of either polyethylene or polypropylene.

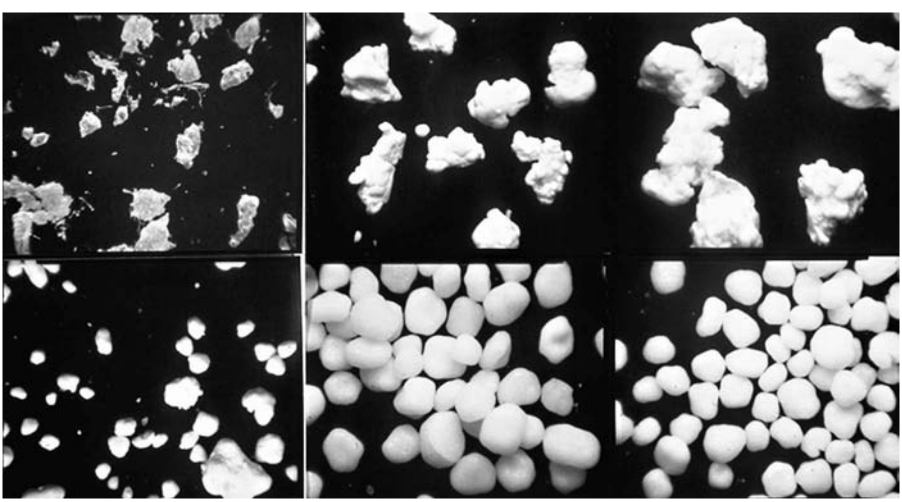

Figure 6.6 Shot shell buffers (10x).

The particular shape and formulation varies from manufacturer to manufacturer and within the product lines of particular manufacturers. As a result, some forensic significance can be attached when the material is recovered from a shooting victim's clothing or at the scene. Figure 6.6 shows some of the different morphologies.

Shot shell buffer is advertised as reducing inter-pellet collisions and consequential pellet deformation. These claims are questionable, based upon observations of numerous shots fired using buffered 00 buckshot loads. One example appeared in Figure 6.1. The presence of buffer in slug loads has another possible purpose: occupying space to prevent the slug from moving back into the shell case.

When a shot shell containing a buffer is discharged, the buffer material exits the muzzle in a conical pattern similar to exit of gunpowder particles. Over time and distance, the buffer material goes to ground due to the effects of air resistance and gravity. The horizontal distance that the buffer travels is primarily a function of the shapes, masses, and initial velocities of the particles. In any event, the distance will be finite and the buffer material would not be expected to travel beyond that certain distance. This information must be determined by testing under the circumstances of a particular case.

Buffered loads, such as Federal 00 buckshot, are frequently used by police agencies. Accordingly, an investigator should look for buffer residue in a police shooting involving a shotgun. Finding the residue can help establish shooter position and directions of shots. When buffer material is located and a suspect with buffered loads in his possession is apprehended, the determination of similar shape and composition for the buffer constitutes circumstantial evidence. A crime laboratory can easily identify the composition of the buffer using instrumental analysis.

Reporting of Results

Shot shell buffer distributions should be reported as a range, similar to the reporting of gunpowder particle test results. In the author's experience, however, a distinct pattern as usually found with gunpowder particles will not typically be found with buffer particles. The significance of finding buffer particles on clothing and other objects is more likely to be limited to allowing an investigator to be able to make a general statement regarding the distance; for example, "This is indicative of a shot being fired within the maximum distance at which buffer material would be expected to be deposited. Using the incident weapon and shot shells like that used in the shooting, this distance was determined to be between 10 and 11 yards."

In the event that an actual pattern of buffer particles is present, test firing could be carried out in the same manner as previously discussed in the section on graphical analysis of shot pellet patterns. The combination of pellet pattern testing and buffer pattern testing helps add validity to the conclusions reached as to approximate muzzle-to-target distance.

Shot Shell Buffer on Victim's Clothing

A body was found in a grassy area near a housing project. The victim sustained several circular wounds to the right side of his head and neck. He was wearing a dark-colored wool sweater. Several small granules of white material were imbedded in the fibers of the sweater. At autopsy, several lead pellets consistent with 00 buckshot were recovered. Because no observable pellet pattern was found, no muzzle-to-target approximation could be made.

A suspect was apprehended a few days later. In his possession were a sawed-off 12-gauge shotgun and several rounds of Federal 00 buckshot. Further examination showed the shot shells to contain buffer material consisting of various sized spheres. Chemical analysis of the buffer confirmed its composition as polystyrene. Using the shotgun and similar ammunition, it was determined that individual shot pellets were first distinguishable at approximately 5 yards. Microscopic examination of the buffer material from the victim's sweater showed it was consistent with the buffer present in the shells in the suspect's possession. Test firing was then carried out to establish the maximum range at which the buffer material would be deposited on a test sweater like that worn by the victim. This was done by first establishing an approximate distance using dark colored cotton twill, followed by firing into cloth panels taken from the exemplar sweater. Ultimately, it was determined that the maximum distance that buffer material would be deposited on material like that from the victim's sweater was 6 to 7 yards.

These results were used to establish an approximate muzzle to target range of 5 to 7 yards. The fact that the buffer material found on the victim's sweater was similar to that found in the suspect's shot shells provided circumstantial evidence of guilt. Based upon these findings and other evidence of involvement, the suspect was charged and later convicted of the murder.

Exercises

1. A shot pellet pattern in a door is observed to have somewhat of an oval pattern that measures 6 inches by 13 inches. For purposes of beginning a search of the scene, about how far away from the door should investigators look and in what direction?

Answer: The 1-inch-to-1-yard rule suggests a distance of approximately 6 yards (short axis of the oval equals 6 inches, 6 inches approximately equals 6 yards). The angle of impact equals the arc sin of the width (short axis) divided by the length (long axis).

2. Why must more than one shot be fired from each distance selected for shot pattern testing?

   Answer: Because pellet patterns vary slightly at a given distance, more than one shot should be fired and an average taken.

3. If a measurable pattern is found on a victim's clothing in a shotgun shooting, how should testing be carried out?

   Answer: A minimum of two shots at each of three different ranges are fired and a graph of the results constructed. Using the graph, the approximate muzzle-to-target distance may be ascertained.

4. What forensic significance can be attached to shot shell buffer material?

   Answer: Chemical analysis can be used to relate evidence to suspect ammunition and an estimate of distance for the shot can be facilitated by the presence of buffer material at the scene or on a victim.

5. What is the 1-inch-to-1-yard rule of thumb and how is it applied?

   Answer: Each inch of pellet spread approximates one yard of muzzle-to-target distance. This distance provides a starting point for searching for additional evidence of shooter position in a shotgun shooting. It most closely approximates muzzle-to-target distance for buckshot and generally shows greater variation for bird shot.

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7

Examination and Testing of Weapons and Ammunition Components

Shooting reconstruction frequently involves examination and testing of weapons and ammunition components. The examination focuses on the recognition and documentation of trace evidence to assist in the reconstruction. Testing parameters include determination of functioning, accuracy, rate of fire, and ejection patterns as discussed earlier.

Trace Evidence Examination

A wide variety of trace evidence may be present on firearms and ammunition components as a result of their use in shootings. Trace evidence may include one or more of the following:

- Hairs and fibers
- Glass particles
- Blood and tissue
- Fingerprints
- Gunshot residue
- Scratches and gouges

Hairs and fibers are examples of transitory evidence that can easily be lost in the recovery, packaging, and transport of firearms and ammunition components. For this reason, it is extremely important that this evidence be visually inspected at the shooting scene and appropriate steps be taken to preserve it. If these precautions are not taken, the evidence may wind up in the bottom of an evidence bag and the examiner who receives the firearm or ammunition component never realizes other evidence is present.

The nose cavities of hollow point bullets are particularly likely to retain trace evidence of all types. In some instances, the debris is present in layers that provide a history of the progression of a bullet through various substrates. Questions about shot order can sometimes be answered by the presence of this material. For example, if two shots have been fired through a vehicle side window and the glass collapsed after the first shot, the presence of glass particles in the nose of only one bullet provides the answer as to which of the two bullets was fired first.

Bullets found at a scene can provide information about suspects. In one case involving the author, a homeowner shot at a burglar and the bullet passed through the burglar's clothing and was found on the floor by investigators. The burglar fled the scene. A suspect was later arrested. Two holes were found in his pant leg. Examination of the bullet revealed fibers embedded in the nose (Figure 7.1). Laboratory analysis showed the fibers from the bullet were consistent with fibers from the suspect's pants. This finding helped convict the suspect of breaking and entering.

When blood or tissue is present on firearms and ammunition components, DNA analysis can identify the source. Blood or tissue on bullets can be used to identify suspects who were shot and fled a scene. It can also be used to determine whether a bullet passed through an individual. On weapons, blood or tissue can provide information as to shot distance as discussed in Chapter 10. DNA technology has advanced to the point where merely

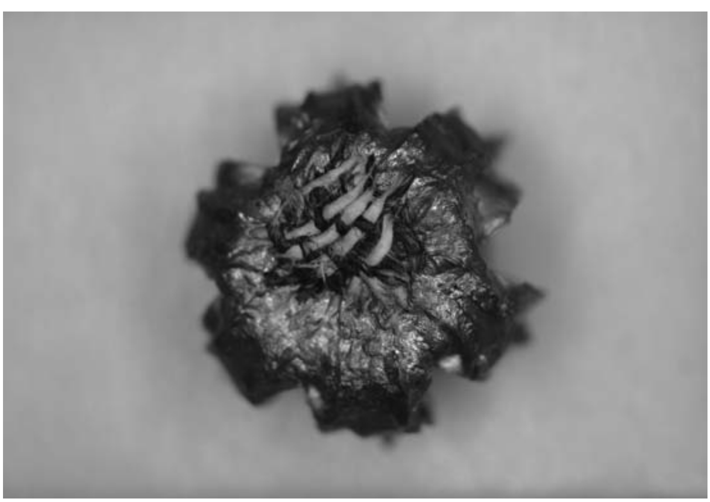

Figure 7.1 Fibers embedded in nose of bullet.

handling of weapons and ammunition can provide sufficient DNA for identification purposes. Swabs of weapons (triggers, stocks, grips, etc.) are taken and used for this analysis.

Fingerprints are, contrary to television and the movies, elusive when deposited on firearms and ammunition components. It is the author's experience that identifiable fingerprints are found in fewer than 5% of the cases involving firearms examined to determine their presence. The number is even smaller for ammunition components, particularly fired cartridge cases. A ploy sometimes attempted by a defense attorney is to use the fact that his or her client's fingerprints were not found on a weapon or ammunition as an indication of innocence. A statement by Herb McDonnel of Corning, New York states the problem clearly: "Absence of evidence is not evidence of absence."

The surfaces of many firearms are simply not conducive to retaining fingerprints. Even if the surfaces do retain fingerprints, the manner in which most weapons are handled precludes the deposition of identifiable prints. The heat resulting from discharge vaporizes fingerprint residues left on most cartridge cases. Additionally, the sizes and round shapes of cartridge cases do not readily lend themselves to the retention of identifiable fingerprints.

On the other hand, it should never be presumed that fingerprints are not present on ammunition and weapons. The failure to examine and test these items is a crucial error. The principle should be that "one test is worth a thousand excuses." From time to time identifiable fingerprints are found on weapons and even on fired cartridge cases. The only definitive way to determine their presence is to carry out testing.

Fingerprints on a Firearm Tell a Story

In a double homicide in Northern Arizona several years ago, the new owners of a truck stop were found shot to death. The cook claimed that he was outside emptying the trash when he heard several loud "bangs." He said he then entered the truck stop to find the owners, a man and his wife, shot to death. As he looked out the front window of the establishment, he saw two young males driving away in a red pickup. He then called 911 and reported the shootings and provided descriptions of the vehicle and occupants.

A short time, later authorities arrested two suspects and began interrogating them. While the two admitted driving by the truck stop, they adamantly insisted they never pulled in, much less shot the owners. As the interrogations continued, crime scene investigators discovered a 380 semiautomatic pistol under some rocks in the rear of the truck stop. The weapon was submitted to the crime laboratory for examination and comparison to the bullets removed from the victims.

A visual examination of the pistol failed to reveal any physical evidence. The weapon was fumed with superglue in an effort to locate any possible latent prints. The superglue produced a single print on the left side of the slide. This print was photographed and then lifted for later comparison.

The pistol was then test fired and the fired bullets and cartridge cases were then compared to the bullets recovered at autopsy and the cartridge cases found at the scene. The pistol was identified as the murder weapon. A comparison of the latent print found on the pistol to those of the two suspects resulted in their elimination. A comparison to the cook's fingerprints, however, resulted in identification. Ultimately, the cook was charged with the murders and convicted at trial.

Function Testing

Function testing is a standard part of the protocol in a firearms-related incident. It is surprising how frequently this important step is ignored, especially in so-called obvious cases (apparent suicides and officer-involved shootings). Regardless of the type of case, if a firearm is involved, it should be ascertained that the firearm functions properly. This is, of course, a role performed by firearms examiners or police armorers.

Function testing includes not only establishing that a weapon will fire as designed, but also involves establishing trigger pull, checking for modifications, examining for malfunctions, checking for broken or missing parts, and determining other evidence related to functioning. Trigger pull, in particular, can play into a shooting reconstruction. An extremely light trigger pull, for, example, can possibly explain the unintentional firing of a weapon. Excessive trigger pull, on the other hand, can help refute a claim of unintentional firing.

A Case of Unintentional Firing Corroborated by Trigger Pull Testing

A young high school coach and his girl friend had been arguing at night. The next morning the argument resumed and was even more heated. According to the young man, when his girlfriend moved toward the night stand where his revolver was kept, he rolled across the bed and grabbed it first. He then stood up with the weapon in his right hand down at his side. The two continued to exchange words when she suddenly grabbed an iron off the ironing board nearby and swung it toward his head.

The man stated that as she started to swing the iron at him, he raised both hands to ward off the blow. As the iron made contact with the gun, he stated that he "flinched" and this caused the gun to go off. The bullet struck her in the right side of the head, passing through her left side and lodging in the wall behind her.

The weapon was a Smith & Wesson 41 Magnum revolver. The man said the weapon was not cocked when the shooting took place. At first glance, this did not seem very plausible because the weapon would have required double action to have been fired and the trigger pull for double action would be expected to be in the 12- to 14-pound range. Examination of the weapon revealed that it had been modified and the double-action trigger pull was only $3^1/_2$ pounds. A trigger pull that light could have resulted in the unintentional firing the man described.

The iron provided further evidence that supported his version of events. An area of dark residue on the right side of the iron was consistent with soot. That would have been the area in contact with the muzzle of the revolver when it discharged. Additionally, high velocity impact blood spatter found on the iron was not found on the handle. If the woman was holding the iron as the man claimed, no blood should have been present on the handle. The soot deposit is shown in Figure 7.2 and the blood spatter appears in Figure 7.3.

At trial, the prosecutor went to great lengths to trivialize the significance of the physical evidence. The jury either did not understand its significance or simply chose to ignore it and convicted the man of second degree murder.

In the author's many years of function testing of weapons, defendants' stories of accidental firing of weapons were corroborated by function testing in only a few cases. Most frequently, a defendant who states that a "gun just went off" is simply indulging in wishful thinking in an effort to somehow shift responsibility. In every case, however, every possible effort must be made to

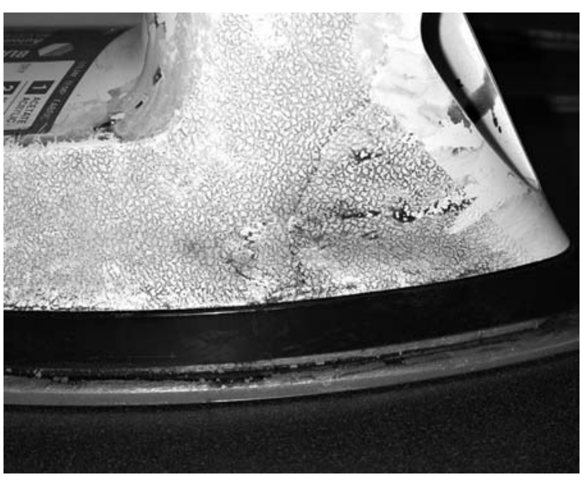

Figure 7.2 Soot on iron.

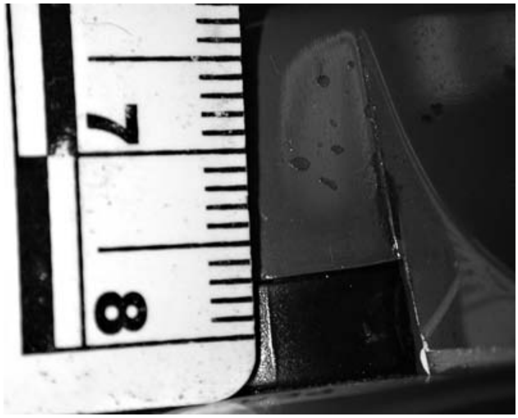

Figure 7.3 High velocity impact spatter on iron.

determine whether there is any feasible way that the shooting could have happened as a result of mechanical malfunction or other circumstance represented by the defendant.

Testing, when done appropriately and thoroughly, can substantiate the presence of mechanical factors that must be taken into consideration. Simply cycling the action of a weapon a few times and deeming it operable is not adequate. Tests that simulate the reported circumstances of the shooting as closely as possible must be conducted. If the weapon was dropped, drop tests must be conducted. If the weapon allegedly fired due to striking of the hammer by some other object, appropriate tests are required.

Function Testing Corroborates Defendants' Stories

Case 1

In a shotgun shooting incident, the defendant claimed that he and the victim had been struggling over a shotgun. He said that his right hand was on the forearm of the weapon when the victim grabbed the barrel and yanked it forward, causing the defendant's right hand to slide across the hammer. The defendant stated that he did not have his finger on the trigger and that the gun discharged only as a result of the hammer coming back partially and falling.

Function testing focused on whether the weapon would discharge in the manner described by the defendant. A shot shell was cut open and the pellets and powder charge removed. The remaining primed case was inserted into the chamber and then the hammer brought back partially and allowed to fall. The weapon was found to fire as evidenced by the discharge of the primer. Based upon this testing, the defendant's story could not be refuted.

Case 2

A biker and his "momma" were stopped on the side of the road taking a rest stop. The biker claimed he took out his 25 semi-automatic pistol to shoot at a beer can. When he did, he said the pistol slipped out of his hand, hit a rock and discharged. The bullet struck the female in the chest and killed her.

A drop test was conducted to determine whether the pistol would discharge as a result of being dropped. The test was conducted by inserting a primed case into the chamber and dropping the weapon butt first from the approximate height the biker described. The weapon discharged the third time it was dropped. The fact that it would discharge at all under these conditions was adequate evidence to support the biker's story.

Firearms Function Test Refutes Defendant's Account

A police officer claimed that her weapon, a Glock 9-mm semi-automatic pistol, had discharged after a door struck the muzzle as she held the pistol. The bullet passed through the door, striking the resident and killing her. The officer had responded to a burglar alarm call and was unaware that the home owner had also been called and arrived at the scene first. Apparently an open back door was responsible for the alarm. It appeared that the home owner was closing the door from the inside as the officer approached from outside.

Several considerations are apparent in analyzing the situation. First, the simple physics of the event, as described by the officer, were wrong. If the officer had her finger on the trigger and the muzzle of the gun was subjected to impact, her trigger finger would have been forced forward, not backward. Second, if the muzzle of her semi-automatic pistol had been struck by the door, the slide would likely have been moved rearward, taking the weapon out of battery and making it unfireable. Finally, if the muzzle of the weapon had been against or near the door upon discharge, a soot deposit should have been left on the door (none was found).

A reenactment using a similar door and weapon loaded with a primed case was conducted. The weapon was held parallel to the ground with a finger on the trigger exerting enough pressure to take up the free travel ("slack"). The door was then repeatedly slammed against the muzzle without discharge. The weapon was then loaded with a live round and fired at near-contact distance. A heavy soot deposit was produced on the target medium.

When the officer was presented with the test results, she admitted that she had fired her weapon as a result of being startled when the door suddenly moved and said the door had never struck her gun. Unfortunately for the officer, this change in stories constituted grounds for dismissal and left the police agency liable for civil action.

Accuracy Determination

Accuracy determination may be required as part of the analysis and reconstruction of a shooting incident. This is particularly true in cases involving weapons with telescopic sights fired at long range, but it can also be an issue with other weapons and in situations involving relatively close ranges. One of the arguments to accepting Lee Harvey Oswald as the lone gunman in the assassination of President John F. Kennedy relates to the fact that the scope on the rifle allegedly used by Oswald had a misaligned scope. If it could have been confirmed that the scope was misaligned prior to the shooting, either Oswald would have had to have been extremely lucky or another shooter was involved. No such confirmation was ever made.

Accuracy determination is a mechanical assessment only and has nothing to do with establishing the abilities of a suspected shooter. It would be foolhardy indeed to attempt to have a suspect demonstrate his or her shooting skills or lack thereof. Johnnie Cochran's famous trial quote, "If the glove don't fit, you must acquit," is the phrase that comes to mind. By limiting testing to the weapon itself, the investigator can at least determine the capability of the weapon under the circumstances of the shooting. Whether a defendant was capable of using that weapon to carry out the shooting must usually be left up to the jury.

Accuracy determinations are usually best carried out by placing the weapon in a machine rest and using a remote trigger release device. In this way, the human factor is virtually eliminated. Such rests are available for both handguns and long guns. The weapon is set up in the rest and a suitable target is placed in a position that approximates the distance of the incident shot or shots. A minimum of three shots should be fired from each distance involved. The group spread is noted and recorded.

It may not be necessary to actually fire a weapon to establish accuracy. In a case in which the author was requested to determine the accuracy of a 22 caliber rifle fitted with a scope, it was possible to merely remove the bolt and insert a laser into the bore. Since the shot in question had been fired from a distance of approximately 50 feet, a target could be set up and the laser beam set on the center of the target. With this done and the rifle set up in a machine rest, all that was required to establish accuracy was to look through the scope. In this instance, the cross-hairs of the scope coincided with the laser dot set at the center of the target. Thus, it was determined that the scope was properly aligned.

Physical limitations can certainly play into the analysis of a shooting incident. If a person has limited vision, for example, the feasibility of intentionally firing a shot at someone at a significant distance and under low light conditions is certainly questionable. Other physical limitations, such as limited use of either hand, can be factors and must be considered as well. These aspects are beyond the scope of the investigator alone and require the expertise of appropriate medical professionals.

Rate of Fire Determination

Rate of fire data for fully automatic weapons can be obtained from manufacturers and other sources. Rates of fire for non-automatic weapons must be established through testing. However, the results obtained are clearly dependent on the physical capabilities of the individual carrying out the test. In other words, such testing is by nature subjective. Conversely, asking a defendant to demonstrate how rapidly he or she can fire a particular weapon and expecting reliable results would be a stretch.

If it is necessary to establish the rate of fire of a non-automatic weapon, one method is to carry out a series of timed firings by more than one individual, then compare and average the results. While this method clearly does not eliminate the subjectivity, the results are probably acceptable for use in analyzing most shootings involving questions about the feasibility of firing a certain number of shots within a given time frame.

A Question of Number of Shots Fired

A moving vehicle is fired upon and the driver shot dead. Evidence indicates two additional shots were fired. A suspect is arrested and a semi-automatic 22 caliber rifle is seized. The shooter had a limited view that would have required rapid firing and rapid re-acquisition of the moving target. The question to be answered was whether three shots could have been fired at the vehicle during the time it was in view. To answer this question, the first step was determining how rapidly the weapon could be fired. Once this was established, knowing how long the vehicle was in view of the shooter permitted determination as to the number of shots that likely could have been fired.

The testing was conducted in an indoor range with the weapon shouldered; the magazine contained 10 rounds. Firing commenced upon the start of a timer and continued until all 10 rounds had been fired. Three individuals were involved in the testing, each of whom fired 10 rounds three times. The results of all the firings were then averaged. Based upon this test, it was determined that four shots could have been fired within the time the vehicle was in view. Since only three shots were in question, the testing resolved the issue.

In reporting the results of rate of fire determination, care must be exercised to not over-extend the meaning of test results. If the rate of fire was determined to be, say, 3.8 shots per second and the question was whether four shots could have been fired, it is recommended that the result be rounded down. In other words, in the interest of conservatism, 3.8 shots per second should be reported as 3 shots per second. This conservative approach is based upon the inherent subjectivity of the testing.

Exercises

1. Why do identifiable fingerprints seldom appear on firearms?

   Answer: The surfaces that are typically handled on firearms do not lend themselves to retention of fingerprints and the manner in which firearms are usually handled is not conducive to leaving complete fingerprints.

2. What sort of trace evidence left on a firearm other than fingerprints could be used to identify the individual who handled the firearm?

   Answer: DNA can be detected on a firearm and used to identify its handler.

3. When should trigger pull testing be conducted?

   Answer: Trigger pull testing should be a routine part of weapons function testing.

4. Why is accuracy determination limited to the mechanical aspects of the weapon only and no consideration given to shooter skill?

   Answer: There is no objective way to assess shooter skill, based on the vested interest of the shooter.

5. A vehicle presents a visible target for approximately 8 seconds. A suspect with a bolt action rifle is arrested. Testing indicates a maximum rate of fire of 1.5 rounds per second. Could the shooter have fired six shots into the vehicle within the time frame the target was visible?

   Answer: The rate of fire is multiplied by the available time to determine the maximum number of shots possible: 1.5 shots per second × 8 seconds = 12 shots possible. Therefore, 6 shots were certainly possible.

Suggested Readings

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Gunshot Residue Testing

8

Gunshot Residue Sources

The gunshot residue (GSR) term can be used to mean different things. This is somewhat understandable because GSR actually includes a number of different components including:

- Primer residue
- Gunpowder particles (partially burned and unburned)
- Stabilizers
- Plasticizers
- Combustion products

The presence of some or all of these components permits an investigator to make certain statements regarding the probability of firing a weapon, a presence in close proximity to a weapon that was fired or handling a weapon, and approximate muzzle-to-target distance.

Primer Residues and Shooter Determination

Primers are responsible for initiating the combustion of a powder charge in a cartridge or shot shell. In metallic cartridges, the priming mixture is found either in the annular rim (rim fire cartridges) or in a cup seated in a recess in the head of the cartridge case (center fire cartridges). Shot shells also utilize center fire primers. Most primers consist of mixtures of compounds containing lead (Pb), barium (Ba), and antimony (Sb). Notable exceptions are the

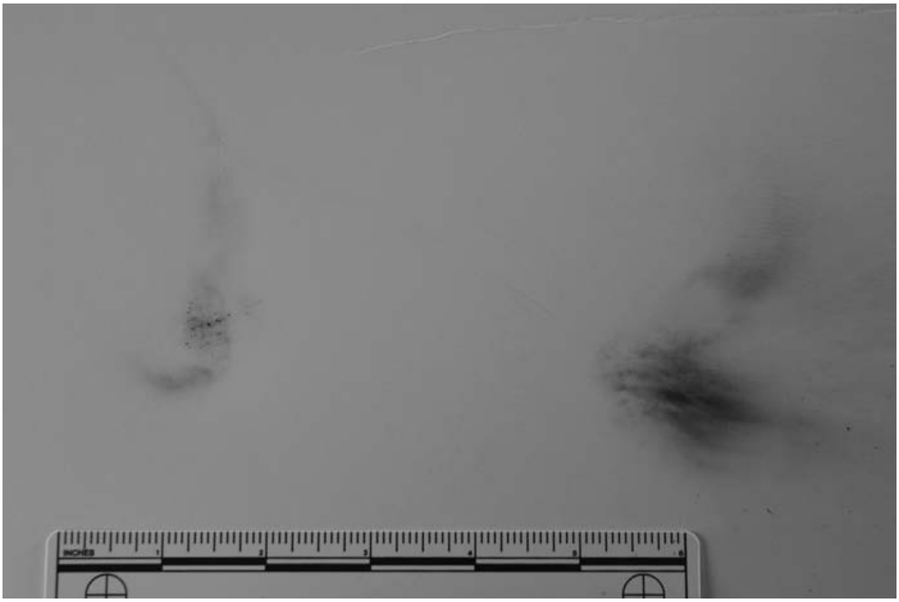

Figure 8.1 Gunshot residue resulting from discharge of a revolver. (Left–cylinder gap; right–muzzle).

lead-free primers that are gaining popularity based on health and environmental concerns. If lead-free primers are known or suspected to have been used, the laboratory needs to have that information. Ammunition that contains lead-free primers is available from a number of manufacturers including Blount Industries (CCI), Federal, Winchester, and Remington.

When a firearm is discharged, primer residues and other components of GSR will emanate from the muzzle, the breech and/or the cylinder gap, depending on the type of weapon. The production of GSR produced by a revolver discharge is shown in Figure 8.1.

The components of primer residue produce a plume that can be deposited on the hands of a shooter or anything else within close proximity. Historically, sampling for primer residues has been limited to the palms and backs of a suspected shooter's hands. Since a plume of these residues is produced, it is reasonable to assume that they might also be deposited on other areas of the shooter's body, such as the face. Anyone who has ever used fingerprint powder or sprayed paint in a confined space has experienced the deposition of residue within the nostrils and on the face. Thus, including the face, facial hair, and surfaces inside the nostrils may be a consideration when sampling a suspect for GSR.

In any event, finding primer residues on a suspect must not be construed to mean that the suspect fired a weapon as opposed to merely being in close proximity when a weapon was discharged or handling a weapon that had residues. Suppose an officer drew his weapon during an arrest, re-holstered the weapon, and then handcuffed the suspect. Could the officer have gotten primer residues on his hands by handling his weapon and then transferred the residues to the suspect during the handcuffing? Theoretically the answer must be yes. It is a widely accepted fact that handling a weapon can result in the transfer of residue from the gun to the hands. Likewise, a transfer can occur from contacts between two surfaces.

For purposes of reconstructing a shooting, one must be careful in concluding that an individual fired a gun as opposed to any of the other scenarios presented. The distinction between homicide and suicide is sometimes attempted based upon the presence or absence of primer residues. The fallacy lies in the fact that primer residues on the hands of a victim could have resulted from being shot just as easily as by firing a weapon.

An additional problem relates to the sampling technique typically used. The method of choice for conducting primer residue analysis is scanning electron microscopy (SEM) coupled with x-ray fluorescence spectroscopy. Confirmation that a particle has originated from the sampling is accomplished with small aluminum disks with adhesive sides. The disks (stubs) are repeatedly pressed against the skin of the hands in an effort to transfer any residue from the hands to the disks via the adhesive. During sampling, it is often difficult to distinguish where the palm stops and the back of the hand starts. Thus, a sample collected from a palm may include residues from the back of the hand and vice versa.

The laboratory analysis of gunshot (primer) residue is best accomplished using computer-controlled scanning electron microscopy (CCSEM). This technique allows definitive results to be obtained through the relatively rapid examination of thousands of particles. As previously suggested, consideration should be given to sampling the eyebrows and any other facial hair.

Some laboratories, due to equipment cost considerations, rely on flameless atomic absorption (FAA) spectroscopy for the analysis of primer residues. This technique is less specific and prone to inconclusive results. Since this was the method that most laboratories initially implemented, gunshot or primer residue testing developed a poor reputation in many areas of the country. Some investigators and even entire agencies stopped using FAA spectroscopy as a result. This disparity in confidence has yet to be totally resolved.

An in-depth discussion of the analytical techniques is beyond the scope of this text. Interested persons should refer to any of a number of excellent reference works on the subject. An Internet search will also provide additional information.

For purposes of shooting reconstruction, our interest is in applying the results to the question at hand. An understanding of the capabilities and the limitations of this evidence is essential, however. As already noted, sampling is not a definitive process for the most part. Another problem relates to time elapsed between discharge of the weapon and sampling. It is generally accepted that primer residues do not persist beyond about 4 hours of "normal activity." That timeframe can be extended through the sensitivity available with modern CCSEM equipment. Ten to twelve hours of activity is the generally accepted upper limit for collecting samples for CCSEM testing.

On the other hand, the sensitivity of CCSEM brings with it some questions. If the technique can locate and identify one or two so-called unique particles (spherical particles containing lead, antimony, and barium), the sources of these particles must be questioned. The example of transfer of residue from the hands of an officer to a suspect during arrest comes to mind again. All these issues are tied to the distrust that some agencies have in CCSEM results.

The use of CCSEM involves the location and identification of particles that are either considered characteristic of or unique to primer residue. These particles are mostly spherical and in the 1- to 10-micron range in size, but non-spheroidal particles are not uncommon. The categories of characteristic and unique particles are as follows.

Particles Considered "Characteristic" of GSR

Lead–antimony (Pb–Sb)
Lead–barium (Pb–Ba)
Antimony–barium (Sb–Ba)
Antimony (Sb)
Barium (Ba)
Barium–calcium–silicon (Ba–Ca–Si) with trace of sulfur (S)

Particles Considered "Unique" to GSR

Lead–barium–antimony (Pb–Ba–Sb) in a single particle

The results of CCSEM typically include a listing of the numbers of particles of each particular composition. Only the presence of particles containing lead, barium, and antimony is considered conclusive with regard to the presence of primer residue. Most laboratories require the identification of at least three such particles. Some laboratories will report confirmation of primer residue on the basis of locating and identifying a single unique particle.

What must be kept in the forefront is deciding when testing is important (i.e., when it should be used). It should be apparent from our discussion of all the various considerations that primer testing is inappropriate for victims of gunshots and cannot distinguish between homicide and suicide. So when would it be appropriate? It is appropriate when an individual of interest has no reason whatsoever to have primer residue present on his or her person.

Case 1: Gunshot Residue Testing Solves Crime

Two young male college students shared an apartment in the early 1980s in Arizona. Each had his own bedroom. One evening one of the men called authorities and reported that his roommate had apparently committed suicide. Officers arrived to find the dead man on the floor of his bedroom with a revolver lying at his side.

Upon questioning, the reporting student stated that he had been in his own room studying when he heard a loud noise. He went to his roommate's closed door, called out, and then entered to find the man lying on the floor. He said he then went straight to the telephone in the living room and called for help; he also said that he did not touch the dead man because of the obviously mortal head wound.

The investigator asked the man how much time elapsed from the time he heard the loud noise until he actually entered the dead man's bedroom. His answer was several minutes. The investigator then asked whether the man touched the gun and he stated that he had not. When the investigator asked the man whether he fired a weapon any time that day prior to the shooting, the man again said no. Finally, the investigator asked whether he had handled any weapons or was near any weapons fired that day. Again the answers were negative. After the man answered no to questions about proximity to weapons, the investigator said he wanted to have a GSR test performed.

The results of GSR testing on samples taken from the palms and backs of both hands by scanning electron microscopy indicated the presence of numerous unique particles consisting of lead, antimony and barium. The laboratory report stated that the particles were "indicative of having fired a weapon, been in close proximity to a weapon being fired, or having handled a weapon." Since the investigator's questions eliminated all possibilities except that the man fired the fatal shot, the GSR testing result was of considerable value to the case. When confronted with the evidence, the man finally confessed to murdering his roommate.

Case 2: Gunshot Residue Testing Inappropriately Applied

Police in a rural community in West Virginia respond to a call from a husband who claims he came home to find his wife shot to death. The woman is found lying on the floor just outside their bedroom with a devastating wound to the forehead that clearly was produced by a shotgun.

A shotgun is found on the floor nearby. Blood and tissue on the walls and ceiling indicate the woman was standing upright when shot.

Several "red flags" enter the investigator's mind immediately. First, women shoot themselves in the head very infrequently. Second, he found no apparent means for her to have reached the trigger to fire the gun and hit her forehead. The shooting appeared to the investigator to be the result of foul play. In an effort to settle the question of homicide versus suicide, he asked the crime scene officers to take samples from the woman's hands for GSR testing. This request was ill-advised at best. Since the woman was the victim of a gunshot injury, the presence of GSR on her body would be expected. On the other hand, not finding residue would not prove anything. Like negative evidence, "absence of evidence is not evidence of absence."

In this particular case, conducting the test was inappropriate and the interpretation of the results was inappropriate as well. The results were positive as expected. However, the investigator interpreted the standard reporting verbiage ("indicative of firing a weapon, being in close proximity to a weapon during discharge or handling a weapon") as an indication of suicide. While GSR testing alone cannot exclude suicide, it in no way promotes it.

Ultimately, the husband was determined to have been responsible, although he claimed the shooting was unintentional and that he had panicked. If anyone should have been tested for GSR in this case, it should have been the husband, particularly since he claimed to have been elsewhere during the shooting. The confusion that resulted by testing the woman was unnecessary and could have been avoided by following the general rule that victims of shootings need not be tested.

One question that frequently arises is whether anything but primer residue could produce positive test results. Certainly lead, barium, and antimony have numerous environmental sources along with various sources associated with manufactured products and pyrotechnics (see Table 8.1). This is why

Table 8.1 Sources of Lead, Barium, and Antimony

Particle Material and Symbol	Melting Point (Degrees C)	Sources
Lead (Pb)	327	Batteries, solders, bearing metals, bullets, shot, paints, cable coverings, glass, matches, dyes, shielding, pyrotechnics
Barium (Ba)	850	Tin, copper, lead, and zinc alloys, radiography, inks, leather tanning, photographic chemicals, insecticides, paper products, pyrotechnics
Antimony (Sb)	440	Hardening alloys, Babbitt metals, paint pigments, safety matches, bearings, pewter, brake pads, pyrotechnics

FAA analysis is not the method of choice for analyzing test samples. It cannot distinguish non-firearms sources from firearms sources.

Some caution must be exercised in the interpretation of positive results for primer residue even with SEM. William Matty, in an article published in the *AFTE Journal* in January 1991, described finding spherical lead particles on test specimens that were produced by the impacts of lead bullets with a vehicle. These particles at first appeared to be primer-based lead.

In summary, the identification of primer residues, when applied under appropriate circumstances, is a reliable and scientifically sound analytical technique that can assist the investigator in the reconstruction of a shooting. The results obtained must, however, be taken within the context in which they have been reported: indicative of possibly firing a weapon, being in close proximity to the discharge of a weapon, or having handled a weapon. Other possible sources of cross-transfer must also be considered.

Muzzle-to-Target Distance Approximation Testing: Inanimate Objects

Competitive shooters typically fire ammunition of their own making (hand loads) so that they can maximize the performance for the particular distance they are shooting and the specific barrel length. Commercial ammunition, on the other hand, must accommodate a wide range of conditions and weapons. Manufacturers incorporate more than enough gunpowder to ensure that bullets will be propelled from barrels ranging from 2 to 30 inches long, for example. The bottom line is that the inclusion of more than enough gunpowder for all typical situations means not all the gunpowder will be consumed during discharge.

Unburned and partially burned gunpowder particles will exit a muzzle in a conical distribution upon firing (Figure 8.2). Persons and/or objects within a few feet of the muzzle will be struck by these particles. In some instances, powder particles can travel unexpected distances. Gunpowder particles can also sometimes pass through various objects such as fabric or

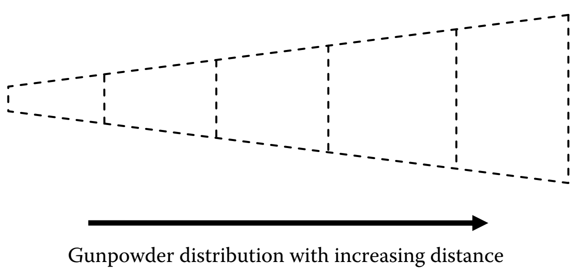

Figure 8.2 Distribution of gunpowder particles.

Figure 8.3 Infrared photography of fabric containing gunpowder particles.

human tissue before coming to rest. Figure 8.3 is a group of infrared photographs of material containing gunpowder particles.

The horizontal distances traveled by gunpowder particles depend to a large extent on the morphologies or shapes of the particles and their masses. Handgun powder is found in spherical (ball), flattened ball, and disk or flake configurations. Rifle powder also includes tubular configurations. Black powder and substitutes such as Pyrodex™ have irregular shapes.

As with any object in motion, two forces act upon gunpowder particles in flight: gravity and air friction. Both forces work to slow down and "pull down" the particles. The greater the mass and the more aerodynamic the shape of the particle, the greater the horizontal distance that would be traveled (for the same initial velocity). A good analogy is comparing the distances that a person could throw a volley ball and a Frisbee. Thus, we could expect ball powder to travel the farthest of the various powder shapes. In the author's experience, individual grains of ball powder can sometimes travel about 20 feet from a muzzle.

As a general rule, if a person is within arm's length or nearer the muzzle of a firearm, we should consider the possibility of finding gunpowder particles on the clothing and/or skin of the person. The estimation of muzzle-to-target distance involves carrying out test firings at measured distances in order to establish a range of distances into which the evidence falls. The presence of intermediary targets (pillows, clothing, doors, windows, hair, etc.), physical contact, or other activity (shaking, rubbing, washing, etc.) can prevent powder deposition or dislodge particles after initial deposit.

Articles of clothing and other inanimate objects must be carefully examined microscopically for the presence of visible powder particles. One useful method for documenting their presence is to use a clear plastic overlay sheet and use a marker pen to note locations and other data about all powder particles found. This results in a record of locations, pattern shapes, and densities prior to chemical testing. A comparison can then be made between the visual results and the results of chemical testing. It is not uncommon for chemical testing to reveal the presence of powder residue that was not microscopically visible. It is also possible for powder particles to be visible and not respond to chemical testing. This is particularly true when blood is present.

The combination of blood and dark material can make location of powder particles difficult. One option is to use infrared film to photograph the area of interest. The infrared film frequently allows powder particles to appear dark against a light background. This provides an alternative to the tedious process of using a clear plastic overlay to manually mark each particle as previously described. Figure 8.3 presents an example of the use of infrared photography of gunpowder particles on a dark garment with blood present.

Chemical testing involves determination of the presence of nitrites (the combustion products of nitrates [gunpowders]) and lead residues from primers and/or bullets. The Griess test or some modification thereof is most often used to determine nitrites. The testing is done in a laboratory. A firearms examiner or criminalist carries out testing on the evidence and then on test panels. Testing is done using the same weapon and ammunition like that used in the shooting under investigation. A typical result obtained for a test panel is shown in Figure 8.4.

The presence of vaporous and particulate lead on inanimate targets provides additional insight into the approximate muzzle-to-target distance. Vaporous lead may be contributed by a primer, a bullet, or the interior surface of a gun barrel contaminated with lead. Particulate lead originates from bullets and contaminated barrels. The typical test used to determine vaporous and particulate lead is the sodium rhodizonate chemical test normally conducted in a laboratory environment. Vaporous lead is indicative of a relatively close range shot, the approximate distance of which must be established through the same kind of testing regimen as for the nitrite test.

A word of caution is in order concerning visual comparisons of residues and distance assessments at shooting scenes. Different brands of ammunition can produce markedly different residue patterns for the same weapon fired at the same distance. This can be seen in Figure 8.5. Unless an

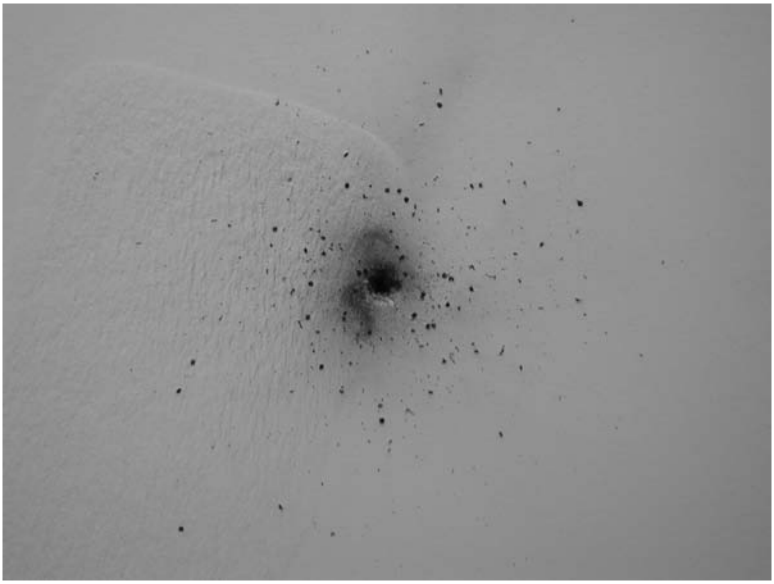

Figure 8.4 Test panel used for approximating muzzle-to-target distance.

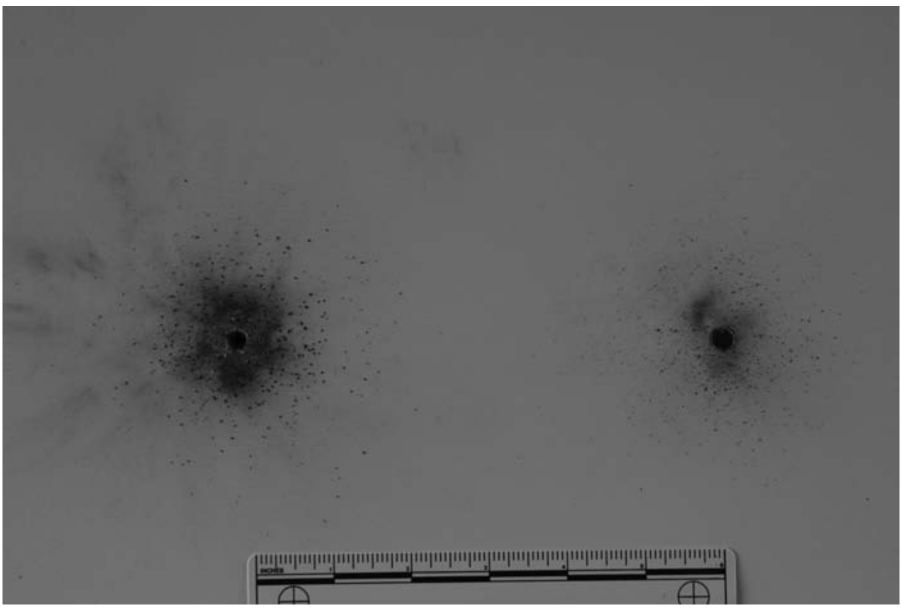

Figure 8.5 Two shots fired from same weapon at same distance with different brands of ammunition.

investigator is certain that the same brand of ammunition was used for all shots producing visible residues, he should be cautious about presuming one shot was fired at a different distance from another shot without additional information.

In the author's experience, particulate lead is a nonreproducible phenomenon with regard to pattern and distribution. Testing associated with past casework has shown widely varying and contradictory results. Some close shots produced patterns of particulate lead of greater diameter than shots farther away and vice versa. For that reason, it is recommended that attempting to relate shot distance to a pattern of particulate lead be avoided. It is reasonable, however, to base some approximation of the maximum possible muzzle-to-target distance on the presence of particulate lead in certain cases. The sodium rhodizonate test identifies particulate lead as a pinpoint response as opposed to a cloud or haze representing the vaporous lead response. For the specific details of the sodium rhodizonate test and the various forms of the Griess test, the reader is encouraged to consult one of the many excellent references on the subject.

If at all possible, testing should include panels taken from the evidence garment or object since different surface textures, thicknesses, and other factors can have significant effects on the deposition patterns obtained. If this is not feasible, a similar material may be substituted. If only a limited amount of evidence material is available, the initial test firing can be done using 12-inch squares of white cotton twill. Once an approximate muzzle-to-target distance range has been established, a panel from the evidence may be used to confirm the results obtained with the cotton twill.

As with primer residue analysis, the shooting reconstructionist will consider and utilize the results of muzzle-to-target distance approximation testing. When no patterns of residue are found on items of evidence or in the complete absence of residue, it is only possible to establish a maximum range for residue deposition. For example, suppose a victim's shirt is tested and no gunpowder particles are found. Assuming that gunpowder particles were not originally present and were later dislodged or that no intervening target blocked the particles, the conclusion would be that the muzzle of the incident firearm was beyond the distance at which gunpowder particles would be able to travel. The weapon, ammunition, and target material would then be used to establish the maximum distance.

If gunpowder particles are identified and no identifiable pattern is present, all that can be said is that the shot was within the maximum distance at which that weapon and ammunition combination would be expected to leave gunpowder particles under the conditions of the shooting. Again, this distance would have to be established through test firing.

Collection of Gunshot Residue from Fixed Inanimate Objects

Gunshot residue can and should be located and lifted from fixed inanimate objects such as windshield glass, vehicle body panels, building doors, walls, and other structures. The procedure for collecting gunshot residue from objects such as vehicle glass, vehicle exterior and interior surfaces, doors, and walls is the same as the transfer method used for garments. The procedure relies upon the greater affinity of gunshot residue for a damp piece of filter paper than for whatever substrate on which it was originally deposited. Obviously, this procedure will have varying degrees of effectiveness. In some situations, it does not work very well, for example, on a substrate composed of a bulky, loosely knit material. One should make no presumptions, however, because "one test is worth a thousand excuses."

Procedure

Visually inspect the area around a bullet hole for the presence of GSR using a hand lens.

1. Make note of any possible GSR observed. Moisten a piece of filter paper of sufficient diameter to cover the area of interest (suitable paper diameters range from about 4 to 18 inches) by spraying it from a bottle of 5% nitric acid (distilled water can be substituted if necessary). The paper should be damp but not dripping wet.
2. Press the damp filter paper against the surface to be tested, using a rubber fingerprint roller to apply pressure and smooth any raised areas. As an alternative, use gloved hands to press out the filter paper. The paper should be marked to designate its orientation on the object tested.
3. After allowing a few seconds for contact, carefully peel the paper off the object and place the paper in a safe place, contact side up, to air-dry for transport back to the laboratory.

In the event that the test paper will be submitted to a laboratory or shipped elsewhere, it should be taped contact side up in a shallow box (such as a pizza box). A second piece of filter paper should then be taped on top of the test sheet (after the test sheet is dried) to ensure that GSR particles are not lost in handling.

The test paper may be tested according to the Griess test procedures for nitrates and the sodium rhodizonate procedures for lead residues. Patterns of nitrates obtained are then compared to test firings from measured distances using the weapon and ammunition components like those involved in the case. Positive sodium rhodizonate responses for lead are compared to known samples. From these tests, an approximate muzzle-to-target distance may be determined.

Muzzle-to-Target Distance Approximation Testing: Human Tissue

Gunpowder particles exit a muzzle at a high rate of speed. These particles are hot even to the extent of being on fire as a result of discharge. When the particles strike the skin, they can penetrate the skin, produce a bruise, or cause a burn. The result appears as a series of dark spots (stippling) around the margins of the wound. The density and pattern diameter of powder stippling provide means for approximating muzzle-to-target distance.

Typically, laboratory analysts work with forensic pathologists and rely upon one another in approximating muzzle-to-target distance where a pattern of powder stippling has been produced. The pathologist measures and photographs the stippling pattern and the firearms examiner or criminalist carries out test firing in order to make an approximation of the range of the shot involved.

A suitable medium must be selected for recording test stippling patterns at various distances. Over the years, various media utilized ranged from painted ceiling tiles to pig skin in attempts to duplicate the stippling effect using something other than human tissue. The author used foam board for this purpose for many years. Foam board consists of a thin sheet of Styrofoam sandwiched between two sheets of poster board. Foam board is sold in office supply and craft stores, mainly for use in making poster presentations. The marking or indenting of the surface of the foam board by powder particles can be equated to the production of stippling. Test results in numerous cases the author has been involved in have shown foam board to produce reasonable representations.

As already discussed in the section on shotgun pattern testing, Craft Paper is preferable at close ranges where muzzle blast is a concern due to the fact that it will not break apart as foam board will. Again, the assumption is that the marking or indentation of the Craft Paper by a powder particle is the equivalent of stippling. Examples of stippling on human skin, a foam board test panel and a Craft Paper test panel appear in Figure 8.6, Figure 8.7, and Figure 8.8, respectively.

Stippling patterns and soot residue pattern shapes can provide information as to the orientation of a weapon at the time of discharge. Circular patterns indicate a more or less straight-on shot as seen in Figure 8.9, while angular shots are exemplified by elliptical patterns. Additionally, contact and near-contact shots can produce soot patterns that define the orientations of

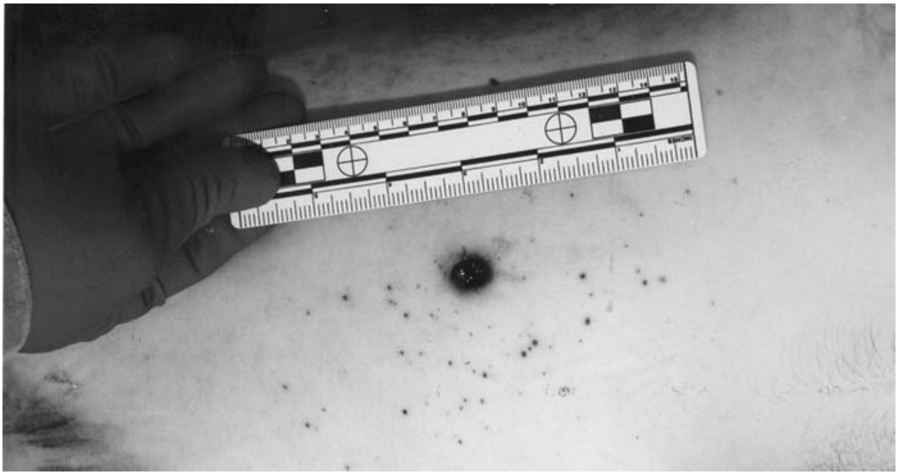

Figure 8.6 Powder stippling on human skin.

some semi-automatic hand guns. The gap between the slide and the frame and the opening in the slide for the recoil spring rod allow soot to exit and be deposited on nearby surfaces. This is illustrated in Figure 8.10.

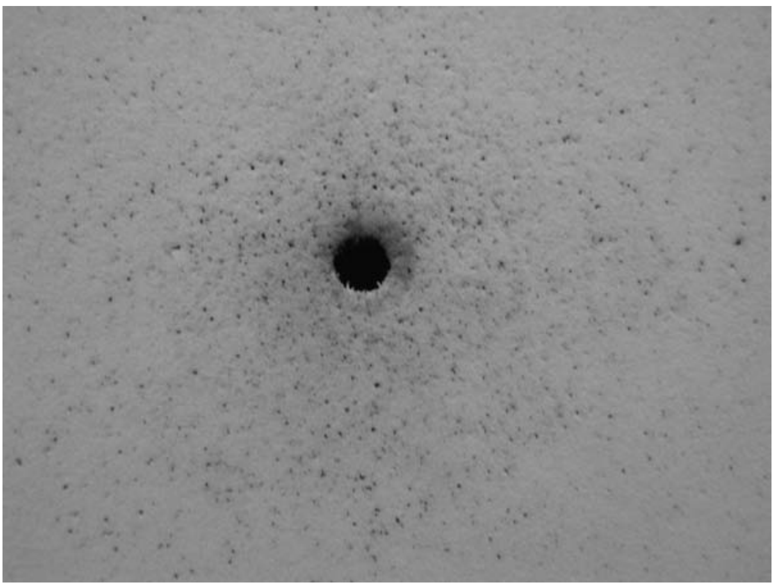

Figure 8.7 Foam board test panel for simulating stippling of human skin.

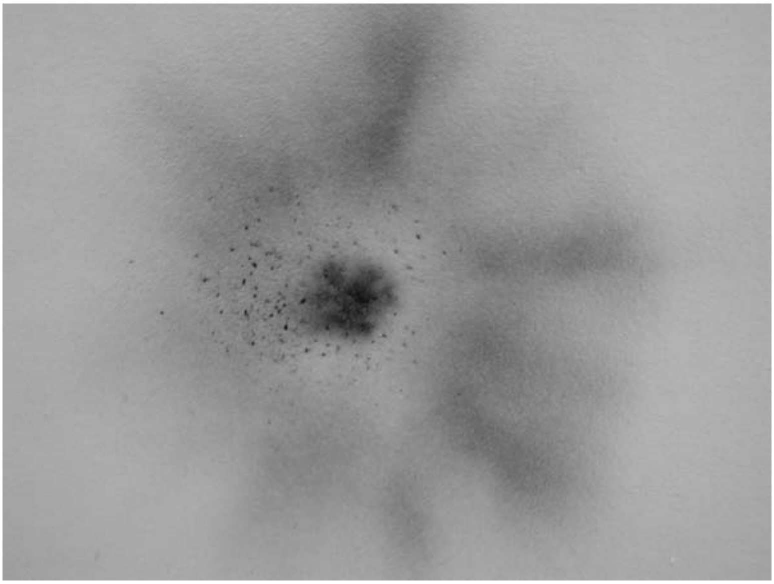

Figure 8.8 Craft Paper test panel for simulating stippling of human skin.

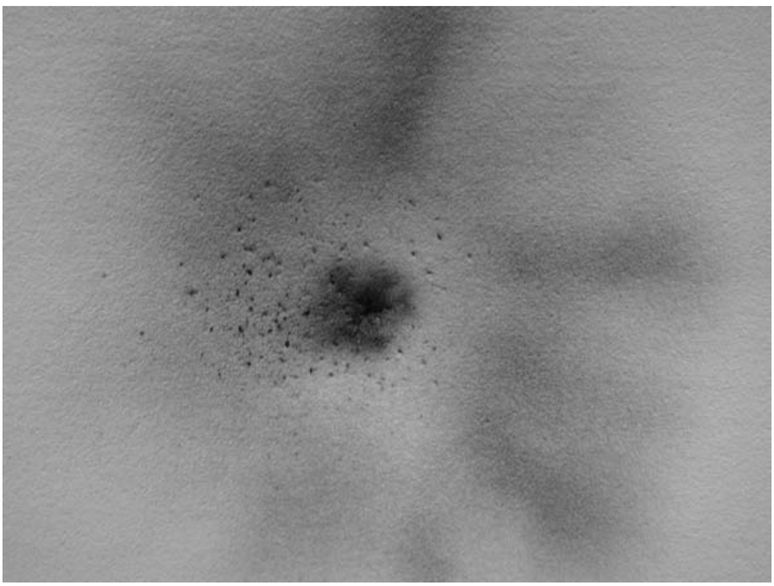

Figure 8.9 Gunshot residue pattern for straight-on shot.

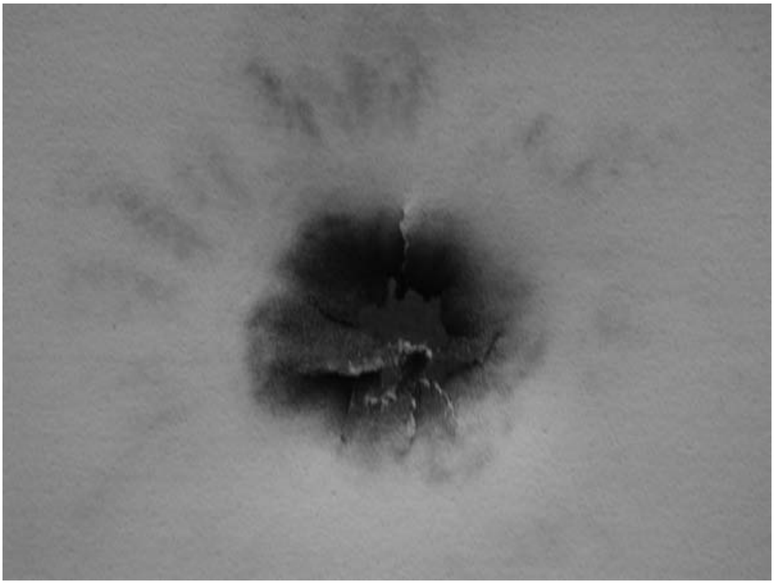

Figure 8.10 Soot deposit from semiautomatic hand gun fired at close range.

Stippling Discredits Officer's Version of Shooting

An officer responding to a domestic disturbance call in an upscale neighborhood during the noon hour exited her patrol unit and she and her partner knocked on the front door. They were greeted by the homeowner who exited the residence and came out to the front porch to speak with the officers. The man was highly agitated and began to curse loudly; he demanded that the officers leave. The female officer took a position to the left rear of the man while her partner stood directly in front of him. As the man started to move toward the officer in front of him, the officer began commanding him to halt. When the man failed to comply, the officer kicked him in the mid-section. The man doubled over momentarily and then resumed moving toward the officer, ignoring additional verbal commands.

The officer then attempted to kick the man in the left knee but lost his balance and fell to the ground. As he fell, he drew his weapon. The officer pointed the weapon at the man from a sitting position on the ground below the man. The man then grabbed the officer's weapon by the barrel. At this point, the female officer said she struck the man in the head with her pistol, causing it to discharge. The bullet entered the back of the man's neck just below the base of the skull, penetrated the brain stem and killed the man instantly.

In reviewing the case, police investigators found the officer's statement as to how the shooting had taken place inconsistent with the physical evidence. According to the autopsy report, an elliptical stippling pattern was found around the wound to the back of the man's neck. This pattern was oriented from 9 o'clock to 3 o'clock, with the majority of the stippling toward the 3 o'clock position. The pattern measured approximately 2 inches by 3 inches. Laboratory testing indicated a muzzle-to-target distance of approximately 8 to 10 inches. This simply did not comport with the officer's story that the discharge resulted from impact of the weapon with the decedent's head. After confrontation with the evidence, the officer admitted that she unintentionally discharged the weapon as a result of having been startled.

Paraffin Test

The reaction of diphenyl amine with nitrate-containing compounds to produce a blue color was developed into a test for the presence of gunpowder on the hands of suspected shooters years ago. The test involved the pouring of melted paraffin over the hands of the individual to be tested. After solidifying, the paraffin was peeled off and subjected to a solution containing diphenyl amine. Any nitrates present reacted by turning deep blue. The test quickly fell out of use because of the many sources of nitrates in the environment that could have led to false positive responses. Modern testing procedures using adhesive-faced aluminum disks and computer controlled scanning electron microscopy have already been described.

New techniques that appear to be based on the old diphenyl amine reaction are available. The old arguments about the reliability of the older paraffin test must again be raised with the newest version. Another concern is the possibility that the paraffin test may preclude subsequent testing by CCSEM. While claims have been made to the contrary, they have yet to be substantiated by reliable sources with no vested interests. The best policy is, without a doubt, to use only proven, scientifically reliable testing and avoid forensic equivalents of get-rich-quick schemes.

Determination of Time since Discharge

A long term goal of shooting incident investigators has been to devise a scientifically valid method for estimating the time since discharge of weapons, cartridge cases and shot shells, that is, a scientific means of verifying the proverbial smoking gun. Obviously, the ability to determine whether a discharge was recent could significantly assist in the reconstruction of a shooting incident.

Andrasko and Stahling of the Swedish National Laboratory of Forensic Science, in a paper published in the *Journal of the American Academy of Forensic Sciences* in 1999, presented a method for estimation of time since discharge of fired cartridge cases. The method is based upon sampling the atmosphere inside a cartridge case and analyzing the samples for the presence of naphthalene or an unidentified chemical designated TEA2-compound. Their article followed a 1998 paper published in the same journal concerning a study of shotguns for time since discharge using the same technique. The studies indicated that it is possible to analyze the atmosphere within shotgun barrels, cartridge cases, and shot shells and estimate the time since discharge. The studies indicated that naphthalene and TEA2-compound persist for only a few weeks. Thus, positive results indicate that discharge occurred within several weeks as opposed to several months. Cartridge cases and shot shells left exposed to the elements were found to lose the components of interest much more rapidly.

The analytical procedure is not widely used beyond Sweden and has not been verified or generally accepted by the U.S. forensic community at this juncture. It does, however, appear promising as a means for acquiring useful information related to certain types of shooting incidents.

Case Study

A 43-year old man who lived alone on a ranch was found shot to death in his bedroom after officers responded to a 911 call from the residence by a voice stating "Send help, I've just accidentally shot myself." The man was found on the floor with a single-action revolver nearby. The telephone was off the cradle and lying on a nightstand. The man was dressed in a pair of jeans with no shirt. A bullet entry wound was observed in his lower right chest and a bullet exit wound was present in his lower right back.

A bullet hole was found in the bedroom ceiling above the location of the body. Four bloodstains were present around the hole in the ceiling. A bullet was ultimately recovered from the attic crawl space.

At autopsy, the pathologist noted and sketched linear soot deposits in the palms of both hands (Figure 8.11) and stippling on the inside of the right arm. A 6-inch pattern of powder stippling surrounded the chest wound.

The firearm was a 45 caliber Ruger New Model Blackhawk (Figure 8.12) belonging to the victim. The chamber contained two fired cartridge cases, one of which was under the hammer. A laboratory examination determined that the weapon was in working order and had a trigger pull of approximately $3^1/_2$ pounds. Blood and tissue adhered to the bullet found in the ceiling. DNA analysis showed the materials were consistent with the victim's DNA.

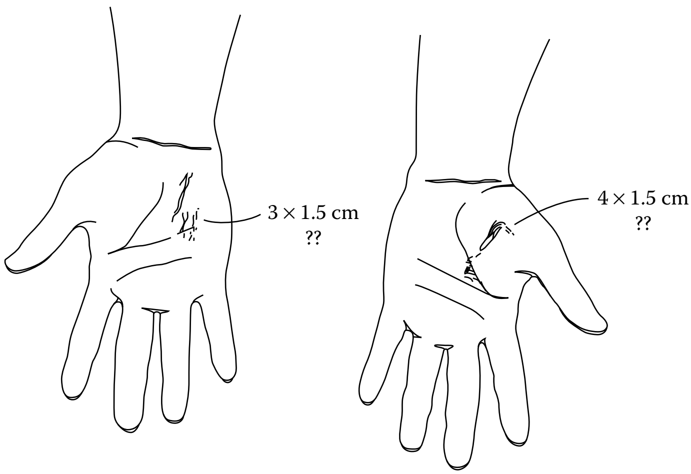

Figure 8.11 Soot deposits in palms of both hands.

The Ruger New Model Blackhawk has a transfer bar safety system that allows it to fire only when the hammer is fully cocked and the trigger is fully depressed. This system will not allow the weapon to fire as a result of a blow to the hammer or being dropped.

The presence of two fired cartridge cases in the cylinder raised a question whether one or two shots were fired. The answer was found by examining the face of the cylinder and noting only one "fresh" cylinder halo or flare at the chamber beneath the hammer. Apparently, the empty round was carried

Figure 8.12 The weapon.

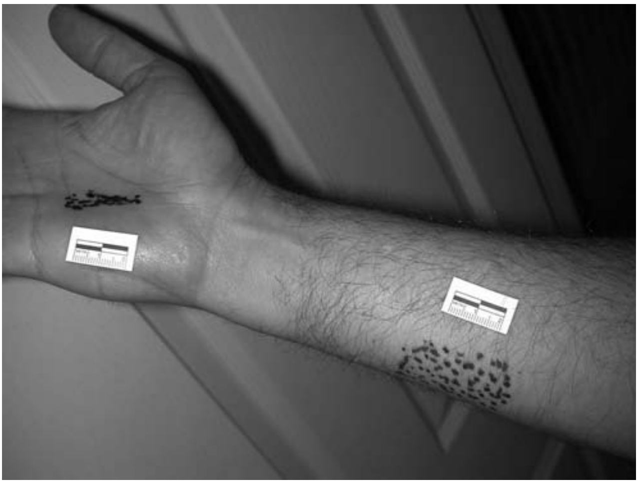

Figure 8.13 Soot and powder on right palm and arm.

as a safety precaution under the hammer even though the transfer bar safety system was totally sufficient. When the weapon was cocked, the fired cartridge case rotated to the right and a live round was then under the hammer.

The obvious question is whether the shooting was accidental as claimed in the 911 call or was it a suicide set up to look like an accident? To answer this question, additional testing and a reenactment were required. The presence of linear soot deposits in the palms of the victim's hands gave a clear indication that his hands were placed on both sides of the weapon at the time of discharge. The powder stippling on the inside of his right arm suggested that the muzzle was close by his right arm at the time of discharge. The author used a marker pen to recreate the soot and stippling pattern on the right palm and arm according to the measurements provided by the pathologist (Figure 8.13). A similar approach was used for the palm of the left hand (Figure 8.14). Using the linear soot deposits in the palm as a guide, the weapon was grasped with both hands. The stippling pattern on the inside of the right arm was found to line up with the muzzle of the weapon (Figure 8.15).

The next step was to carry out test firing to determine the approximate muzzle-to-target distance required to produce the 6-inch stippling pattern on the man's lower right chest. Using the weapon and ammunition like that remaining in the weapon, shots were fired into white foam board at measured distances. Based upon the results, the approximate muzzle-to-target distance was determined to be 12 to 24 inches. The trajectory of the bullet through the body appeared to be downward. The autopsy report indicated no impacts

Figure 8.14 Soot deposit on left palm.

with bone. The bullet hole in the ceiling meant the bullet traveled upward. This meant that the victim was bent over at the waist and/or stooped over when the shot was fired.

In order to assess the likelihood of suicide, it was necessary to examine the man's personal, financial, and medical history. This investigation revealed no possible motive for suicide. The location of the wound and the trajectory of the shot through the body were not suggestive of suicide. How could the

Figure 8.15 Position of weapon.

shot be accidental if the hammer had to be fully cocked and the trigger pulled in order to fire?

The man was involved in the popular sport of cowboy shooting competition. Thus, it was easy to imagine that he might have been practicing fast draws. The fact that he did so with a loaded weapon obviously violated all firearms safety considerations. Nonetheless, he had an apparent reason for "playing" with a loaded gun.

Testing was conducted with the unloaded gun to see whether it could be fired with the force of one or both forefingers and that was determined easily. Finally, a reenactment was conducted to determine the feasibility of holding the gun in the palms of both hands with the barrel pointed toward the person holding it and leaning forward until the butt of the gun made contact with the floor. With knees bent in a stooping position and the torso bent forward at the waist, the gun butt touched the floor. Carrying out this scenario in a fairly rapid manner, it was found that the forefingers could easily move forward and depress the trigger with enough force to fire the weapon. This indicated that there was a mechanism by which the shooting could have been unintentional. While it certainly could not be said that the reenactment duplicated exactly what happened, the absence of any evidence to the contrary made it a very probable explanation.

Exercises

1. Which one of the following is not a component of GSR?
   a. Gunpowder
   b. Soot
   c. Vaporous lead
   d. Nitric acid

2. What substrate properties are best suited to preparing test firings for stippling ?
   a. Glass
   b. Plastic
   c. Foam board or Craft Paper
   d. Wood

3. What produces stippling?
   a. Partially burned gunpowder
   b. Unburned gunpowder
   c. Lead vapor
   d. Both a and b

4. What is the method to use for lifting gunshot residue from a vehicle windshield?
   a. Gel lifting
   b. Adhesive lifting
   c. Transfer to moistened chemical filter paper
   d. Tape lifting

5. What should be done to preserve gunshot residue lifts for lab submission?
   a. Place in sheet protector
   b. Air dry and place face up in a shallow box
   c. Photograph
   d. Both a and b

6. What should be done with bloody garments with bullet holes?
   a. Discard them
   b. Cut out the area of the hole and submit for testing
   c. Air dry and package in paper
   d. Place in an airtight plastic container

7. How do crime scene investigators best locate gunshot residue?
   a. Using a magnifying glass
   b. Visually
   c. With a magnet
   d. Using a tape lifter

8. Assuming the materials listed below all have the same initial velocity, which travels the farthest?
   a. Particulate lead
   b. Gunpowder particles
   c. Soot
   d. Vaporous lead

9. What force(s) act on gunpowder particles in flight?
   a. Gravity
   b. Air friction
   c. Surface tension
   d. Both a and b

10. How is muzzle-to-target distance expressed?
    a. As a range
    b. As an approximation
    c. As an exact distance
    d. Plus or minus a few feet

11. How should articles of clothing suspected of holding gunshot residue be packaged?
    a. Separately and in paper
    b. Together in paper
    c. Together in plastic
    d. Separately in plastic

12. What type of gunpowder would probably travel the farthest if they all had the same initial velocity?
    a. Sphere or ball
    b. Flattened ball
    c. Flake
    d. Tubular shape

13. What is the general rule for finding a pattern of gunshot residue?
    a. Within arm's length
    b. Nearer than 12 inches
    c. Nearer than 6 inches
    d. Nearer than 3 inches

14. Individual particles of ball powder might be found as far as _____ away.
    a. 20 feet
    b. 6 feet
    c. 1 foot
    d. 3 feet

15. What is the value of photographs of stippling patterns on bodies?
    a. They are useless for comparison purposes
    b. They are very valuable for testing and/or comparison purposes
    c. They are more important for illustration purposes than anything else
    d. They reveal the type of powder used

Answers: 1-d, 2-c, 3-d, 4-c, 5-d, 6-c, 7-a, 8-a, 9-d, 10-a, 11-a, 12-a, 13-a, 14-a, 15-b.

Suggested Readings

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9

Bullet Hole and Wound Characteristics

Bullet Holes in Clothing and Underlying Tissue

It is important for a scene investigator to have an understanding of bullet holes in inanimate objects and the ways their appearances are affected by changes in muzzle-to-target distance and changes in ammunition. Such knowledge allows the investigator to recognize certain characteristics associated with close range shots as opposed to distance shots, for example. This information can be vital when assessing a scene for other evidence of shooter position. Likewise, it is important to be able to recognize the general characteristics of bullet wounds related to distances of shots.

For purposes of our discussion we will follow the conventions recognized and used by many forensic pathologists when describing muzzle-to-target distance. The contact/near contact, intermediate, and distant shots comprise the range of delineations that we will discuss. We will not try to distinguish between hard and loose or soft contacts. The *contact/near contact* phrase will be used where the muzzle is either touching the target or is just slightly away from it.

Some bullet entry and exit basics should be explained before we proceed further with a discussion of bullet hole and bullet wound characteristics.

- Bullets penetrating targets at approximately 90 degrees tend to produce circular entry holes or wounds.
- Bullets penetrating targets at less than 90 degrees tend to produce oval entry holes or wounds.
- The smaller the angle of impact, the longer the oval entry hole or wound.

- Bullets striking intermediary targets tend to produce irregular entry holes or wounds in secondary targets due to destabilization (yawing).
- Bullet holes in elastic media, including human tissue, tend to be smaller in diameter than the bullets that produced them.
- Bullet entry holes and wounds can often be distinguished from exit holes and wounds by the visible presence of bullet wipe and/or abrasion rings or collars.
- The size of a bullet entry relative to an exit does not always fit the "small entry, large exit" theory, but depends on target type and bullet design.

When a weapon is discharged, rapidly expanding gases erupt from the muzzle. These gases are extremely hot as a result of the combustion of the powder charge. The combination of the heat and the expanding gases can cause damage to anything in close proximity. With regard to articles of clothing, differences will be noted depending on whether the fabric is made of natural fibers such as cotton or synthetic fibers such as nylon. Additionally, the fabric weave can produce varying effects. The particular weapon and ammunition combination used introduces additional variables and, in the case of contact shots, requires determination of how tightly the muzzle was held against the surface.

As shown in Figure 9.1, a 22-caliber handgun was fired at contact distance using Winchester 22 long rifle ammunition. The shots were fired into cotton

Figure 9.1 Long rifle (22-caliber) ammunition fired into cotton twill.

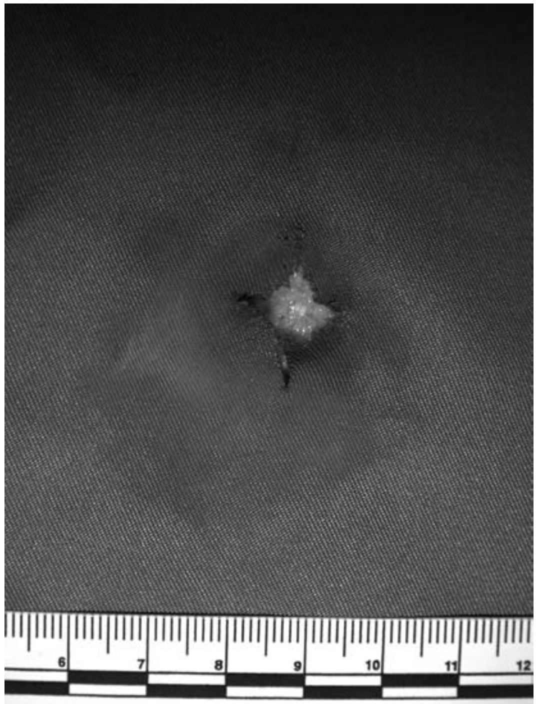


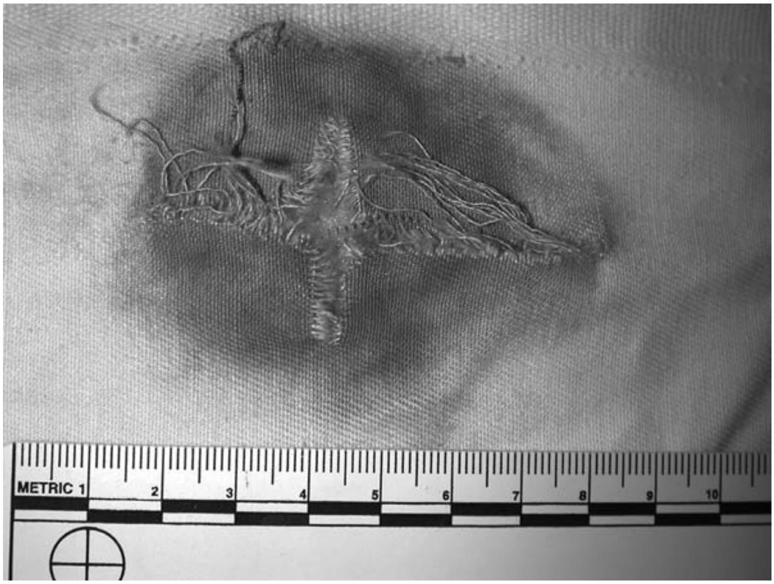
Figure 9.2 Long rifle (22-caliber) ammunition fired into polyester fabric.

twill, a fabric with a relatively tight weave. Figure 9.2 shows the same contact shot but with polyester material in place of the cotton twill. Figure 9.3 shows the result of a similar series of shots from a 9-mm handgun into cotton twill and polyester material.

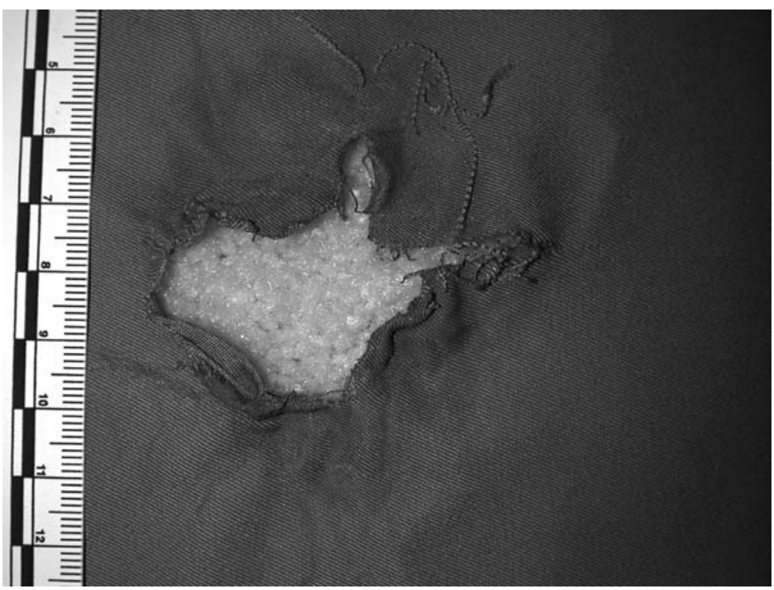
The characteristics for contact/near contact shots into fabric are summarized in Table 9.1. These characteristics vary somewhat, depending on the ammunition and the fabric as already noted. For example, few or no soot deposits may be apparent. In other situations, due to "dirtier" loads, soot deposits will be very evident. Likewise, tearing may or may not occur, depending on fabric weave and the particular load fired.

Normally, a hand lens or magnifier is required for observation of the singeing or melting of fibers around the margins of a fabric. Sometimes, however, it is possible to see these effects with the unaided eye. If conditions permit, it may be possible to feel the characteristic globular nodes present on the melted ends of synthetic fabrics.

Table 9.2 summarizes the possible indicators of an intermediate range shot. "Intermediate" may be misunderstood by persons not familiar with the term. The intermediate range is simply defined as the range at which that



(a)



(b)

Figure 9.3 Nine mm ammunition fired into cotton twill (a) and polyester (b).

weapon and ammunition combination will deposit visible powder particles on a given target. Thus, *intermediate range* is a function of fabric type and ammunition type (caliber or gauge and powder type and quantity). Change one variable and different results may be produced. In short, if visible gunpowder

Table 9.1 Characteristics of Contact/Near Contact Shots into Fabrics

Natural Fibers (Cotton, Wool, Silk, etc.)	Synthetic Fibers (Nylon, Polyester, etc.)
Stellate or irregular tearing	Stellate or irregular tearing
Burning or Singeing	Melting
Possible soot deposits (particularly with loose contact and near contact)	Possible soot deposits (particularly with loose contact and near contact)

Table 9.2 Characteristics of Intermediate Range Shots into Fabrics

Natural Fibers (Cotton, Wool, Silk, etc.)	Synthetic Fibers (Nylon, Polyester, etc.)
Visible powder particles	Visible powder particles
Possible soot deposits (depending on distance)	Possible soot deposits (depending on distance)
Bullet wipe	Bullet wipe

particles are observed around the margins of a bullet hole in fabric, the muzzle-to-target distance is of intermediate range.

Distant shots into fabric do not produce any of the characteristics seen with contact/near contact shots or intermediate range shots except for bullet wipe. Bullet wipe consists of the grease and soot deposits transferred from the surface of a bullet to the margins of the material (e.g., fabric, wood, skin) through which the bullet passes. In effect, the target material wipes the bullet clean as it passes through. Bullet wipe may not always appear or it may be present but difficult to visualize due to the presence of blood and/or its deposit on dark clothing or material. Table 9.3 summarizes the characteristics of distant shots into fabric.

The characteristics of contact/near contact shots in human tissue are more recognizable than contact/near contact shots into fabric. Of particular note is the possible presence of an abrasion ring surrounding the entry wound where tearing of the tissue has not taken place. The abrasion ring is the result of the stretching of skin followed by abrasion caused by the bullet as it passes through. It should be noted, however, that no abrasion ring may be visible due to the tissue destruction. This is also the case for entry wounds to the palms of the hands and soles of the feet due to the skin structure.

As with fabric shots, bullet wipe may also be present in a human flesh wound. Table 9.4 summarizes the characteristics. It should also be noted that

Table 9.3 Characteristics of Distance Shots into Fabrics

Natural Fibers (Cotton, Wool, Silk, etc.)	Synthetic Fibers (Nylon, Polyester, etc.)
Bullet wipe	Bullet wipe

Table 9.4 Bullet Entry Wound Characteristics in Flesh

Contact/Near Contact	Intermediate Range	Distance
Stellate tearing	Powder stippling	Abrasion ring
Soot deposits in/around wound	Possible soot deposits	Bullet wipe
Charring	Abrasion ring	
Powder in wound	Bullet wipe	
Abrasion ring		
Bullet wipe		
Muzzle imprint		

a contact/near contact shot can produce a muzzle imprint, particularly when underlying bone is present as in a head shot. Muzzle imprints are abrasions resulting when discharge gases cause the skin to expand outward against the muzzle of the weapon. Figure 9.4 depicts a muzzle imprint from a 12-gauge shotgun. The weapon was an over/under double barrel shotgun. The muzzle imprint of the upper, unfired barrel is clearly visible to the right of the entry wound produced by the lower barrel.

It is very important to be able to recognize the presence of an abrasion ring or collar around the margins of a bullet wound as the ring or collar is a clear indication of an entry wound rather than an exit. The situation is not as clear-cut with a shored exit wound. This type of wound is the result when

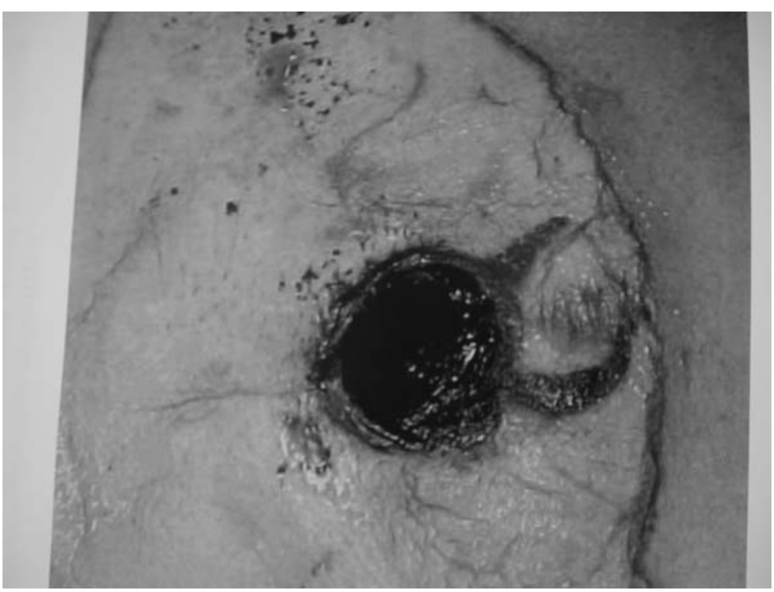


Figure 9.4 Muzzle imprint of over/under 12-gauge shotgun.

the area of the body where the bullet exits is supported or tightly bound by clothing such as a vest. A shored exit wound can sometimes be recognizable by an associated fabric impression. Of course, any question concerning the origin of an abrasion ring around the margins of a bullet wound should be left to a forensic pathologist.

When a weapon is fired from any distance such that gunpowder particles can impact the skin around an entry wound, such impacts will typically be manifested by what is generally called powder stippling. Partially burned and unburned gunpowder particles are expelled from the muzzle upon discharge along with soot. If the muzzle is close enough to the victim, both soot and stippling are likely to be present. As the muzzle of the weapon is moved away from the intended target, a distance will eventually be reached at which the soot does not reach the target. Gunpowder particles, by virtue of their greater mass, can travel greater horizontal distances than soot particles. Thus, powder stippling effects will still be produced after the soot deposition ceases with increased muzzle-to-target distance.

Powder stippling is manifested by small, dark spots around the margins of a wound. These spots can represent bruises or abrasion from the impacts of the gunpowder particles with the skin. The potentially injurious nature of gunpowder particles to human skin is evidenced by close range shots into painted metal surfaces, such as car doors, and the subsequent chipping of the paint around the bullet hole as a result of the powder impact. Powder particles can even embed themselves into the skin to produce powder "tattoos." Figure 9.5 illustrates powder stippling.

As already stated, the particular round and weapon involved will significantly affect the distances over which soot and powder will travel. As a general

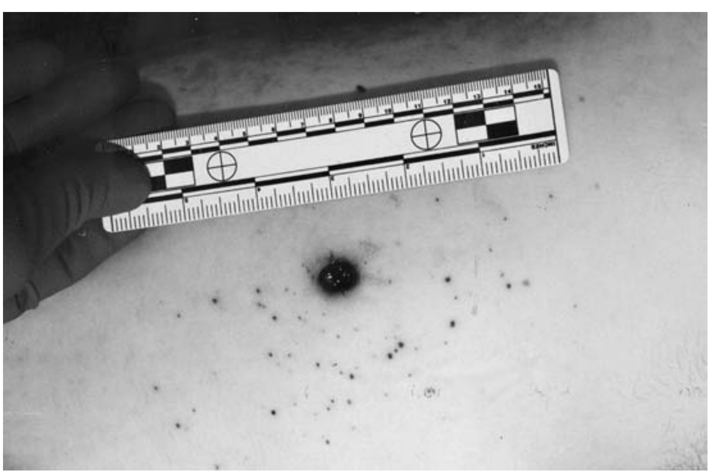


Figure 9.5 Powder stippling of human skin.

rule, we typically do not see soot deposition beyond about 24 inches. As for powder deposition, the general rule is that we do not expect to see it beyond "arm's length." As with all rules, these are offered for general investigative purposes only and are not intended to represent absolutes. Only through actual test firing with the weapon and ammunition like that used in the shooting can we establish approximate muzzle-to-target distances to any reasonable certainty.

It is important for the investigator to be fully aware of possible reasons why some characteristics of bullet holes in human tissue and in inanimate objects may not conform to their expected or predicted appearances. This is especially of concern when few or no gunpowder particles (inanimate objects) or stippling (human skin) are found. The possible conclusions when little or no gunpowder or stippling is present are:

1. The muzzle-to-target distance was too great to produce more of a pattern.
2. The shot was close enough for the powder to strike the surface but something prevented the gunpowder from reaching the surface or removed the powder after it impacted.

Any intervening target may be capable of preventing the powder from reaching the target. Thus, when a weapon is fired through a pillow and into a victim, most or all of the powder would be stopped while the bullet would still pass through. Other common intermediary targets likely to be encountered at shooting scenes include hair, articles of clothing, glass windows, wooden doors, walls, and curtains. Another possible reason powder particles may not be visible upon examination at a crime laboratory or at autopsy is due to handling. Since the top priority at any shooting scene is to administer aid to the injured, clothing is frequently ripped or cut apart and removed by paramedics during life-saving efforts. This process can and does alter the amount of gunpowder that may have been present initially, particularly when the powder is only loosely held on the surface of a garment due to the distance of the shot and/or the type of fabric (smooth, tight weave versus loose, bulky weave).

In the case of powder stippling of human skin, the mechanisms by which it is produced make it unlikely that simply wiping or washing the surface of the skin will obliterate it. In other words, one would not expect a simple mechanical action in the form of wiping or washing to remove evidence of burning or bruising. It is also highly improbable that wiping or washing will remove powder embedded in the skin. Overlying hair can prevent the production of stippling, even at close range. For this reason, it is important to collect hair covering a wound and submit it to a crime laboratory for examination. As with any natural fiber, overlying masses of hair will exhibit burning and singeing as a result of a close range shot.

Reconciling Bullet Holes in Clothing with Underlying Wounds

Quite often information about the positions of the victim's gunshot wounds at the time shots were fired can be ascertained by examining and comparing the locations and characteristics of bullet holes in clothing and underlying wounds. It is unfortunate in some jurisdictions that the determination of muzzle-to-target distance is based solely on the pathologist's findings without regard to the fact that the wound was covered by an article of clothing. It would seem apparent that the outermost layer would be the most logical thing to examine and test for purposes of establishing approximate muzzle-to-target distance, but this type of examination is sometimes overlooked.

Clearly, it is possible for an individual to receive a contact shot to his shirt, for example, while his wound exhibited the characteristics of an intermediate range shot in the form of powder stippling. This could merely result from wearing a loose-fitting garment and having it hang away from the body at the time the shot was fired. While this possibility may not necessarily represent a fatal flaw in the reconstruction of a shooting, failure to consider it certainly represents a less than thorough examination of all the available evidence.

Proper protocol requires the examination and testing of all overlying garments that bullets pass through, as well as having a forensic pathologist conduct an autopsy and examine the bullet wounds. Under the ideal scenario, findings of the crime laboratory and the autopsy results will be reviewed and corroborated before any apparent disagreement is revealed in a court room.

In a case the author is familiar with, a woman wearing a white robe was shot to death with a 357 magnum revolver. The laboratory examiner did not know the woman was wearing the robe inside out when she was shot. The bullet entered her left side, traversed her thoracic area, and exited her right side. When the pathologist examined the victim at autopsy, the robe was not present. He noted an entry wound to the left lateral area with an exit out the right lateral area. No gunpowder particles (stippling) were found around or in the entry wound. As was the practice of the examiner's office, the findings were reported without further explanation.

When the firearms examiner received the white robe, it had been turned back right side out. This was done at the scene when paramedics removed the robe to administer first aid to the victim. Following examination of the robe, the firearms examiner concluded that the shot was fired from right to left based upon some apparent bullet wipe around the margins of what was actually the interior surface of the exit wound. When trial began and the pathologist and the firearms examiner testified, they presented entirely different findings.

The pathologist correctly testified that the shot was from left to right. The firearms examiner incorrectly testified the shot was from right to left. Unfortunately for the firearms examiner and the prosecutor, the judge first noted the discrepancy. Once the disagreement was pointed out, the truth was revealed. The firearms examiner's error was compounded by her reluctance to accept any responsibility for the gaffe. Had she read the autopsy report before she made her examination and prepared her report, she surely would have seen the problem. Worse still was the fact that she failed to examine the inner surfaces of the robe (that had been on the outside at the time of the shooting). If she had done so, the bullet hole characteristics clearly would have indicated something was amiss. The lessons to be learned here, and at a much smaller price than that paid by the firearms examiner, are:

1. The autopsy report and the criminalistics report should be in concert.
2. The criminalist or firearms examiner should read the autopsy report prior to issuing a criminalistics report.
3. The pathologist and the criminalist should communicate with one another on cases of mutual concern.
4. A specific party should be charged with comparing the findings in such cases before reports are issued.
5. The prosecutor should have assembled his witnesses together for a pretrial conference in order to discuss their planned testimony.
6. Both sides of any garment bearing bullet holes must be examined in a laboratory.
7. Paramedics should report any alterations to garments at the scene.

In some cases, it may be necessary to use a mannequin to assist in determining the relationship of bullet holes in clothing to wound locations. Consideration must be given to the stature of the individual involved in the incident. The determination is simplified when the available mannequin closely approximates the stature of the shooting victim. If it does not, appropriate compensations must be made. In what may clearly be a worst case scenario, someone of similar stature may be cajoled into donning disposable coveralls, face mask, gloves and booties and then putting on the victim's outer garments. This is not advisable when the clothing is heavily coated with dried blood and/or tissue. In such cases, the potential health risks may be deemed too excessive.

Figure 9.6 shows a mannequin dressed in the shooting victim's clothing consisting of a sweat shirt, jeans and a leather bomber jacket. In this case, the mannequin was a good fit for the shooting victim in terms of stature after a little height adjustment. The question was whether the victim had his arm extended as if holding a weapon when he was shot. When the position of the victim's arm at his side was simulated, a bullet hole near the cuff of the jacket did not line up with the entry wound above the victim's wrist.

Figure 9.6 Mannequin.

However, when the arm was extended partially out in front, the hole in the jacket lined up with the wound in the arm. See Figure 9.7 and Figure 9.8.

Another good example of the value of reconciliation of bullet holes in clothing with wounds in underlying tissue in the course of a shooting reconstructions is the graze wound. When a bullet passes through folds of fabric,

Figure 9.7 Representation of arm at side.

Figure 9.8 Representation of arm extended forward.

a series of in and out holes appear. A pathologist's report of a graze type injury may be of value, but the combination of the wound appearance and a description of a bullet hole in clothing can provide strong evidence as to the probable position of the victim at the time of bullet impact. Figure 9.9 depicts the typical folds that appear when a trouser leg is bent. It is doubtful that an in–out–in–out–in–out pattern would result in any other manner.

Figure 9.9 Representation of folds in jeans.

In summary, wound characteristics should be reconciled with bullet holes in clothing as part of a shooting reconstruction effort whenever appropriate. Questions regarding bullet paths and directions should be resolved via a comparison of laboratory findings with pathological findings. Any questions that arise can often be answered by placing a victim's clothing on a mannequin or individual of comparable stature.

Bullet Holes in Glass and Glass Injuries

When a bullet passes through glass, it is important to be able to determine the directionality of the shot. For example, in a shooting involving a vehicle, was the bullet fired from inside the car out or from the outside in? In most cases, the answer is fairly easy to ascertain, but some situations can present obstacles to this determination that range from difficult to insurmountable.

Before proceeding with a discussion of bullet hole characteristics in glass, a brief description of glass manufacture and the types of glass commonly encountered in shooting incidents is in order. Glass is described chemically as a super-cooled liquid. Glass manufacture in the United States can be traced back to the Jamestown colony in Virginia. Sand, lime, and potash were heated to the melting point to produce a molten soda-lime glass that skilled glass blowers formed into various types of containers and objects. This process can still be observed by tourists visiting the restored Jamestown Village.

Modern glass is made using several different processes, including rolling molten glass and a technique involving molten tin that the molten glass floats across. The tin–float process offers an inexpensive route to quality glass. Tin particles are fused to the "down side" of the glass and thus provide a means for ascertaining shot direction as will be discussed later in this section.

Safety plate glass is required for vehicle windshields. This type of glass is also used in large storefront windows and usually consists of two sheets of plate glass surrounding a piece of clear plastic. The plastic is cemented to the glass sheets to form a laminate. The end result is that if an object such as a bullet, passes through the glass, the glass essentially holds together even after fracture because of the plastic sheet.

All side and rear window glass found on U.S.-manufactured vehicles is tempered. All glass on European vehicles is typically tempered. Tempered glass is much stronger than ordinary plate glass. It consists of a single glass sheet subjected to stress through heat treatment during manufacture. The stress induced during heat treating causes tempered glass to "craze" or fracture into tiny, rectangular fragments upon impact and the fragments pose little threat of injury. Tempered glass is also found in shower enclosures, shower doors, windows, and other glass panels found in buildings. Crazing results when a bullet passes through tempered glass, so it can be readily identified.

Plate glass used in ordinary business and residence windows consists of a single sheet of non-tempered glass. Plate glass for commercial use is sometimes reinforced with internal wire mesh. When plate glass breaks, dangerous "spears" of glass result.

When a force impacts a sheet of glass of any type, bending, stretching and, ultimately, breaking occur. This is manifested by fracture lines that radiate out from the point of impact like spokes on a wheel. With windshield glass, these radial fractures first occur on the sheet of glass on the side opposite to the side impacted. Ultimately, both sheets will exhibit radial fractures but they will usually not coincide. Also present will be a series of concentric fractures that form as the glass bends in the direction of the force. These fractures are initially formed on the same side of glass impacted by the force. As the bending of the glass continues, both sheets of glass become involved. The number of concentric fractures is related to the type of glass, the size of the window, and the rigidity of the window in the frame. Concentric fractures may be minimal or completely absent in some cases. When combined with the radial fractures, concentric fractures give the appearance of a spider web (Figure 9.10).

Radial fractures from adjacent bullet holes can reveal shot sequences since radial fractures in the same sheet will never cross. When a radial fracture terminates into another radial fracture, the terminating fracture emanates from a shot that followed the one with the non-terminating fracture. Look closely at Figure 9.10 and see whether you can determine which shot was

Figure 9.10 Radial and concentric fractures in safety plate glass.

Figure 9.11 Tempered glass (first shot).

fired first. The answer is found at the bottom of the figure, just left of center. The shot to the right preceded the shot to the left.

The same effects are exhibited by tempered glass and ordinary plate glass. With tempered glass, however, the crazing reduces the degree of concentric fracturing and increases the degree of radial fracturing but in a wavy pattern. This is clearly visible in Figure 9.11. Also, only the first shot through tempered glass results in radial and concentric fractures. Subsequent shots only knock out portions of the remaining crazed glass, as shown in Figure 9.12. The figure also shows what typically happens when a bullet passes through tempered glass. A large portion of the glass, if not all of it, is blown out. However, it is often still possible to discern radial fractures from the first shot if enough

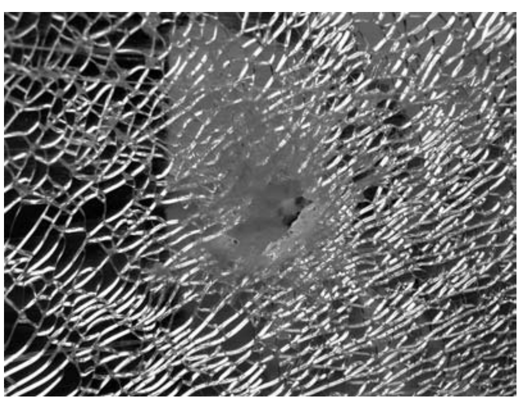


Figure 9.12 Tempered glass (subsequent shot).

glass remains. After-market window tint film, if present, will often hold crazed glass in place unless some additional force of impact occurs.

When moving vehicles are involved, the location of tempered glass fragments in the road can be deceiving. The location may not coincide with the point at which shots were fired. In several cases the author has investigated, shots were known to have been fired from a position considerably uprange from where glass fragments were found. This was simply because the glass held together as the vehicle continued to travel forward until road vibration or a collision caused the glass to fall out.

It is important that glass with bullet perforations be documented as soon as possible. Attempting to move vehicles before documenting the bullet holes in tempered glass will usually cause the glass to fall out, even when strips of tape have been placed over the glass. Windshields, on the other hand, are not nearly as fragile.

The determination of direction of force, that is, the direction the bullet was traveling, is possible by noting which side of the glass exhibits a beveled or dished margin at the bullet hole. As when a bullet passes through a human skull, the beveled side will always be on the exit side because a bullet passing through glass creates a cone effect of force. This means more glass is lost on the exit side. For shots at impact angles smaller than 90 degrees, asymmetrical beveling is produced. These effects are represented in Figure 9.13.

Sometimes, especially with tempered glass, this effect is difficult to see or cannot be seen because of the loss of glass. However, most tempered glass is made by the tin–float process. The side of the glass lying against the molten tin is impregnated with tin particles. To determine which side was the outside,

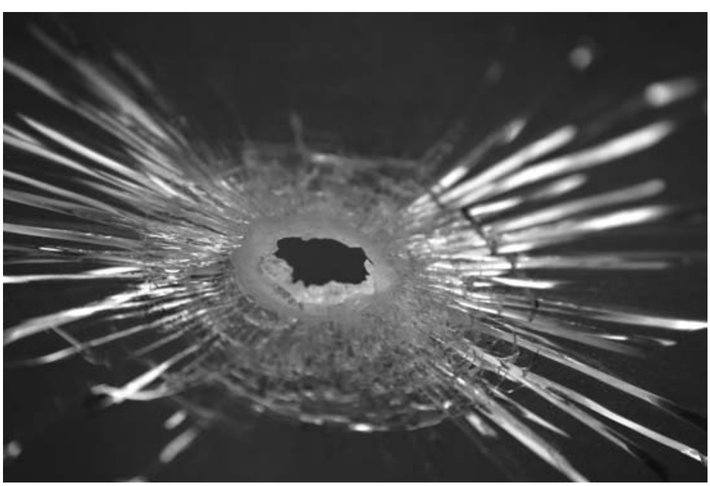


Figure 9.13 Beveling on exit side of glass.

one only needs a piece of glass remaining in the frame. Exposing each side of the fragment to ultraviolet light causes the side with the tin particles to fluoresce; the other side will not. If fragments from the bullet-hole margins can be found on the ground or elsewhere and beveling is discernible, ultraviolet fluorescence can be used to establish shot directionality. In the case of windshield glass, the beveling will usually appear on both sides but will be more pronounced and more uniform on the exit side.

If penetration is incomplete, the beveling is on the impact side. This is frequently encountered when BB guns are fired at storefront windows. The tiny, irregular holes produced are indicative of this impact and are referred to as spalling. It is not limited to BB guns, however, and may result from bullet impact if a significant loss of velocity takes place before the shot strikes the glass. In the author's experience, this situation is not frequently encountered.

Another way of ascertaining the direction of force is to examine the concentric and radial fracture edges of a fragment of glass still remaining in a broken plate glass window or windshield. This allows the examiner to denote which side of the fragment is facing out and may be accomplished by simply marking an "O" on the outside surface of the fragment with a marker pen before removal. Additionally, radial fracture edges and concentric fracture edges should also be marked prior to removal. An easy way to distinguish them is to remember that "concentric [the concentric edge] comes to" and "ray [the radial edge] goes away."

With the fragment appropriately marked, the edges are then examined for the presence of conchoidal fracture lines. As it turns out, the conchoidal fracture lines form right angles, the orientation of which depends on whether a radial or a concentric fracture edge is involved, as illustrated in Figure 9.14. The radial fracture edges tend to show this effect more reliably. If an intact piece is not available, a piece from the floor or ground may be used if it is

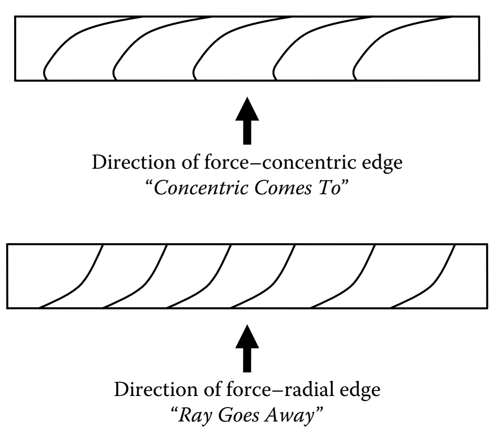


Figure 9.14 Conchoidal fracture edges.

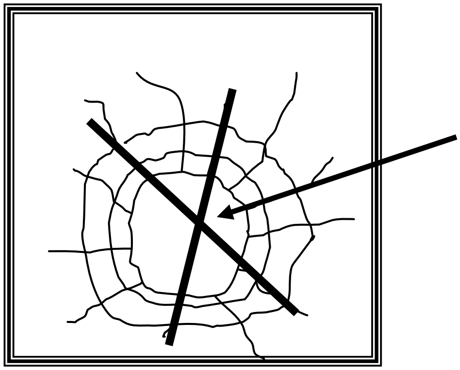


Figure 9.15 Determining point of impact in glass. Strips of tape are placed across radial fractures where a large section of glass is missing.

possible to determine its orientation in the window. This is often a difficult task. In the case of tempered glass, the tiny fragments do not usually permit this determination.

It is sometimes important to ascertain exactly where a bullet impacted a glass window. As long as radial fractures are present, all that is required is to find the point of intersection of two radial fractures. This is easily accomplished with masking tape. Two strips of tape are run across the window in alignment with two radial fractures. The point of intersection of the strips of tape is the point of impact. The glass can then be measured, sketched, and photographed to document the point of impact. Figure 9.15 illustrates this technique.

Glass injuries occur when an individual is within close proximity to a glass window when a bullet passes through. They appear as small, punctate injuries and can sometimes be mistaken for stippling. Identification of tiny glass fragments within the wounds by a pathologist is essential.

The presence of glass injuries and their location on the body of the victim can assist in the reconstruction of a shooting. Questions about the positions of the arms of a driver in a vehicle shootout, for example, can frequently be answered if bullets have passed through the driver's door glass and/or the windshield and position information can also be used to establish bullet directionality when bullets pass through glass on both sides of a vehicle and the glass totally falls out. Thus, glass injuries on the left side of a driver's body require bullet entry from the driver's side if the driver was seated behind the wheel and facing forward.

In an officer-involved shooting incident, a question arose about the justification for the use of lethal force. According to the officer's statement, the decedent, who was sitting in the driver seat of a vehicle with the engine running, had his hands "on the steering wheel as he gunned the car toward me." This action served as the officer's basis for firing the fatal shots that first passed through the windshield and then the driver door glass. At autopsy, examination of the decedent's wounds revealed small, punctate wounds on the inside of the forearm of his right arm and on the outside his left forearm. This indicated that his arms and hands were above the driver door window sill and in a position consistent with holding a steering wheel. Further examination revealed that the officer's stated position and the trajectory of the shots were consistent with the glass injuries that occurred while the decedent's hands were on the steering wheel. These facts along with other physical evidence resulted in exoneration of the officer.

Glass lodged in the cavities of hollow point bullets or embedded in the noses of lead bullets can provide information as to which window was impacted. A crime laboratory can conduct analyses of control samples from each window perforated by bullets and compare the physical properties (density, refractive index) and the elemental analyses to the fragments recovered from bullets.

When bullets impact glass of any type, a cloud of pulverized glass is produced. If a person is anywhere in the immediate vicinity, chances are he or she will be covered by the tiny fragments. Collection of a suspect's clothes and subsequent laboratory examination and analysis of any glass particles found can be used to put an individual at the scene of a shooting where glass was shot through. Although modern computer-controlled glass manufacturing techniques tend to minimize the analytical distinctions among different batches of glass, these distinctions are still viable means of identifying which glass splinter came from which window.

Sometimes questions arise as to whether a vehicle side glass was fully raised prior to a shootout. Even when most of the glass falls out as a result of a bullet strike, it is often found that the upper window channel will retain a few fragments of tempered glass. By noting and photographing it, confirmation that the window was up at the start of the shooting can be made.

A word of caution is in order about attempting to reconstruct trajectories through windshield glass fragmented by bullets. Fragmentation is particularly common when semi-jacketed hollow point bullets are involved. When bullets pass through slanted windshields, they fragment. The fragments then strike secondary targets such as seat backs inside the vehicle. The tendency is often to use the secondary (into the seat back) impact point of the largest fragment (usually the bullet core) as the second point of reference. While it is certainly expected that the largest mass will exhibit the closest trajectory to the original bullet, this result is quite unpredictable. Merely "connecting the dots" (using the primary and secondary impact points to establish trajectory) could lead to proposing a shooter position that would not necessarily represent the true position.

When bullets strike slanted windshield glass directly from the front at, say, the mid-section, an elongated hole is usually produced because the bullet strikes at the angle of inclination of the windshield (assuming a shot fired more or less parallel to the ground). In tests conducted by the author, the width and length of the resultant bullet hole for a particular caliber was somewhat dependent upon bullet design. For example, the percent error for the angle of impact calculation using the hole width-to-length ratio was 18% for hollow point 40 caliber bullets (Winchester and Federal) and only 3% for blunt-nosed soft point (Winchester) bullets in one test. The wide range of results was determined to be the consequence of differences in deformation upon impact and the resultant bullet hole dimensions. Once again, the investigator would be well advised to carry out testing under the particular conditions associated with the shooting incident under study.

As part of the documentation of bullet holes in windshield safety plate glass, the orientation of elongated (oval) bullet holes should be noted. The simplest method is to use a straight edge to bisect the axis of the hole and then use a protractor to measure the degrees of cant of the long axis (as represented by the straight edge) to the left or to the right of vertical. The straight edge is laid down on the glass and the protractor is then placed on top of it. The base of the protractor is aligned with the plane of the front of the vehicle. Shots fired straight on should show zero degrees (or very close to zero) of cant from vertical for the long axis. Shots fired other than directly from the front of the windshield will be recognized by a cant to the left or right of the resultant oval bullet hole. The degree of cant will approximate the lateral angle for the shot. For example, if a windshield has an oval-shaped bullet hole and the long axis of the hole has a 30-degree cant to the right of vertical, the shot was fired from approximately 30 degrees to the left of a vertical through the center of the hole (see Figure 9.16).

The vertical angle cannot be reliably determined from the length and width measurements of bullet holes through windshields because of bullet deformation and fragmentation and the irregular breakage of windshield glass. In the one test conducted by the author with 40 caliber Federal Tactical rounds, no reproducible results could be obtained and none of the vertical angles of impact calculated from bullet hole width-to-length ratios were within fewer than 15 degrees of the actual.

One should be cautious about using a tertiary bullet hole in a seat and an entry hole in a windshield to fix trajectories of shots fired through windshields that then pass through human targets, and enter seat backs. Obviously, bullet deflection can and often does occur under these conditions.

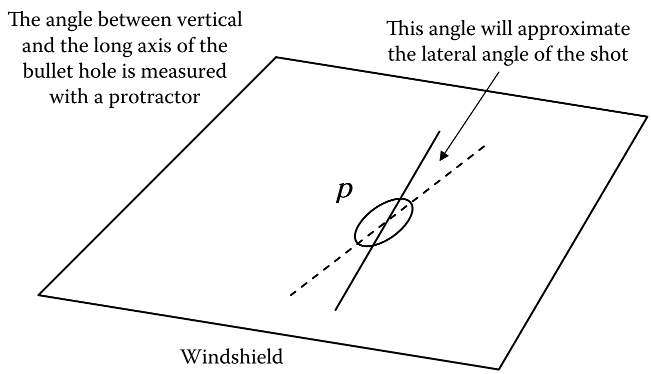


Figure 9.16 Documenting bullet hole in glass.

Attempting to determine shooter position from the entry hole in a windshield and a bullet entry wound for an individual inside the vehicle also has some limitations. The position of the victim can be established fairly well if the bullet exits the body and then penetrates the seat back or other interior component. When this does not take place, the investigator cannot necessarily assume a particular position for the shooting victim. One must always consider the possibility of movement during the shooting, particularly when multiple shots are involved.

In the author's experience, some significant bullet deflection (approximately 6 degrees) can result from perforation of a windshield. This is based on numerous test firings using 40-caliber Smith & Wesson rounds with semi-jacketed hollow points. This is contrary to a report published in the *AFTE Journal* by Gary Rathman several years ago. However, his tests did not include 40-caliber, semi-jacketed hollow points as used in the author's tests. This finding once again underscores the necessity for incident-specific testing. In summary, the following checklist should be considered and applied as appropriate at each shooting involving glass.

Glass Evidence Checklists

Determination of Directionalities of Shots

1. Look for beveling around the margins of a hole (if center of hole is blown out, attempt to locate fragments and reconstruct; use ultraviolet light to determine outside surface). Beveled or dished margin will be the exit side.
2. Examine radial and concentric fracture edges (plate glass and other non-tempered glass only) for the presence of conchoidal fractures. Remember that *Ray goes away* and *Con comes to.* The conchoidal fractures along

the edges form right angles away from the direction of force for radial fractures and toward the direction of force for concentric fractures.

Determination of Shot Sequence

1. Plate glass and windshields: look for intersecting radial fracture lines. When one radial fracture line stops against another, the continuing fracture occurred first.
2. Tempered glass: the first shot will exhibit radial fractures and possibly concentric fractures as well. Subsequent shots will show no radial or concentric fractures.

Glass Evidence Collection

1. Collect control samples from each section of broken glass.
2. A piece of fractured glass (non-tempered only) still remaining in the windshield should be marked to show inside and outside surface orientation and radial and concentric fracture edges and then collected.
3. Glass embedded in or adhering to bullets must be collected.
4. Articles of clothing from individuals suspected of being near glass struck by bullets must be collected.

Documentation of Bullet Holes in Glass

1. Measurements of bullet hole length and width should be recorded.
2. Orientation of oblong holes, especially in windshield glass, should be recorded: the cant of the long axis of the hole relative to a vertical (see Figure 9.16).
3. Close-up photographs with and without a scale should be taken.

Glass Injury Documentation

1. Any apparent glass injuries on persons involved in shootings should be documented photographically (see Figure 9.17 and Figure 9.18).
2. A pathologist should document and collect glass from the bodies of deceased individuals.

Side Glass Position Determination

1. Examine upper window channels for the presence of glass fragments that would indicate that the window was up before breakage.
2. Check the position of the lower window channel to establish window position.

Figure 9.17 Glass injury to inner arm.

Test Firing for Confirmation Purposes

1. Carry out test firing whenever appropriate and necessary (to confirm trajectories, ascertain hole characteristics, etc.).
2. Test firing should be conducted under the same conditions as the shooting.

Bullet Holes in Tires and Other Elastic Materials

When bullets perforate elastic substrates such as tires and plastic vehicle body panels, the holes created will be smaller than the bullet diameter due to the elasticity of the material. This is somewhat analogous to the passage of a bullet through human skin. The initial stretching is followed by perforation and then elastic rebounding. During the passage of the bullet through the medium, scuffing of the outer margins occurs. This is analogous to an abrasion ring around the margins of a wound in human tissue. Measuring the diameter of the outer scuff ring will provide a reasonable approximation of the bullet diameter (caliber) that produced it. However, it is unwise to specify a particular caliber based on this information alone. A more cautious approach would be merely to specify the measured value. It is safe to presume that the bullet that produced the scuff ring was not significantly smaller than the maximum diameter of the scuff ring.

Figure 9.18 Glass injury to shoulder.

Tires are often perforated or penetrated by bullets during shootouts. Depending on the bullets involved and the locations of entries and exits, such bullet holes can be difficult to find and misleading in appearance. A bullet hole in a tire sidewall produced by a round-nosed, 22 caliber bullet can be particularly misleading. A practical exercise involving such a defect is used by the author in shooting reconstruction classes conducted for police agencies. It is common for students to opine that a defect was produced by an ice pick rather than a 22 caliber bullet. This is because the resultant bullet hole is very tiny as a result of elastic rebound of the tire after perforation (see Figure 9.19).

When hollow-point bullets of larger caliber, say 9 mm, are used, the result is typically a pronounced hole caused by the "cookie cutter" effects of the hollow points. Thus, even when no bullet has been recovered, an investigator is on fairly firm ground to speculate that a hollow point bullet produced a defect of this type. The abrasion collar produced as a result of the stretching

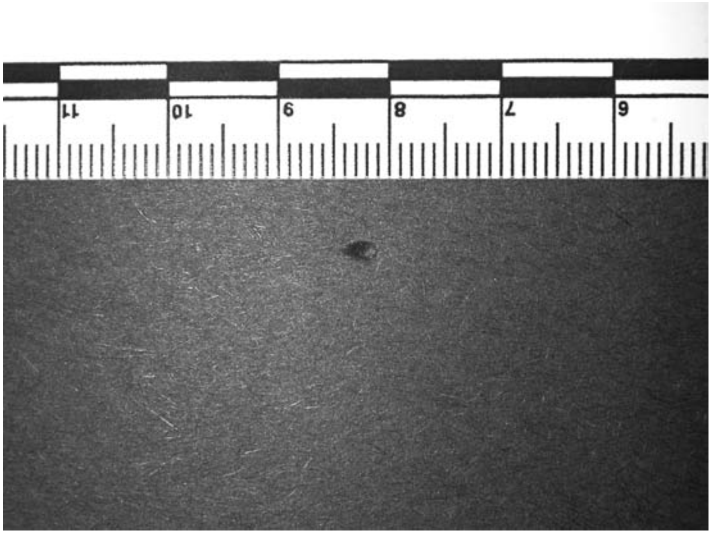


Figure 9.19 Twenty-two caliber bullet hole in tire sidewall.

and abrading of the outer margin by the bullet can provide some clue as to approximate bullet diameter (caliber). While it is generally unwise to specify a particular caliber from such a measurement, as already stated, one can at least proffer the measurement obtained. Figure 9.20 shows the result of the firing of a hollow point bullet into a tire sidewall. Blunt-nosed bullets cause holes with more irregular margins.

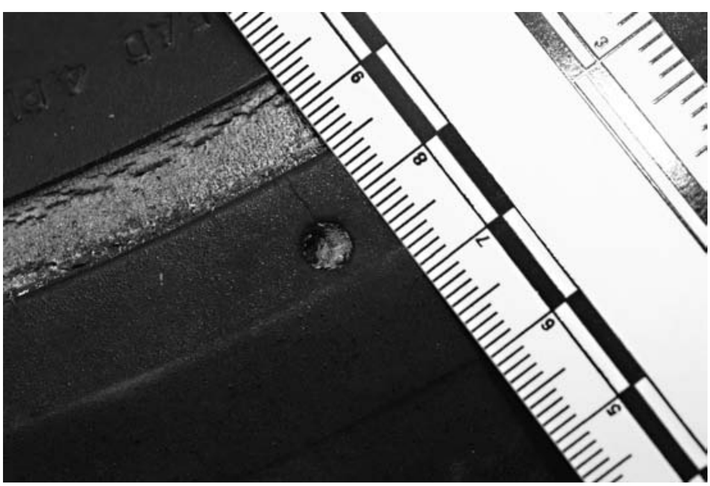


Figure 9.20 Nine-mm hollow-point bullet hole in tire sidewall.

It can be very difficult to locate bullet holes from shots fired into the tread areas of tires. If a vehicle that participated in a shootout has one or more flat tires, we would obviously want to have the wheels removed and the tires broken down to search for bullets and/or bullet fragments. It is easier to identify bullet holes in tires from the insides. Another method is to reinflate a tire, place it in a tub of water, and look for air bubbles in order to locate bullet holes.

If different bullet types such as lead and jacketed bullets are involved in a shootout where tire perforation has taken place, it is possible to have the crime laboratory analyze the margins of the defects for lead, copper, antimony, aluminum, etc. and possibly determine the type of bullet that produced the defect, assuming that no other distinguishing features of the bullet are present. This would have to be considered before inserting trajectory rods into the holes in tires.

The author has been involved in the investigation of several cases in which police officers shot out tires of suspect vehicles in an effort to stop the individuals from fleeing. The time required for a tire to go flat obviously involves a number of variables including location of the bullet hole in the tire (tread versus sidewall), size and construction of the tire, and size of the hole produced. Through numerous test firings conducted during shooting reconstruction classes, the time for a tire to flatten was found to vary from as little as 5 seconds for an inexpensive 13-inch tire with 2-ply sidewalls shot in the sidewall with a hollow point 40 caliber bullet to 15 minutes for a 15-inch pursuit tire of the type used by law enforcement shot in the sidewall with a 9-mm round-nosed bullet. Obviously, various other tire and bullet combinations could produce varying results. In any event, if an officer is standing in front of a vehicle and a shot is fired into a tire in an effort to stop the vehicle from striking the officer, the effort is ineffective.

Today's automobiles are produced with numerous body panels, moldings, and covers made of plastic. As with tires, bullet holes in plastic will be smaller than the diameters (calibers) of the bullets that produced them. An investigator should not assume that bullet holes in plastic parts located near larger bullet holes in sheet metal were made by different caliber weapons. This situation is illustrated in Figure 9.21. The difference is obviously very pronounced and it is easy to see why one might think different calibers were involved. The key is to look closely for abrasion rings on the plastic components.

Documentation

As with all physical evidence associated with a crime scene, proper documentation of bullet holes and wounds is critical to the reconstruction effort. The basic principles of crime scene documentation apply here: sketch and

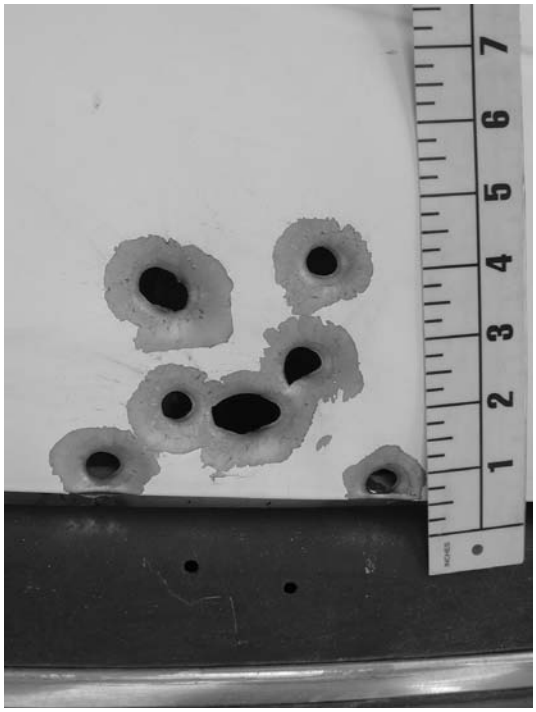


Figure 9.21 Same caliber bullet holes in metal and plastic.

photograph. The documentation of wounds will typically reside with the pathologist. Most medical examiners' offices are well equipped to take appropriate photographs. When this is not the case, the investigator must take the responsibility for scale photography.

Certainly all pathologists will document wound locations according to accepted forensic protocol. These measurements become critical when bullet holes in clothing are to be reconciled with wound locations. In the ideal case, of course, the criminalist and the pathologist would work in concert to make these kinds of evaluations at the time of autopsy.

The basic rules of crime scene photography must be followed (see Chapter 16). Overall photographs are followed by close-ups. A scale should be included in all close-up photographs along with an indicator as to the hole or wound photographed and its orientation. In the case of clothing, it is often advisable to place a piece of contrasting color card stock behind a bullet hole so that the hole will be visible in the photograph and not be lost in the surrounding cloth.

Sketches should be made of all clothing items and should include measurements that designate the positions of all bullet holes. Figure 9.22 is an

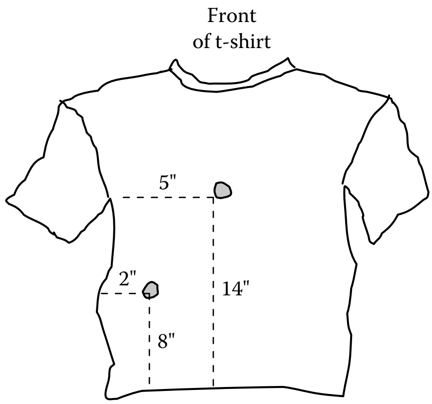


Figure 9.22 Documenting bullet holes in clothing.

example of the type of sketch that should be made. Sketches should be included in bench notes as back-up for photographs. Similar sketches should be made for windshields and windows. It is particularly advisable to include indicators of shot directionality, such as beveling, in sketches.

Photographing bullet holes in glass can be challenging due to the reflective nature of glass. The use of a detachable flash to achieve oblique lighting is mandatory. Many times, however, available light alone is satisfactory. The value of digital photography is that lighting factors can be determined at the scene and appropriate accommodations made.

In some instances, the use of black construction paper behind glass is necessary to eliminate the transparency and its associated problems. The investigator should carry black construction paper with his or her photography equipment. The construction paper can be taped to or held behind the piece of glass with the bullet hole. This technique is particularly useful in photographing ricochet marks on glass as will be discussed in the next chapter. Special considerations in documenting bullet holes in vehicles are discussed in Chapter 13 in the section titled "Shots into Vehicles."

Case Study

In an officer-involved shooting that occurred following a night-time traffic stop, the position of the driver became an issue. According to the officer, the driver came to a stop, exited his vehicle, and assumed a shooting stance as he faced the officer's vehicle. The officer instinctively ducked below the dashboard of his patrol vehicle. Realizing that he was vulnerable to being shot in that position, the officer opened the driver's side door and quickly moved to the passenger side rear of his patrol unit. He drew his service weapon as he moved, then opened fire upon sighting the man in the dim light.

The officer shot the man a total of seven times including three shots to the right arm, two shots across the left leg (right to left), a grazing wound to the outside of the left leg and a shot to the left forehead. Eight fired cartridge cases were found on the ground to the right of the officer's vehicle. The rear window of the man's vehicle had been shot out and a bullet graze mark extended across the top of the vinyl roof of the vehicle.

The man was found on the street beside his vehicle. His cap, with an apparent bullet hole through the left front, was also found on the street. No gun was found. The man was pronounced dead at the scene and his body was removed. The crime scene unit then arrived to process the scene.

The grand jury issued no bill of indictment against the officer following an investigation of the shooting. However, a civil suit was filed against the police department collectively and the officer individually for wrongful use of lethal force. Strong support for the officer's version of events was found in the fact that a resident who witnessed the shooting from her living room window called 911 and reported that "an officer and another man are out in the street shooting at each other." Although no gun was found, her call helped corroborate the officer's statement that the man had assumed a "shooting stance."

The plaintiffs claimed that the fact that the rear glass of the man's vehicle had been shot out was evidence that the man was "shot while seated in the vehicle trying to surrender." Proof they claimed was the fact that particles like those from the rear glass were found around the bullet hole in the front of the man's cap.

The author was retained by the police agency to review the plaintiffs' allegations and conduct an independent reconstruction of the shooting. At the outset, the claim that glass particles consistent with the rear glass (tempered glass) had been found around the margins of the bullet hole in the cap appeared to be compelling. Whenever a bullet passes through glass, the bullet carries tiny particles of glass along. These glass particles produce the punctate injuries around a bullet entry. In this case, the cap would have received most of the glass particles. It seemed strange that no glass injuries were found on the man's face. They would have been expected if the plaintiffs' version of how the shooting took place was correct.

Examination of the cap revealed the entry hole in the left front was perfectly round. This did not seem to fit the scenario of a bullet traveling through the rear glass before passing through the man's cap and entering the left side of his brain. Striking the rear glass would have produced destabilization and distortion of the bullet, a 45 caliber Federal Hydra-Shok™. Distorted or destabilized bullets do not produce circular entry holes.

Additionally, an irregular apparent exit hole was found in the top of the cap. This would have been illogical if the man was shot inside his vehicle since no blood, tissue, bone, hair, or bullet fragments were reported on the headliner above the driver's seat or inside the car except for a small bullet jacket fragment found on the back seat. No blood, hair, tissue, or fibers indicative of a bullet to the head were found. The only significant blood stains were on the ground outside the vehicle.

To confirm that the bullet would have been destabilized and distorted by passing through the rear glass, test firings were conducted using tempered glass as an intermediary target. In each of three firings into tempered glass placed in front of a cloth target, the bullets were found to fragment and their jackets separated from the cores. No round holes were produced in the secondary cloth targets.

Although the plaintiffs' expert failed to request a microscopic examination of the man's clothing, the examination was performed and numerous glass particles consistent with the glass from the cap were found. This did not seem consistent with an injury resulting from a bullet passing through the rear glass because the decedent's torso would have been protected by the front seat back.

The plaintiffs' expert created a videotape of test firings into rear windows and provided it to the author under the rules of discovery in the civil case. In reviewing the tape frame by frame, the answer as to how glass from the rear window might have reached the man's clothing as he stood outside the vehicle was found. As a bullet struck the rear window in the plaintiffs' test firings, a cloud of glass could be seen moving toward the driver side of the vehicle. It was clear that anyone standing outside the vehicle near the driver compartment would likely have been covered with glass particles. Confirmation was obtained by test firing after white sheets were spread on the ground next to the driver compartment. The sheets were recovered and examined for glass particles. Numerous glass particles were found after each test.

During the original crime scene examination, one of the investigators noticed a piece of glass lying on the rear shelf of the vehicle with what appeared to be a bullet deflection mark. Also found was a bullet jacket fragment with pulverized glass on it. This evidence indicated that the bullet that blew out the rear glass fragmented on impact as the test shot bullets had done. The bulk of the bullet deflected off the glass and never entered the interior of the car.

The fact that the driver was shot three times in the right arm was important for several reasons. First, the shots were consistent with the officer's perception that the right arm (i.e., extended out and holding a gun) was the source of the threat, just as he reported. This was confirmed through reconciliation of the decedent's wounds with the bullet holes in the right sleeve of the jacket he was wearing. The bullet holes in the jacket did not line up with the locations of the entry wounds in the right arm unless the arm was extended. Furthermore, this proved that the shot to the head could not have been the first shot, as the plaintiffs alleged because the man would have been unable to raise his right arm after the bullet passed through the left side of his brain.

The case took a full week to present. The jury deliberated less than 20 minutes before denying the plaintiffs' claim. The glass evidence, the reconciliation of the bullet holes in the jacket with the wounds to the right arm, and the other associated evidence constituted overwhelming proof that the man was standing outside his vehicle pretending to point a gun at the officer when the officer shot him.

Exercises

1. A bullet hole is found in a plate glass window. How can you determine whether the shot was fired from inside the building?

   Answer: The side that has a beveled margin is the exit side.

2. Two bullet holes are found in the windshield of an automobile. Can you determine which shot was first?

   Answer: If two radial fractures intersect, the bullet hole with the radial fracture that dead-ends into the radial fracture associated with the other hole was the second shot.

3. An autopsy report states, "No soot or powder particles were found in or around the wound." What, if anything, should be done with overlying clothes from the victim?

   Answer: Two steps should be taken. First, the clothing must be submitted to the crime lab for examination and tested for gunshot residue. Second, the bullet hole locations in the clothing must be compared to the locations of the wounds.

4. A tiny hole in a tire sidewall is found following a shootout. Based on its small size, the hole does not appear to have been caused by a bullet. Should anything further be done with the tire?

   Answer: Yes, the tire must be removed from the rim to determine whether a bullet or bullet fragments can be located. The small hole may well have been produced by a small caliber bullet such as a 22.

5. In a shooting incident involving a vehicle, a question arises whether a particular individual was standing near a vehicle during the shooting. The windshield of the vehicle was struck numerous times by

bullets. What, if anything, can be done to attempt to determine the man's proximity to the vehicle?

Answer: The man's clothing must be collected and submitted to the crime lab along with a sample of glass from the windshield. The impact of a bullet on glass produces a shower of tiny glass fragments that may be deposited on the man's clothing if he was standing near the windshield when the bullets struck.

6. A police officer stated that he was standing in the proximity of the front of a vehicle as he attempted to get a suspect out of the vehicle. The officer also said the suspect started the vehicle and began driving toward him. He said he then shot the left front tire in an effort to stop the vehicle. How effective would that have been?

   Answer: Shooting a tire will cause all but "flat-proof" tires to go flat eventually. The reality, however, is that 10 to 15 seconds or more would be required. The officer would not have been able to prevent the vehicle from striking him by that action alone.

7. During a shooting incident, a glass door of a vehicle is shot out by an officer. Broken glass from the door is found in the street several yards from the officer's stated position. Is the officer lying or is it possible he does not recall his actual position?

   Answer: Probably neither is true. Glass in vehicle side windows shot through in the course of a shooting incident will often hold together as the vehicle continues to travel along. Ultimately, a vibration or secondary impact will likely cause the glass to finally fall out. Thus, it is not uncommon for glass to be found at a position different from the point of bullet impact.

8. A bullet hole is found in a tire sidewall. It is determined that the bullet actually passed through both sidewalls and exited to an unknown location. An abraded margin is apparent at the exterior bullet hole. The hole measures approximately 3 mm across. The abraded area has a diameter of approximately 10 mm. What can be said about the bullet that passed through the tire?

   Answer: The hole in the sidewall that measures 3 mm in diameter suggests that the bullet that produced it had a hollow point. As far as the abraded area is concerned, the best that can be surmised is that the bullet that produced it did not have a diameter considerably greater than 10 mm.

Suggested Readings

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10

Bullet Ricochet Phenomena

Ricochets are common in shooting incidents, particularly those that occur outdoors. In order to reconstruct shootings in which ricochets are involved, one must understand the phenomenon and be able to recognize the indicators of directionality that may be present. Although ricochet studies have been conducted on a wide variety of substrates and reported in the literature, specific information about directionality determination and related evidence that may be present has been minimal. A review of the basics of ricochet phenomena is helpful for facilitating a discussion of the information that may be offered to the watchful eye of an investigator. First, a few working definitions are essential.

Terms Associated with Ricochets

Ricochet A change in angle and/or direction of a fired bullet **or** pellet as a result of impact with a substrate.

Ricochet mark A two-dimensional effect without discernible depth (such as a ricochet off an automobile windshield without surface penetration).

Ricochet crease A three-dimensional effect with discernible depth (such as a ricochet off an automobile hood).

Angle of impact The angle of incidence of the impinging bullet or pellet to the substrate.

Angle of deflection Lateral deflection (left or right) of a ricocheting bullet or pellet.

Angle of ricochet Angle of departure of **a** departing bullet **or** pellet as it leaves a substrate.

Critical angle Angle at or below which a ricochet would be expected for a given bullet **or** pellet and a given substrate.

Frangible surface Surface that is subject to crumbling or breaking upon application of force, e.g., asphalt or concrete.

Non-frangible surface Surface that tends to bend or stretch upon application of force, e.g., sheet metal.

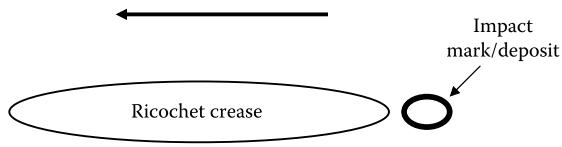
Producing Ricochet

Ricochet is a phenomenon of low rather than high velocity. This is because high velocity bullets, such as a 223 caliber traveling at 2800 feet per second, have a propensity to fragment upon impact rather than be deflected. This, of course, depends on the bullet design and composition, substrate composition, and other variables. We generally expect large, slow-moving bullets to be deflected off various substrates more frequently than small, high-velocity bullets. As always, exceptions will arise, depending on the specific circumstances. Although ricochet phenomena are most often discussed for bullets, pellets and shot can ricochet off surfaces as well.

In order for a bullet or pellet to ricochet off a given substrate, it must impinge at or below the critical angle (the angle at or below which a ricochet is predicted). The critical angle must be determined for a particular bullet and substrate through testing. The literature contains published studies concerning critical angle determinations. However, for them to have specific value to an investigator involved in reconstructing a shooting, that same substrate, bullet, cartridge, and weapon used in the incident would have to be used. The chances of having all those identical components available are fairly slim.

With regard to the appearances of bullet ricochet marks and creases, a few general statements may be made.

- Ricochet marks and creases may be produced on virtually any surface.
- The harder the surface, the smaller the ricochet angle.
- The lower the angle of impact, the longer the ricochet mark **or** crease.
- The lower the angle of impact, the more likely that a mark rather than a crease will be produced.



Structure 10-1

Directionality Based on Point of Impact

Directionality of travel from ricochet marks or creases can often be ascertained by a variety of indicators. Bullets and pellets often leave visible deposits of lead and/or copper at the points of initial impact for ricochet creases or marks. These deposits serve as ready sources for establishing directionality. Structure 10-1 shows a distinctive impact mark or deposit.

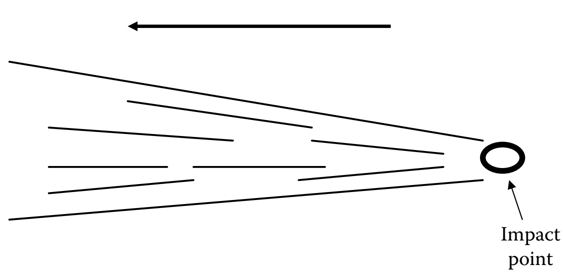
Other Indicators of Directionality

V Shape

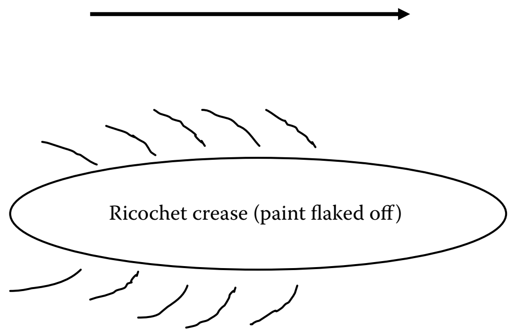
When lead or lead-nosed bullets and lead pellets produce ricochet marks by striking hard surfaces at very low angles, the shapes of the marks can aid in determining shot directionality. A V-shaped deposition of lead may be present. The shot directionality goes from the vertex of the V toward its top. This pattern is a result of the ever-increasing contact between the bullet or pellet with the substrate and the resultant deformation of the bullet or pellet. This effect tends to be more pronounced for bullets as compared to shot pellets as a consequence of shape (elongated versus uniform) as represented in Structure 10-2.

Fracture Lines on Painted Surfaces

When painted metal surfaces are impacted by bullets or pellets, stress fractures will often be produced. Shot directionality is often easy to ascertain



Structure 10-2



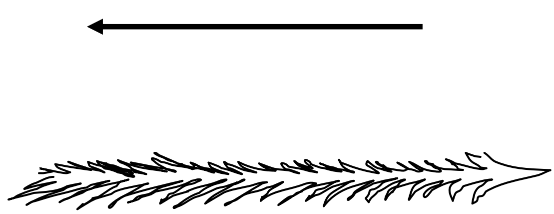
Structure 10-3

from the fracture line patterns. The direction of force will, of course, be the same as the shot direction. As the force emanates through the paint layer, it produces cracks resembling a wake coming off the hull of a boat moving through water.

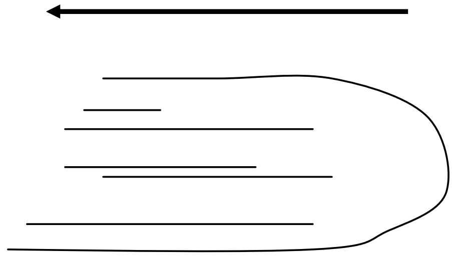
Even when all the paint flakes off in the immediate area of the ricochet crease, stress marks may be visible at the outer margins of the ricochet crease. This phenomenon is represented in Structure 10-3.

It is also possible for a stress fracture pattern to appear on the underside of a ricochet crease in painted sheet metal. An interesting phenomenon can be observed in these cases. A "reversed directionality" or "Christmas tree effect" of the stress fracture pattern is produced, as shown in Structure 10-4.

The "reverse directionality" phenomenon on the underside of bullet or pellet ricochet creases on painted sheet metal can be extremely useful if it is difficult to establish shot directionality for the upper surface. Of course, gaining access to the under-surfaces of bullet ricochet creases can be complicated by the structure of the material and/or the presence of other obstacles. This is particularly true with vehicle body panels that usually have structural bracing. Nonetheless, this is something that an investigator should be aware of and look for when possible. Remember, the bullet direction is "down the free."



Structure 10-4



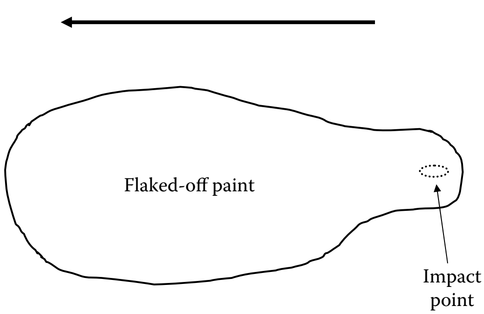
Structure 10-5

"Classic" Ricochet Mark

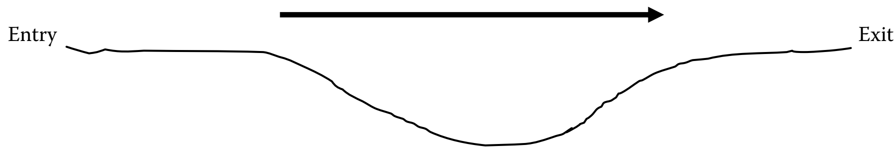
The rounded edge of a ricochet crease or mark is a good indicator of directionality. This is the point at which the bullet first impacts the substrate and begins to change course. The rounded edge will define the directionality of the ricochet. This is probably the most commonly seen ricochet mark for round-nosed lead bullets. See Structure 10-5. In the event that the ricochet mark or crease is uniform in appearance (both ends look the same) and no other indicators are present, the directionality must be classified as indeterminate.

"Pear" Effect

Ricochets off painted sheet metal structures such as automobile body panels often produce paint flaking in a pear shape. The directionality will be from the top of the pear toward the bottom. Lead and/or copper transfer at the point of impact may also be present to simplify the determination of directionality. Even when true pear shape flaking is not present, more paint will typically be missing on the exit end of the ricochet crease (ricochet marks typically do not produce paint flaking). The direction of force will be the same as the direction of bullet travel. The source of this particular phenomenon is simply the mechanical disruption of the paint by the impacting bullet. Thus, more paint will be typically lost on the exit end due to the force going in that direction (Structure 10-6).



Structure 10-6



Structure 10-7

Ricochet Crease Profiles

The profile of a ricochet crease may aid the investigator in establishing directionality. For non-frangible surfaces such as sheet metal, bullet impact produces stretching of the metal. This stretching results in the greatest depth at the exit end of the ricochet crease. This profile is represented in Structure 10-7. With frangible surfaces, such as asphalt, the greatest depth is typically at the entry end. The impacting bullet dislodges bits of the frangible substrate and pushes them forward. Thus, the exit end has less depth than the entry end as illustrated in Structure 10-8.

Ricochet with Partial Penetration

Due to the thin sheet metal now used in the manufacture of automobiles in the interest of reducing weight for improved fuel economy, bullets often show partial penetration along with ricochet. Other substrates, such as windshields, may show this phenomenon as well. If a bullet fragments, a portion may actually penetrate the substrate. When partial penetration of a steel vehicle body panels occurs, the inner surface of the ricochet crease will usually have metal “fingers” that point in the direction of travel of the bullet. In other words, the bullet pushes the torn edges of metal in the direction it travels, as shown in Figure 10.1.

Internal Ricochet

It is not uncommon for a bullet to penetrate a vehicle body panel, only to strike an internal brace or other obstruction and ricochet internally. This is obvious due to the protrusion created. The “Christmas tree” effect previously

Structure 10-8

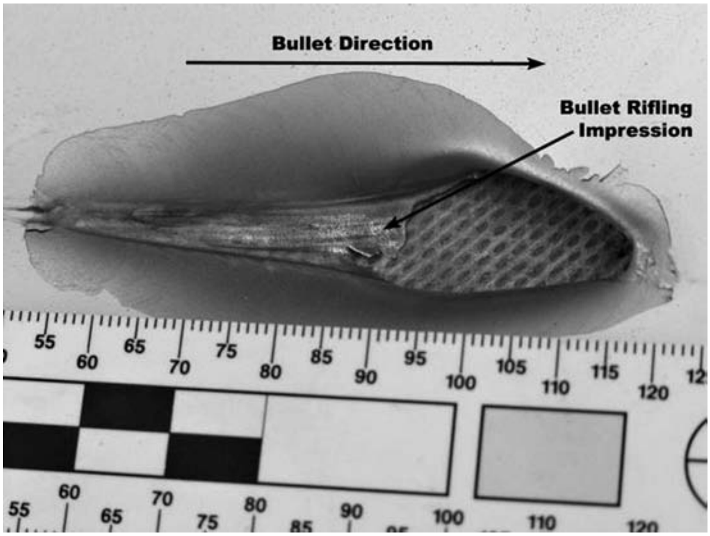


Figure 10.1 Ricochet with partial penetration.

described may be visible but usually no determination as to directionality is possible without the ability to view the internal surfaces of the panel.

Ricochets off Glass

Both creases and marks can be produced by bullets ricocheting off glass. This phenomenon is typically observed only on safety plate (laminated) glass of the type found in vehicle windshields (Figure 10.2). The tempered glass normally used on the sides and rears of vehicles is designed to shatter into small rectangular solids upon impact and thus does not typically allow visualization of ricochet marks and creases although they can sometimes be found.

Ricochet creases in glass will sometimes produce a "jellyfish" effect on the stress cracks that may allow directionality to be established. The theory is simply that the stress cracks follow the force direction as illustrated in Structure 10-9. In some cases, stress cracks are circular (surrounding the impact area), making directionality determination on this basis impossible.

Ricochet marks on glass are frequently hard to locate and rather fragile (rubbing across them can obliterate them). Figure 10.2 illustrates a ricochet mark on glass.

In one case in the author's experience, however, a very prominent ricochet mark was produced on tempered glass by a 45 Federal Hydra-Shok©

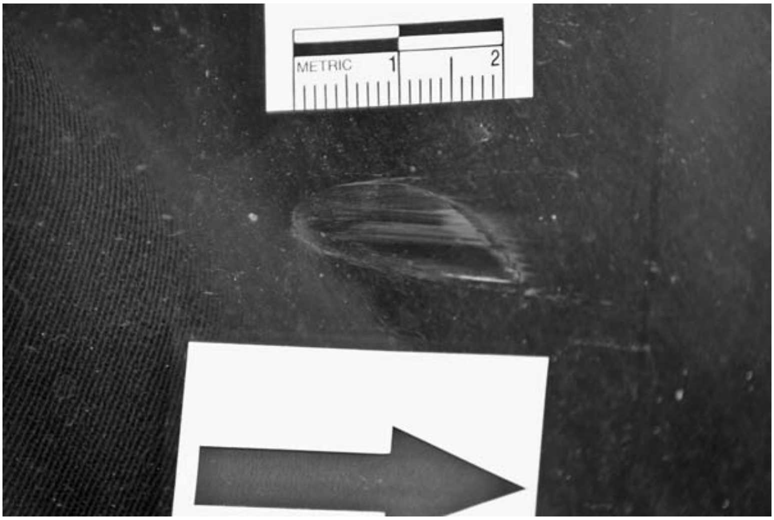
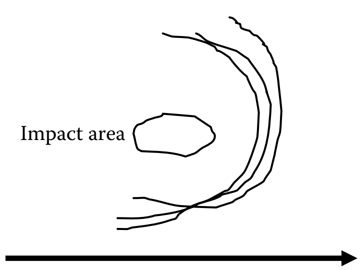


Figure 10.2 Ricochet mark on glass.

that resulted in the transfer of both copper and lead. Directionality was clear from the classic rounded edge at the point of impact. Unfortunately, the crime scene examiner who astutely recognized the significance of the mark and collected the fragment of glass that contained it was unable to determine its original orientation in the rear glass. This rather unique mark is seen in Figure 10.3.

Perhaps even more surprising than the actual persistence of this particular mark on tempered glass is the existence of what appears to be individual characteristics transferred from the rifling marks on the bullet that produced the mark. This particular subject is discussed in the next section.



Structure 10-9

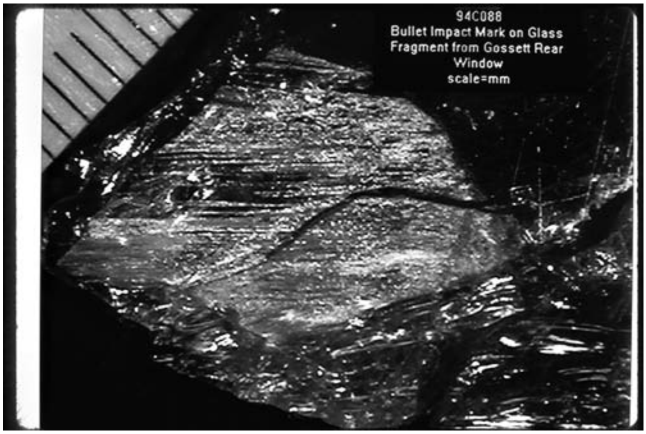


Figure 10.3 Unique ricochet mark on glass.

Direction of Twist Determination from Ricochet Mark

Bullets fired from rifled weapons will rotate either clockwise or counterclockwise, depending on the direction of twist of the rifling in the barrel. It is possible to distinguish twist direction from ricochet marks produced on certain surfaces and accurately predict shot direction.

Figure 10.4 shows the ricochet mark associated with the particular rifling present in the barrel of a weapon. Such marks are most often found on hard surfaces such as steel or concrete. To assess these types of ricochet marks, the investigator should look directly above the mark. The dashed lines represent the axes of the two marks. Bullets with right twists produce ricochet marks with "tails" to the right of the long axis. Conversely, bullets with left twists produce tails to the left of the long axis of the ricochet mark (Figure 10.4).

The tails observed for ricochet marks are consequences of flattening of the bullet by the initial impact with a substrate and the continuing rotation of the bullet as it departs the substrate. Figure 10.5 depicts a view directly into the nose of an oncoming bullet as it starts to depart (ricochet off) the substrate. Note the flattening on one side caused by the impact with the substrate.

The lateral deflection of a bullet in correspondence to the rifling direction of the barrel from which it is fired is readily observed in water traps for test fired bullets. Firearms examiners find that bullets with right twists tend to deflect to the right in a water trap and the reverse applies to bullets with left twists. This can also be demonstrated graphically using tracer ammunition such as the readily available Hornady Vector™ to produce

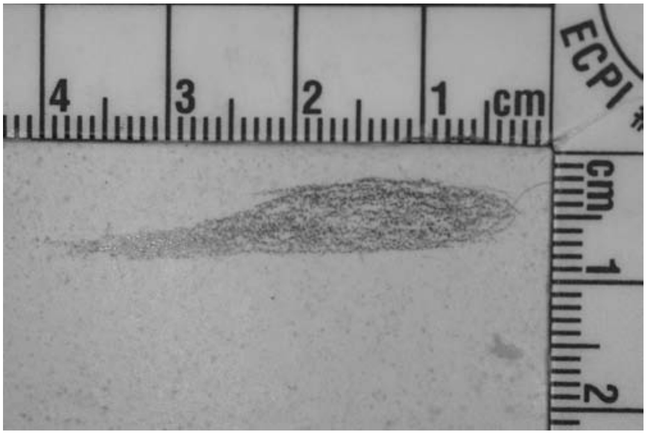


Figure 10.4 Ricochet "tail" mark.

ricochets with visible paths. Figure 10.6 illustrates lateral deflection in a single plane.

It is fairly common to find rifling marks left in ricochet marks or creases in a variety of substrates. The author has been involved in several cases in which rifling marks found in ricochet creases were used to include certain weapons as having possibly fired the ricocheting bullet and to exclude others. It remains to be seen whether a genuine identification from a ricochet mark or crease is possible.

This phenomenon appears most often when painted metal surfaces are involved. However, as described in the section on ricochets off glass, these general rifling characteristics can and do appear on various substrates and should always be sought by an investigator. Remember that a ricochet mark

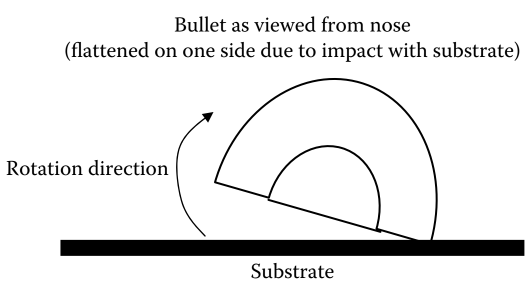


Figure 10.5 Production of ricochet "tail" mark.

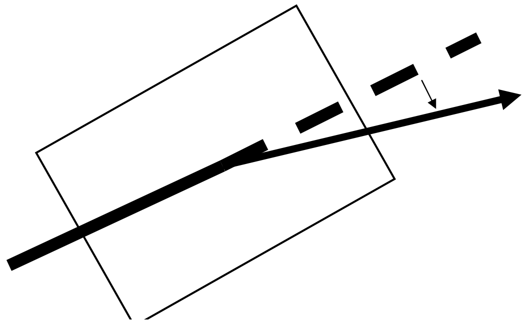


Figure 10.6 Lateral deflection of ricocheting bullet with right twist.

or crease is actually a negative of the bullet surface. Thus, when rifling impressions can be seen, the direction of twist seen in the ricochet crease or mark will be the opposite of the twist direction of the bullet that created it, as illustrated in Figure 10.7.

The documentation of rifling in bullet ricochet marks or creases requires photography of the evidence along with a casting of the mark or crease using Mikrosil™ or another suitable casting medium. This is necessary in order for the firearms examiner to properly measure the rifling dimensions and can also be useful in determining directionality by providing profile information. This is particularly critical for ricochet creases because they are three-dimensional.

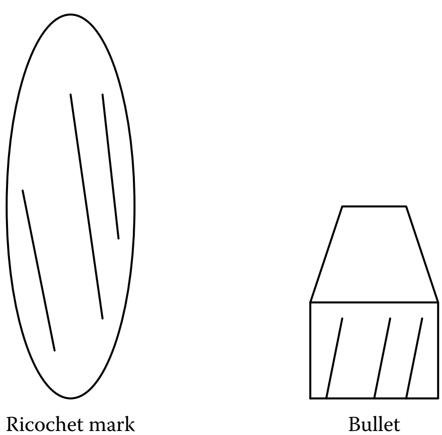


Figure 10.7 Rifling marks on ricochet crease and the bullet that produced them.

Taking a photograph and failing to make a casting would fall short of properly documenting the evidence.

Establishing Critical Angles

It may be necessary to establish the critical angle for a given bullet and substrate combination. This is done through field testing in which the weapon involved in the shooting under investigation is fired using cartridges or shot shells like those used in the shooting. Use of a portion of substrate from the actual shooting scene is preferable, but a similar substrate may be used if necessary.

Other equipment required includes a machine rest for the weapon (Zero One™, Ransom Rest™ or other), a table or fixture to hold the substrate in place, and a target or witness panel. It is typically easier to mount the weapon in the machine rest, place the assembly perpendicular to the substrate, and adjust the angle of impact at the substrate rather than adjust the angle at the weapon as shown in Figure 10.8. The substrate is adjusted to the desired angle by placing blocks or shims under one end. The line of fire is perpendicular to the front edge of the substrate and parallel to the plane of the fixture or table used to hold the substrate. An initial setting of the angle of impact is tried. If the bullet ricochets, the angle of impact is increased until

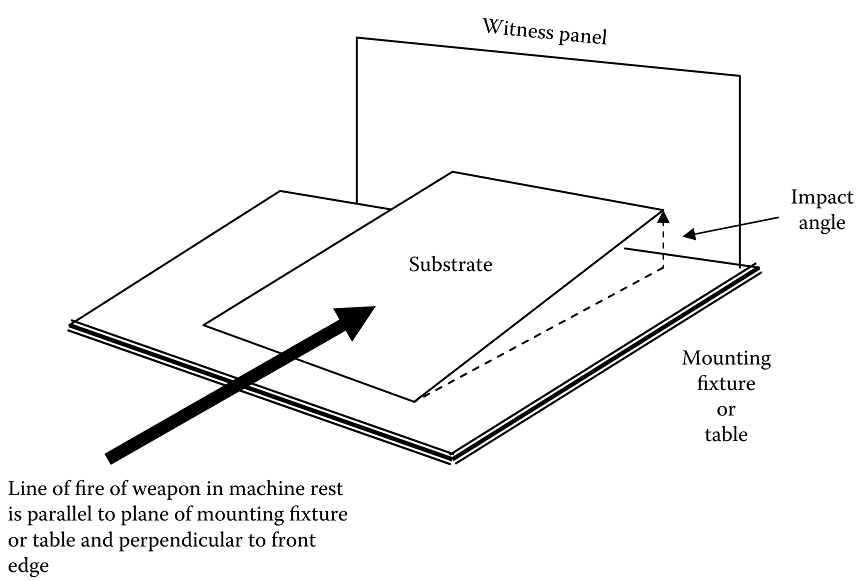


Figure 10.8 Set-up for determining critical angles.

penetration occurs. If the first shot results in penetration, the angle of impact is decreased until ricochet occurs. Once an angle that reliably produces ricochets has been established, the critical angle has been ascertained.

Establishing Ricochet Angles

By definition, a ricochet angle is the interior angle between the axis of the departing bullet and the substrate. This angle may be determined simply by placing a witness target or panel behind the substrate that produces ricochet. The height of the hole produced in the witness panel above the plane of the substrate forms one of the legs of an imaginary triangle used to determine the angle of ricochet as illustrated in Figure 10.9.

As an example, suppose we wish to determine the ricochet angle of a Federal 38 Special round-nosed lead bullet off a 1/2-inch steel plate when fired from a Smith & Wesson model 36 revolver at an impact angle of approximately 10 degrees. We would set up the steel plate on a suitable table at the shooting range along with the weapon in a Ransom Rest mounted on a rotatable table that would allow adjustment of the axis of the bore of the weapon to 10 degrees (this can be measured using an angle gauge). We use a piece of cardboard as a witness panel and place it perpendicular to the steel plate, then fire a series of three shots, replacing our target (witness panel) after each series. We then measure the heights of each of the three holes in the witness panels above the plane of the steel plate. The distance from the ricochet crease to the witness panel represents the second leg of the right triangle we will use to determine the ricochet angle as shown in Structure 10-10. X represents the distance from the end of the ricochet mark or crease to the target panel. Y equals the height above

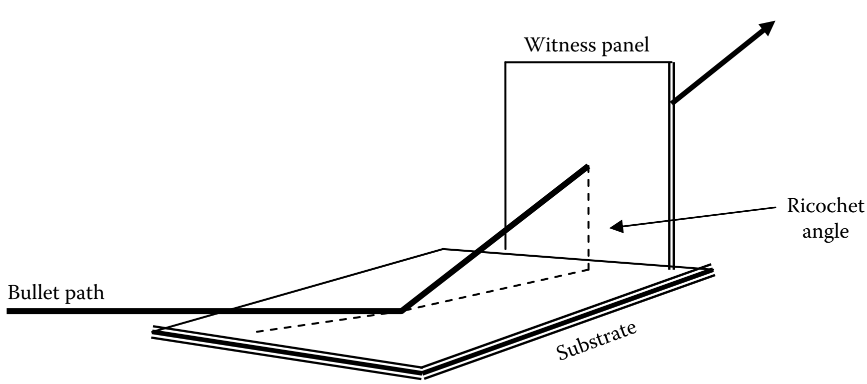
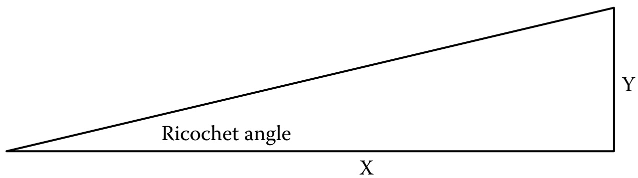


Figure 10.9 Set-up for determining ricochet angles.



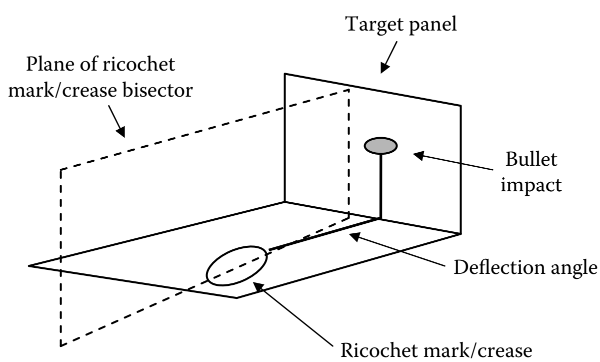
X = Distance from end of ricochet mark/crease to target panel
Y = Height above plane of substrate to hole in target panel
Ricochet angle = Arc tan of Y/X

Structure 10-10

the plane of the substrate to the hole in the target panel. The ricochet angle equals the arc tangent of Y/X.

Establishing Deflection Angles

The deflection angle is the lateral deflection of the bullet trajectory axis upon ricochet. This deflection will be to the left or the right, depending on bullet rotational direction. A general directional determination is typically all that can be reliably determined in terms of deflection. If, for some reason, it is necessary to determine the deflection angle, the same type set-up used for ricochet angle determination could be used. A bisecting line would be drawn through the ricochet mark or crease. The intersection of the plane of the target panel with the perpendicular plane containing the bullet ricochet bisector allows determination (measurement) of the angle of deflection. See Structure 10-11.



Structure 10-11

Establishing Shooter Position

In order to establish shooter position for a ricochet mark or crease, we must determine the angle of impact. When the ricochet mark or crease is fairly uniform in shape, the calculation of the angle of impact can be made based upon the length and width of the mark or crease according to the relationship

$$\text{Angle of impact} = \text{arc sin width/length}$$

If the ricochet mark or crease is asymmetrical, a best-fit oval can be approximated but the results obtained will be affected accordingly. As always, test firing to duplicate the questioned evidence is highly desirable and provides the most reliable results.

Once an angle of impact has been approximated for a ricochet mark or crease, the shooter's height, dominant hand, and weapon position must all be considered in establishing approximate shooter position. When no information is available to the contrary, the assumption that the shooter used his dominant hand to pull the trigger and held the weapon in a typical position must be made. Appropriate caveats must be included in all associated opinions formed.

The use of a scale drawing and/or reenactment simplifies the determination of approximate shooter position. When conducting a reenactment, appropriate documentation in the form of photographs and videotapes should be included. As always, it is incumbent upon the investigator to consider all possible positions — not only the one that happens to fit a particular theory. In most cases, some positions are more probable than others.

Documentation

In summary, it is possible by recognizing various indicators to reliably establish bullet directionality from resultant ricochet marks and creases. It may also be possible to determine general rifling characteristics from the same ricochet marks or creases. Proper documentation of marks or creases consists of taking photographs and making casts. Casts of the creases or marks should be submitted to a qualified firearms examiner for comparison with similar casts of the interior surfaces of the barrels of suspect weapons.

It must be emphasized that the various phenomena presented are merely possibilities that should be considered. Never assume that any or all of the various indicators will always be present. The specific appearances of bullet creases and marks will always depend on a number of variables that include bullet design or composition, substrate, texture or hardness, angle of impact, critical angle, and bullet impact velocity.

Evidence of Ricochet

A field investigator should seek a number of items to serve as evidence that a ricochet was involved in an incident. The first is a bullet with a flat side. Bullets frequently are found lying on a floor or on the ground at crime scenes. Every bullet should be inspected for evidence of flattening indicative of a ricochet. Trace evidence consistent with a particular substrate may be found on bullet surfaces and may provide the identity of the substrate that produced the ricochet. Examples include wood, paint, sheet rock, and asphalt. Irregular wounds and bullet holes are other indicators of possible ricochet. Flattened, destabilized ricocheting bullets will produce irregular wounds in bodies and irregular bullet holes in inanimate objects. When these are apparent, the investigator should consider the possible responsibility of a ricochet.

Case Study

A man carrying a rifle was seen getting out of his vehicle at a housing project in Oklahoma. He walked from the parking lot into a quadrangle area between the residential buildings. Once inside the quadrangle, the man was confronted by a group of young men. According to the man, he fired several shots into the ground to "hold them back" before running back to his car and leaving. Following the confrontation, a 12-year old girl was found on the ground behind the crowd shot dead. She had a large, irregular entry wound above the right eye.

At autopsy, a 7.62-mm steel-jacketed bullet with a steel center post (Chinese manufacture) was removed from the child's brain. The bullet was observed to have a flattened side. The bullet was consistent with 7.62 × 39 Norinco brand cartridge cases found at the scene. An SKS rifle was later recovered from the suspect when he was arrested.

Investigators found four apparent bullet strikes in the ground in the area between where the suspect and the group of men stood. Two bullets recovered from the ground in the area were similar to the bullet removed from the victim. No bullets or bullet fragments were found around the other two marks in the ground.

After examining the physical evidence and reviewing the circumstances of the shooting, several observations were made. First, the wound in the victim's head should have been small and circular not large and irregular as it was. Second, the bullet had a steel center post and a steel jacket and should have passed through the child's head rather than being stopped within her skull. The fact that the fatal bullet was flat on one side provided further evidence that a ricochet was responsible for the child's death.

A reconstruction of the shooting was conducted at the scene. This was accomplished by using the position of the girl's body, the location of the bullet

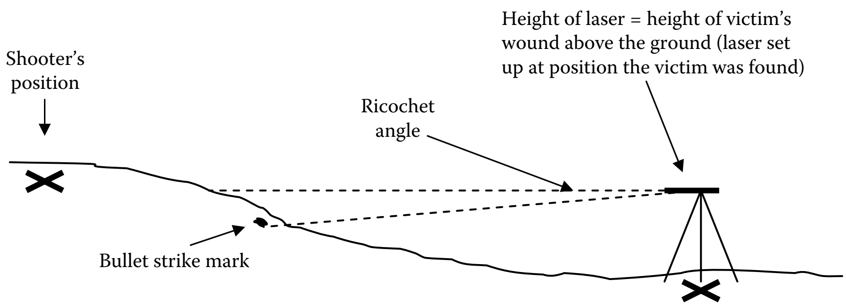


Figure 10.10 Tripod-mounted laser used for determination of ricochet angle.

strikes in the ground, and what witnesses said was the position of the shooter. Using an individual of the same height as the shooter and pointing the rifle at the area of the bullet strike marks, it was determined that a ricochet angle of 5 degrees would have been required in order for the bullet to hit the victim.

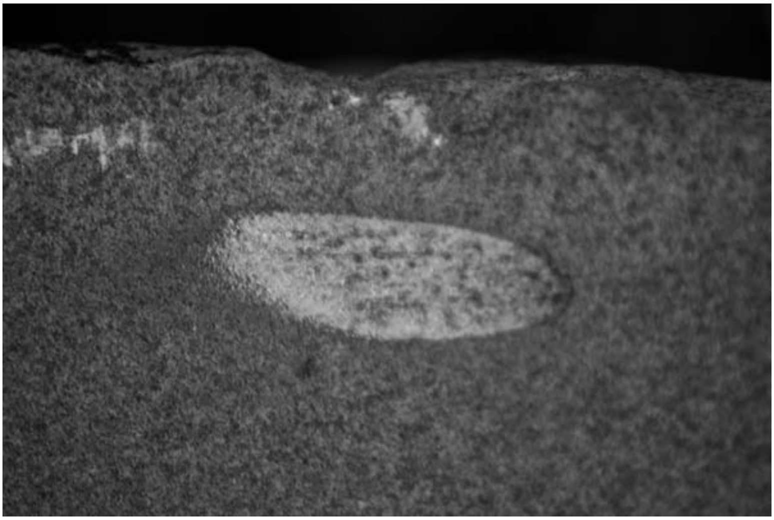
The methodology used involved setting up a tripod-mounted laser at the location of the victim. The height of the laser was adjusted to the height of the victim's wound above the ground. In the absence of information to the contrary, the assumption was made that she was standing upright. Figure 10.10 illustrates the set-up. An angle gauge was placed on top of the laser in order to determine the ricochet angle. As indicated in the figure, the laser was first set parallel to the ground (zero degrees on the angle gauge), then rotated down to the bullet strike mark (ricochet mark) and the angle read directly from the gauge.

The angle was entirely consistent with a ricochet. When this information was combined with the other facts of the case, it became clear that a ricochet had indeed taken place. Of course, the shooter was still a long way from an innocent party, having come to the housing project with a weapon and having fired shots. He was charged with and convicted of manslaughter after the findings were revealed to the prosecutor.

Exercises

1. For each of the following ricochet mark or crease images a through h, determine the directionality (right to left or left to right) and indicate what specific markers of directionality you used to arrive at that determination.

   Answers: a, b – right to left (rounded edge on right)
   c – right to left (pear shape)
   d – right to left (dark side on right)
   e – right to left (dark side on right)
   f – left to right (rounded edge on left)
   g – left to right (rounded edge on left)
   h – right to left (rounded edge on right)

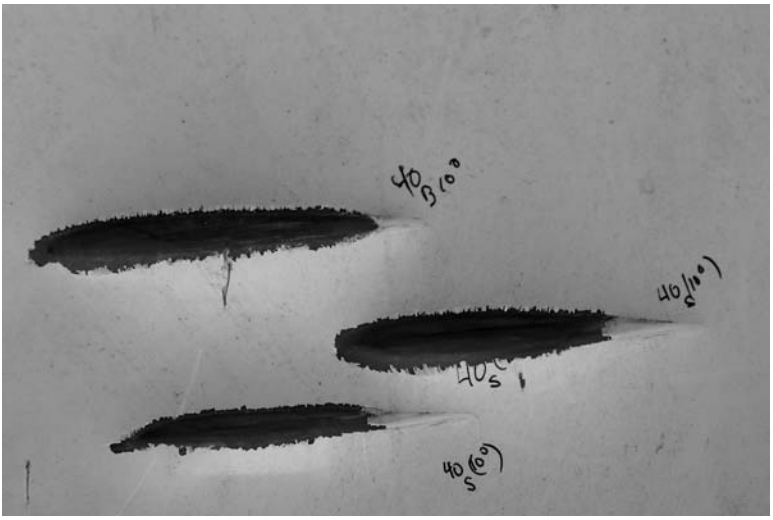


(a)

2. For each of the following ricochet mark or crease images a through h, determine the direction of twists of the barrels used to fire the bullets that produced them.

   Answer: F – both left to right; top is left twist; bottom is right twist. G – left to right; right twist. H – right to left; left twist.

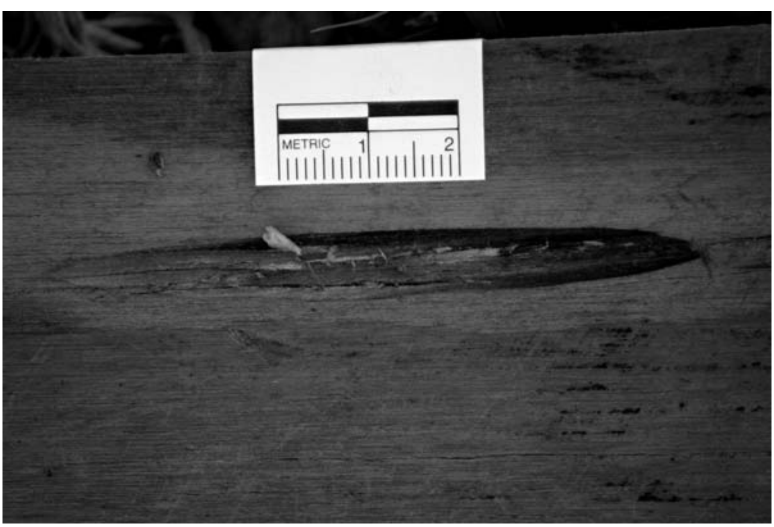
(b)



(c)

3. A bullet ricochets off the hood of a police patrol vehicle and you wish to determine the directionality of the bullet that produced the ricochet. An examination of the ricochet crease fails to reveal any indicators of directionality. Is there anything else you can do?

   Answer: Attempt to look at the underside of the ricochet crease in the hope of finding the "Christmas tree" effect and, thus, determine the directionality of the shot.

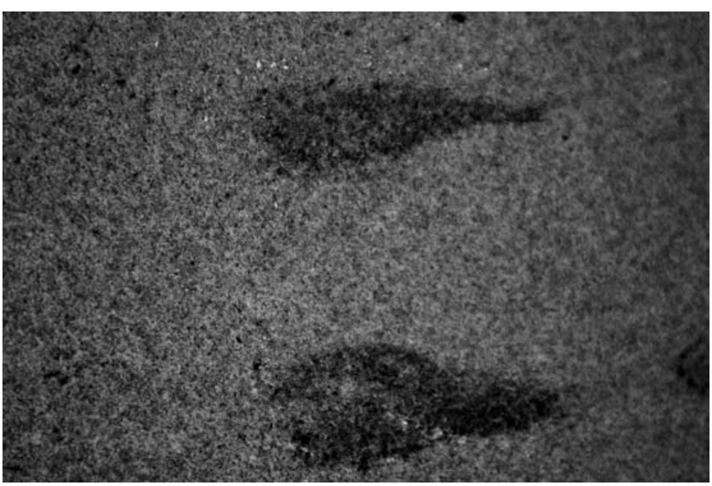


(d)

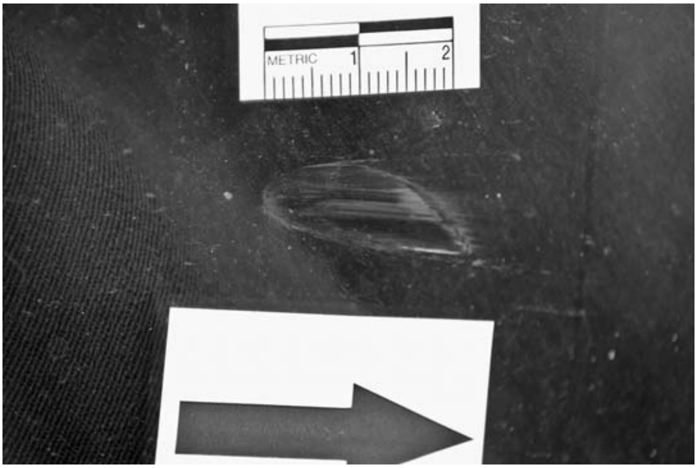
(e)

4. An investigator locates an apparent ricochet pattern on smooth concrete. The pattern was produced by a shotgun firing 00 buckshot. The individual pellet ricochet marks are all teardrop-shaped and more or less symmetrical. Why? Can directionality be established?

   Answer: Since buckshot is spherical and has no left or right rotation, the resultant ricochet mark should be symmetrical. Directionality may be established by carefully examining for signs of initial impact in the form of heavier lead deposits at one end.



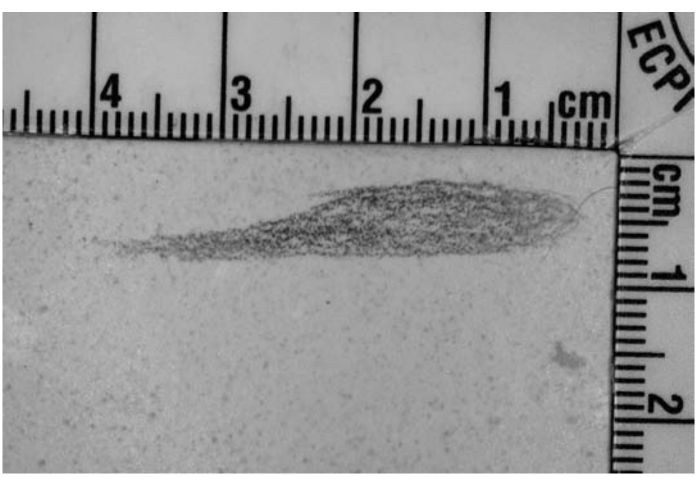
(f)



(g)

5. A ricochet mark on a section of hardwood flooring is observed to be symmetrical in shape. The length of the long axis is found to be 51 mm and the length of the short axis is found to be 11 mm. What was the approximate angle of impact for the bullet that ricocheted?

   Answer: Angle of impact = arc sin of width/length = arc sin of 11/51 = 12 degrees.



(h)

Suggested Readings

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11

Bloodstains and Blood Spatter at Shooting Scenes

Blood Characteristics and Drop Formation

Bloodshed is an expected consequence of a shooting. The locations of the resultant bloodstains and their sizes and shapes can provide useful information about the events of the shooting. In order to properly assess the bloodstain evidence associated with a shooting incident, the investigator must have at least a basic understanding of bloodstain pattern analysis so that appropriate documentation can be prepared. The documentation allows someone with the appropriate training and experience to evaluate the evidence. Ideally, someone who has that expertise will be present at the shooting scene to make first-hand evaluations. Some basic facts that all criminal investigators should know about blood include the following:

- The average adult human body contains 5 to 6 liters of blood.
- Blood consists of a combination of solids and a liquid containing dissolved gases.
- The liquid portion of blood is called plasma and constitutes about 55% of the volume.
- The solid portion includes red cells, white cells, and platelets.
- Red cells transport oxygen via hemoglobin.
- White cells fight infection.
- Platelets form clots to stop blood losses from breached veins and arteries.
- The liquid remaining after the solids separate is called serum.

- Blood is red because of the red cells and the presence of oxygen molecules.
- Blood darkens as it ages and loses oxygen.
- Blood is about six times as viscous as water.
- Blood drops are spherical in flight; actually they are oscillating spheres.
- Blood striking a surface at approximately 90 degrees produces circular stains (the smoother the surface, the smoother the stain edges).
- Blood striking a surface at fewer than 90 degrees produces elongated stains.
- Direction of travel of a bloodstain is indicated by the shape of the stain; the direction of travel is from the large end toward the small or irregular end.
- Bloodstains resulting from impacts at fewer than 90 degrees (Figure 11.1) have three general shapes, depending largely on the substrate surface texture and angle of impact.
- The angle of impact for a bloodstain equals the arc sin of stain width divided by stain length (IA = arc sin width/length).

As noted earlier, the angle of impact calculation for a bullet hole or ricochet mark or crease is calculated the same way as the angle of impact of a bloodstain.

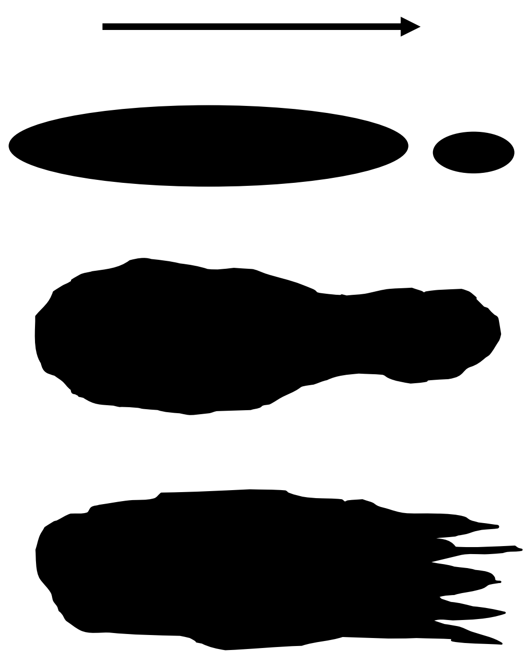

Figure 11.1 Basic bloodstain shapes impacting surfaces at fewer than 90 degrees. All stains travel left to right.

As with bullet holes and ricochet marks and creases, non-symmetrical bloodstains must be approximated as to the "best-fit oval."

Thus far, this text has stressed the importance of experimentation and testing for final confirmation of theories developed via incident analyses and reconstructions. It also stressed the importance of duplicating the circumstances of the incident as closely as possible. This is particularly true in cases involving blood because of its unique properties. Simply substituting water containing red food coloring will not work in a test intended to determine the behavior of blood. This is apparent in a comparison of the physical characteristics of blood and water:

Parameter	Water	Blood
Density (g/ml at 4°C)	1.0	1.1
Specific gravity	1.00	1.06
Viscosity	1	6
Surface tension (dynes/cm)	72.5	50

Significant differences between the viscosities and surface tensions of water and blood are apparent. The intermolecular forces of attraction involved for the various components of blood account for these differences. The old saying that "blood runs thicker than water" clearly has a scientific basis. Viscosity is directly related to liquid flow rates. The greater the viscosity of blood means it will flow at a much slower rate than water.

In order for a drop of blood to form, gravity must overcome the surface tension that holds the blood together in one mass and overcome the forces of attraction between the blood and the surface. In effect, this means a drop will form and break away whenever its weight is sufficient to overcome the forces of attraction that tend to hold it together. This can be aided by external forces such as shaking, slinging, or an abrupt halt in the swing of a blood-covered object.

In terms of drop formation as a result of impact on a blood source, the greater the force, the smaller the size blood drop that will be produced. From a mathematical perspective, this is an inverse relationship. Accordingly, a small force imparted to a blood source, such as stepping into a blood pool, produces relatively large bloodstains.

With regard to distance of travel for blood spatter, the smaller the size of the spatter, the shorter the distance of travel from the source (this is a direct relationship as opposed to an inverse relationship). A good way to present this concept to a jury is to make an analogy to a garden hose with an adjustable spray nozzle. Most people are aware that the fine mist adjustment of the spray nozzle will not project water nearly as far as a coarse or stream setting. The reason, of course, is that the larger volume drops have more mass and, subsequently, more momentum with which to resist gravity and air friction. Hence, they are able to travel farther from their source in any direction.

Blood Spatter Associated with Firearms Injuries

At this point, it may be helpful to clarify terminology. The result of a force acting on some blood source is termed *spatter*. This term is frequently erroneously used interchangeably with *splatter*. Perhaps the best distinction that can be made is to note that *spatter* is a noun and *splatter* is a verb. Spatter is the result of the action or force.

The forces that act on blood sources to produce spatter are generally categorized as low, medium, or high velocity. Low velocity events include dripping blood or any blood traveling with a velocity no greater than approximately 5 feet per second or slower. Low velocity stains are generally 3 mm or larger in diameter. The satellite spatter resulting from blood dripping into blood holds a potential pitfall for the unwary and will be discussed later in this chapter.

Medium velocity impact spatter is typified by blunt force trauma such as a blow from a club. The resultant stains are on the order of 1 to 3 mm in diameter. The wielding of a club can also produce cast-off blood if the weapon becomes covered with blood and continues to be used. Distinctive linear patterns are often present and enable the analyst to accurately propose the source of production.

In a shooting, we deal with bullets impacting blood sources (human bodies) at high velocities (more than 200 feet per second). The resultant drops tend to be quite tiny (of the order of a pin head or smaller) and are best described as forming an aerosol mist. This high velocity impact spatter (HVIS) should be looked for whenever a shooting incident is investigated. However, the absence of HVIS can be due to a number of reasons. Heavy clothing, hair, and other intervening objects can prevent its deposition on objects in proximity to the victim. The tiny droplets can simply be indistinguishable when they fall on dark objects. They can be hidden in the fibers of deep pile carpet or on debris-covered floors or the ground.

When HVIS is deposited on someone or something as a result of a gunshot, it is typical to also find larger size stains that do not fit the accepted criteria for HVIS (stains 1 mm in diameter or smaller). This can be disconcerting to an investigator who is not experienced in bloodstain pattern analysis. What must be kept in mind is that secondary spatter that is greater in size will frequently also be present as a result of the forces of bullets, combustion gases, and or pre-existing wounds. The determining factor with regard to designating a particular stain HVIS is whether the preponderance

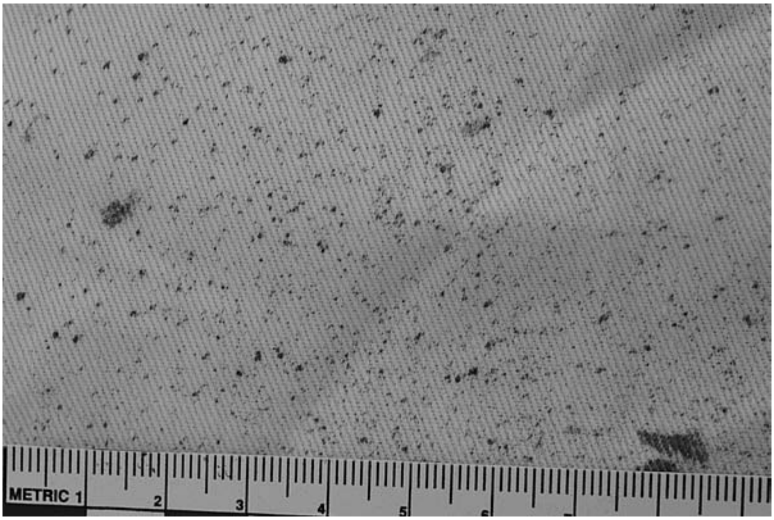

Figure 11.2 High velocity impact spatter from gunshot.

of the individual stains is 1 mm or smaller in size. Figure 11.2 illustrates a typical stain resulting from a gunshot.

Four situations may produce the aerosol mist along with larger sized stains, bits of tissue, and skin. These include (1) entrance wounds, (2) exit wounds, (3) pre-existing bloody wounds, and (4) a muzzle blast within close proximity to a blood source.

As a point of clarification, our previous descriptions referred to stain diameter as the main criterion for categorizing the responsible dynamic (low, medium or high velocity). However, many stains are produced when blood strikes a surface at less 90 degrees and thus produces an elongated stain. Accordingly, the stain width or short axis measurement would be comparable to diameter.

When a bullet passes through human tissue (a perforating in-and-out wound), two types of spatter can be produced. The spatter that moves in the same direction as the exiting bullet is called forward spatter. The spatter that goes back toward the direction from which the bullet came is called back spatter. Thus, back spatter is associated with entrance wounds and forward spatter is associated with exit wounds.

The aerosol mist typical of HVIS will typically be accompanied by larger spatter, tissue, skin, and/or bone fragments. Thus, as already discussed, HVIS often presents itself as a combination of stain diameters, the majority of which will be 1 mm or smaller. Both back spatter and forward spatter will have conical distributions from their source. The size of this conical distribution tends to be greater for forward spatter emanating from an exit wound because

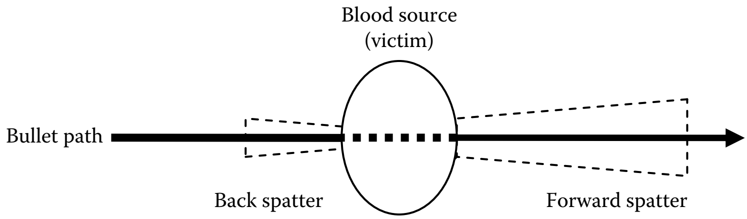

Figure 11.3 Forward and back spatter in perforating wounds.

the force is directed along the same path. This effect is enhanced when the exit wound is larger than the entry wound, as illustrated in Figure 11.3.

Some obvious contradictions to the proposed model for producing back spatter and forward spatter exist. Close range shots from high-powered rifles and shotguns, for example, produce large, excavating entrance wounds that direct large amounts of tissue, skin, bone, and blood drops of all sizes back toward the shooter. The small entrance wound–large exit wound theory depends on the location of the body and the weapon used. A rifle fired at close range into the abdominal area, for example, can exhibit a large entrance wound and a small exit wound.

Blood on and in Weapons

The combustion gases from discharge may aid in the production of the aerosol mist that typifies gunshot-produced spatter. This is particularly true for contact shots to the head where the gases collect between the skull and the scalp prior to erupting back toward the muzzle of the gun (the path of least resistance). It is not unusual for blood to be deposited on and in weapons under these conditions.

In experimental work done by the author concerning this phenomenon, a number of 38 special revolvers having barrel lengths ranging from 2 to 6 inches were test-fired into blood-soaked sponges to determine the likelihood for blood deposition at various muzzle-to-target distances. The results of this limited study indicated that barrel length was of no particular importance with regard to blood deposition in and on the weapons tested. Muzzle-to-target distance, as expected, was the controlling factor in determining whether blood deposition occurred. Blood inside the bores and on the exterior surfaces of the guns tested was found to be limited to contact or near contact distances.

As a standard practice in firearms examinations related to shooting incident reconstruction, it is highly recommended that weapons be carefully examined for the presence of blood in the bores and on exterior surfaces. A gun cleaning patch should be run through the bore (and each chambers of a revolver) and then examined and/or tested for blood. Vincent Di Maio, in his text titled *Gunshot Wounds,* noted that blood in the bore of a weapon can survive one or even two test firings. Accordingly, test firing should not preclude bore examination.

The examination of a bore may be carried out using a bore scope. A bore scope is equipped with tiny mirrors at the ends of small-diameter steel tubes that allow inspection of the interior surfaces of barrels without disturbing potential evidence. The device also allows recording of images via interfacing digital cameras prior to the removal of suspected bloodstains. This is clearly a superior method for documenting the presence of blood as compared to simply reporting the presence of blood on a swab passed through the bore. On the other hand, not bothering to check for blood at all is an unpardonable failure.

Blood on Hands of Shooter

A great deal of significance, particularly by the uninformed, is frequently placed on the lack of HVIS on the hands of victims of gunshot wounds to the head in cases that involve the question of homicide versus suicide. In any shooting incident, HVIS should be looked for, but, as already discussed, not finding it cannot be considered proof positive of anything except proof that it was not found. Studies have shown that in the majority of known cases of self-inflicted gunshots to the head with a hand gun, blood was not found on the shooter's gun hand. In the case of a shooting in which blood is found on the weapon and to an extent that it is inconceivable that it would not be also present on the hand holding the gun, some explanation must be found by the investigator. Possible explanations could include clean-up or the use of gloves.

Conversely, finding HVIS on the hands is proof positive that they were in reasonable proximity to the source of the HVIS. Again, the fine aerosol mist of blood associated with a gunshot can be very difficult to see and must be carefully sought. In a best case scenario, a wide distribution of blood will be present on the weapon along with an obvious absence on the handle. Blood spatter on the hand should "fill in the gaps." When the presence of HVIS is limited to the hand, it should be present on the back of the hand as opposed to the palmar surface. Finding HVIS on the palm is an indication of something other than gripping and firing a weapon with that hand.

Blood on Objects at Shooting Scene

It is widely accepted that HVIS can travel no farther than about 4 feet due to the actions of gravity and air friction that bring the tiny drops to ground. Thus, finding HVIS on a wall in the area of a bullet hole means the victim had to have been within about 4 feet of the wall when shot. Again, consideration must be given to the presence of persons or objects that could prevent the aerosol mist of blood from reaching potential targets within the scene.

A common misconception regarding non-aerosol bloodstains at shooting scenes is that such stains are produced whenever a person is shot and the location of these bloodstains is consistent with the individual's position. While it is certainly possible for blood to be deposited by a shooting victim at the location where he was shot, many reasons can explain why that does not always happen. First, if the area of the gunshot is covered by articles of clothing, the blood can be absorbed by the clothing. If the individual who is shot remains upright and mobile, it is quite possible that bleeding will be internal only for some period. Thus, finding bloodstains near where a gunshot victim ultimately goes down and dies may not coincide with where he was standing when shot.

Blood pools can provide information about the location of a shooting victim in a certain place for whatever period of time would be required for the blood pool to have formed. Exactly how long that might be is usually beyond the expertise of the investigator and falls into the realm of the pathologist.

The question whether a shooting victim was standing, kneeling, or positioned otherwise is often posed to bloodstain pattern analysts. While the question can sometimes be answered to a degree, the answer must be based upon something other than bloodstain diameter versus height above the target. It is well known that as height above a target increases (up to a maximum distance of 6 or 7 feet), stain diameters of falling blood drops increase. The problem with using a comparison of stain diameters to attempt to establish height of fall is that the drop diameter is unknown and cannot be determined.

Suppose an individual was standing upright when shot through the arm. As blood starts to fall to the floor, bloodstains are formed. During the scene investigation, the examiner looks at these bloodstains with an eye toward determining the victim's position (upright or kneeling, say). The blood drops resulting from the wound will display differing volumes. This leads to the possibility that a large drop falling from a lower position could have a diameter similar to that of a smaller drop falling from a greater height. For this reason, speculation about height above the ground cannot be given any credence without knowing what the drop volume is and, in the context of a crime scene, drop volume cannot be ascertained.

Non-Gunshot Dynamics That Mimic High Velocity Impact Blood Spatter

Classifying bloodstain dynamics on the basis of stain diameter alone is risky. Bloodstain pattern analysts know that as much information as possible is required before rendering an opinion about the dynamic responsible for a particular pattern. As an extreme example, suppose a bloodstain pattern is observed to consist of mainly stains having diameters smaller than 1 mm and, on that basis, the investigator declares the pattern to be indicative of a gunshot. Later it is determined that no gunshot was involved — not a good situation for a crime scene reconstructionist.

Two non-gunshot dynamics can mimic HVIS. Blood dripping into blood results in satellite spatters that fall into the range of size of HVIS. This source of tiny bloodstains may or may not be readily ascertainable. Suppose that an individual was standing beside blood dripping to the floor from a blow to another man's head. As each drop hits previously deposited drops, satellite spatters land on the individual's right shoe. The bloodstains on the shoe are later used to place the individual as standing with his foot beside the victim's head as the victim lay on the floor after being shot in the head — an erroneous conclusion resulting because blood dripping into blood mimics HVIS.

The second non-gunshot dynamic that may easily be mistaken for HVIS is expiratory blood. Whenever the airways (nose and/or mouth) contain blood, sneezing, coughing, gurgling, sudden exhalation, and similar actions can produce tiny spatters that mimic HVIS in appearance. Frequently, the presence of air bubbles can be seen in the form of spatters with "fisheye" appearances. Also, the dilution of the blood with saliva sometimes can be recognized. An investigator can have a crime laboratory analyze it for the presence of the amylase enzyme. The absence of amylase, however, cannot eliminate the possibility of the presence of expiratory blood.

In summary, the scene investigator who finds what appears to be HVIS should first establish that a gunshot was involved in the incident under investigation, then eliminate the possibility that non-gunshot dynamics were responsible for the observed pattern.

Blood and Use in Timeline Development

An investigator should consider a number of issues associated with bloodstains and pools of blood at crime scenes as a timeline is developed and the reconstruction proceeds. In order for these considerations to be valid, their presence must be strictly correlated with time of observation. In other words, using the presence of dried or clotted blood to contradict a defendant's version of events is meaningless unless the time of observance is relevant and can be reliably established. Observing clotted blood in a crime scene photograph, for example, may have no significance if the photograph was taken hours after the blood was shed. The three items that should be sought and documented when blood is found at a scene are:

- Dried blood
- Clotted blood
- Lividity

The significance of each factor is entirely dependent upon establishing when it was first observed and how its presence relates to the purported timelines represented by victims, witnesses and/or defendants.

The time required for blood to dry depends on a number of factors. The volume of the bloodstain or pool has a considerable effect as do temperature, humidity, air current and surface absorption characteristics. In any event, if the first responder to arrive at a shooting scene notes dried bloodstains and blood pools to be present and the blood was supposedly shed within minutes of arrival, further investigation is warranted. Bloodstains and pools dry from outside to inside, that is, an outer crust forms and continues toward the center of the stain or pool over time. Rings of dried (skeletonized) blood that remain after a wet center portion was wiped away may indicate attempts to clean the stains. The required time for a bloodstain to dry on skin and other surfaces may be shorter than 5 minutes for small stains and considerably longer for larger stains and pools. If a possible contradiction arises between the timeline presented by an involved individual at a scene and the presence of dried blood, testing may be carried out to resolve the issue. The test conditions must duplicate those at the crime scene as nearly as possible.

The presence of blood clots and pools of clotted blood also give the investigator a way of estimating time passage at a scene. The time required for blood to clot varies but the minimum time required is generally accepted to be in the 6- to 8-minute range. This should not be taken to mean that a large pool of blood can entirely clot within that time; it may mean only that clotting began.

The presence of spattered blood clots is indicative of the passage of time between an initial injury and a secondary injury. If an individual was beaten, for example, and then shot, the shot could produce spattered clots.

Lividity, while clearly within the purview of the forensic pathologist, is something that an investigator should recognize when present and it should be documented appropriately. Lividity is the settling of blood following death. Gravity causes blood within the body to settle at the lowest possible point. Lividity manifests as a red–purple appearance of the skin. The time required for lividity to first appear varies with individuals and environmental conditions. It is generally accepted that lividity takes at least 20 minutes to appear. After 8 to 10 hours, lividity becomes "fixed." This means that the original position will be indicated by the persistence of lividity if a body is repositioned after fixation.

Case Studies

Case 1: Blood Solves a Shooting

A man was shot in the chest by his estranged wife after he allegedly attacked her with a butcher knife. Investigators found the man lying on the floor with a knife in the hand of his outstretched right arm (see Figure 11.4). An

Figure 11.4 Victim lying on floor and holding knife.

examination revealed blood in the man's mouth and nose. Numerous tiny blood spatters were present on the backs of his hands and on the wall nearby (see Figure 11.5). When the palm of the man's right hand was examined, a significant amount of blood was observed, but similar blood was not observed on the knife (Figure 11.6 and Figure 11.7).

Clearly, the knife was placed into the man's hand following the deposition of the blood. The tiny spatters were obviously expiratory blood and not HVIS based on the presence of clothing over the chest wound that would have prevented back spattering and also because of the blood in the victim's air passages. Further confirmation was provided by the corresponding tiny spatters on the wall down near the baseboard.

When confronted with the physical evidence, the woman ultimately confessed to shooting the victim and then placing the knife in his right hand. The bloodstains on the floor and wall revealed that the victim's original position was different from the position in which he was found. Investigators also noted that the dried blood on the man's right hand was flowing in the wrong direction (Figure 11.8).

Case 2: Bloodstains and Lividity Contradict a Suspect's Story

A man claimed that he shot his father in self-defense and that he called the 911 emergency number "immediately" after the shooting and then

Figure 11.5 Bloodstains on left hand and wall.

Figure 11.6 Palm of victim showing bloodstains.

Figure 11.7 Knife handle.

Figure 11.8 Wrong-way bloodstains on right hand.

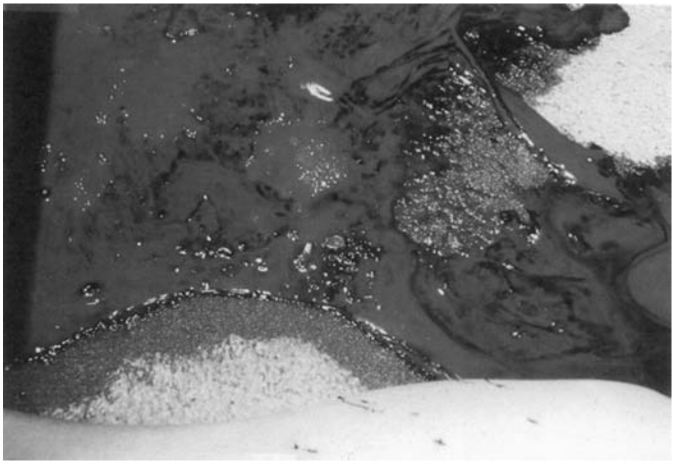

Figure 11.9 Pool of clotted blood. Note drying at margin.

began mouth-to-mouth resuscitation, following instructions from the 911 operator. Officers arrived within 8 minutes of receiving the call. They noted that a large pool of blood that the victim was lying in was clotted and had an outer ring of dried blood (Figure 11.9). It was apparent that more than 8 minutes would be required for the entire pool of blood to have clotted and for the blood to have started drying. It was also apparent that the man had been lying on his right side long enough for blood to seep under his right shoulder into the carpet and for lividity to appear on his right side. Furthermore, no blood was visible on the victim's son's mouth or fingers and it would have been present if he administered mouth-to-mouth resuscitation as he claimed. The victim's son was convicted of murdering his father, primarily on the basis of evidence indicating that he tried to cover up his crime. [Note: The use of human blood for experimental purposes in shooting reconstructions poses potential health risks. In the interest of avoiding biohazards, animal blood offers a reasonable alternative.]

Exercises

1. Gun shots produce
   a. Forward and back spatter
   b. Only forward spatter
   c. Only back spatter
   d. The answer depends on a number of variables

2. HVIS spatter on or in a weapon is characteristic of
   a. A contact shot
   b. A near contact shot
   c. A distance shot
   d. Both a and b

3. HVIS on the hand of a shooter is indicative of
   a. Suicide
   b. Homicide
   c. A defensive posture
   d. It cannot be determined without additional information

4. The appearance of tiny blood spots with a "fisheye" appearance means
   a. Expirated blood is likely
   b. Blood was partially wiped away
   c. A gunshot was involved
   d. No saliva was present

5. What does the failure to find HVIS mean?
   a. No gun shot was involved
   b. Aspirated blood was the source
   c. Blunt force trauma was involved
   d. No determination can be made without more information

6. The presence of both tiny and larger bloodstains in a pattern means that
   a. They were not caused by a gunshot
   b. A gunshot could be involved
   c. A head shot was involved
   d. A contact shot was involved

7. Which of the following is most likely to produce back spatter?
   a. A head shot at 2 inches
   b. A chest shot at 4 inches
   c. A foot shot from 12 inches
   d. A leg shot from 2 feet

8. Which one of the following is most likely to produce back spatter?
   a. 12-gauge shot gun
   b. 22 revolver
   c. 38 special revolver
   d. 9-mm pistol

9. Which one of the following would be most likely to totally or partially reduce back spatter?
   a. T-shirt
   b. Heavy coat
   c. Medium length hair
   d. Tight jeans

10. Blood spatter designated as high-velocity impact spatter would be produced by
    a. Blunt force
    b. Gravity (dripping)
    c. Cast-off
    d. Gunshot

11. Blood spatter that would travel a horizontal distance of about 4 feet would be produced by
    a. Gunshot
    b. Blunt force
    c. Blood dripping into blood
    d. Cast-off

12. With gun shots, more blood spatter is produced
    a. In a forward direction
    b. In a rearward direction
    c. Inside a wound
    d. At impact

13. High velocity blood spatter has a diameter
    a. Of 1 mm or smaller
    b. Of 1 to 3 mm
    c. Of 3 to 5 mm
    d. Larger than 3 mm

14. Blood spatter from a gunshot can travel horizontally about
    a. 2 feet
    b. 4 feet
    c. 6 feet
    d. 10 feet

15. Types of bloodstains other than HVIS that may be present at shooting scenes include
    a. MVIS
    b. LVIS
    c. Transfers
    d. All of the above

    Answers: 1 - d, 2 - d, 3 - d, 4 - a, 5 - d, 6 - b, 7 - a, 8 - a, 9 - b, 10 - d, 11 - a, 12 - a, 13 - a, 14 - b, 15 - d.

Suggested Readings

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Officer-Involved Shootings

12

General Considerations

When a police officer is involved in a shooting incident in the line of duty, it is critical that each aspect of the necessary scene documentation be handled with the utmost care and thoroughness. This is not because an officer-involved shooting carries any more significance than any other type of shooting, but because this type shooting is sure to attract maximum scrutiny at both the criminal and civil level. Ever since the Rodney King police beating incident in Los Angeles during the 1980s, use of force by police officers at all levels has remained the subject of intense review and discussion.

The standard operating procedure for most police agencies is to launch simultaneous administrative and criminal investigations when an officer has been involved in a shooting incident. Many police agencies have shooting review teams or boards that, in effect, reconstruct officer-involved shootings. As with any shooting reconstruction, the success or failure rests with the quality of the scene documentation. While the general approach to the reconstruction of an officer-involved shooting should be no different from the reconstruction of any other shooting, a number of special considerations must be addressed. A suggested protocol for the documentation of the physical evidence in an officer-involved shooting is discussed below.

Protocol for Officer-Involved Shooting

1. Gunshot residue tests should be conducted on all persons (including officers) at the scene who could have possibly been involved in a shooting incident.

2. All weapons (including officers' weapons) should be taken into evidence at the scene for function testing and firearms identification (bullet–cartridge case comparison, distance determination testing, and ejection pattern testing as appropriate), making sure to note positions of safeties, presence of trace evidence, and load status.
3. Cartridge case and/or shot shell locations at the scene must be properly documented and appropriate measurements recorded.
4. Measurements must be made of the diameters of all bullet and pellet holes. If gunshot residue (GSR) is a consideration, GSR lifts should be taken from the surfaces of all bullet and pellet holes and the surrounding material.
5. Measurements should be taken to fix locations of all bullet and pellet holes (X and Y coordinates).
6. X and Y angular coordinates should be calculated for trajectory determinations for all bullet and pellet holes.
7. Lengths and widths of all shot shell pellet patterns must be measured (measure diameter if circular).
8. If footwear impressions are possible issues at the scene, officers' shoe impressions should be taken or his or her shoes or boots should be taken into evidence along with those of any suspects.
9. Clothing containing bullet or pellet holes worn by anyone at the scene should be taken as evidence for GSR and distance determination testing.
10. All clothing bearing possible bloodstains must be taken into evidence for further examination and testing.
11. All blood spatter patterns must be appropriately documented and representative samples taken.
12. If trace evidence is a potential factor, appropriate control samples (hairs, fibers, etc.) must be collected from all individuals present including officers. All clothing taken should be packaged separately to prevent cross-contamination.
13. All minor wounds, scratches, and abrasions that are potentially related to the incident must be documented photographically.
14. Any bullet ricochet creases must be photographed and impression casts prepared.
15. If tire impressions are involved, test impressions of all vehicles present should be prepared.

In officer-involved shootings in which more than one officer is present, there is often no question about which officer did the shooting. All officers at a scene typically agree as to who fired and who did not. As a general rule, however, it is important to follow the same protocol for every officer at the scene. With regard to GSR testing, it is both appropriate and recommended that sampling be done on the hands of all officers involved. Appropriate sampling involves the use of adhesive-backed aluminum disks designed specifically for scanning electron microscopy (SEM) analysis. The collection of these samples does not necessarily dictate that SEM analysis be performed. The samples can be maintained and available should a question ever arise as to possible firing of shots by other officers. Not collecting these samples at the scene could subject a department to needless criticism and possibly set the stage for allegations of cover-up.

The same reasoning applies to taking the weapons of all officers present into evidence for determination of loading status and function testing at a minimum. Officers should be instructed that the procedure represents a routine that will be followed in all officer-involved shootings in order to lessen the impact of having to give up their service weapons following a shooting incident. The recording of loading status should be done at the scene and officers should be instructed not to reload prior to arrival of investigators. The caveat for loading status determination is that the weapon did, in fact, have a round in the chamber and a full magazine prior to the shooting. Sometimes this is not the case, even though an officer may believe that it was. From time to time, an officer may fail to add an additional round to the magazine following loading the magazine and chambering a round at the start of a shift. Accordingly, when a round is missing, consideration must be given to the possibility that the weapon did not have a full magazine to start with.

Most larger departments employ armorers who are responsible for the repair and maintenance of departmental weapons. Armorers can also carry out function testing and examine officers' weapons to ensure that they meet departmental standards and have not been modified in any way. The downside to having a police armorer examine and/or test officers' weapons is that they are typically not trained or qualified in the area of trace evidence analysis. Hairs, fibers, blood, paint, glass, and other trace evidence on or in an officer's weapon can be important factors in the reconstruction of a shooting. Therefore, the best policy for a department to follow in the investigation of an officer-involved shooting is to have officers' weapons examined and tested by a firearms examiner in a forensic laboratory. That way, any trace evidence present can be turned over directly to a trace evidence analyst.

Advances in DNA technology allow the identification of DNA on weapons, ammunition, holsters, batons, and other items. Whenever an officer-involved shooting arose from a struggle over an officer's weapon or other physical contact with the officer, consideration should be given to swabbing the surface of the involved item for DNA testing. The results can be used to confirm an officer's statement that an assailant tried to take away his weapon, for example.

In the author's experience in reviewing officer-involved shootings, trace evidence examinations of officers' weapons are seldom conducted, particularly when the weapons go to an armorer rather than to the crime laboratory. A forensic firearms examiner can carry out all the testing that an armorer would perform in addition to ensuring the specialized testing that only a forensic examiner can perform (e.g., trace evidence examination).

Another standard test that should be conducted on officers' weapons is trigger pull determination. This will reveal the occasional instance where an officer modifies his weapon by installing lighter trigger springs. This is usually not in conformity to departmental policy and can contribute to unintentional firing. Trigger pull testing may become an important issue to a department facing a lawsuit as a result of an officer-involved shooting.

Another routine procedure should be documentation of locations at the scene of all ammunition components (bullets, fragments, cartridge cases, and shot shells). An equally routine procedure should be the forensic comparison of these ammunition components with the suspected weapons used. The fact that there is no apparent question as to the officer who did the shooting does not preclude this aspect of the investigation.

When cartridge case and shot shell locations are properly documented and the direction of firing is known, the position(s) of the shooter(s) may be established through ejection pattern testing, as described in an earlier chapter. This type of testing need only be carried out when deemed necessary and appropriate. It is not generally necessary to carry out ejection pattern testing for every shooting incident, officer-involved or not.

In any shooting analysis or reconstruction, the x and y linear measurements and the X and Y angular measurements must be determined for every bullet and pellet hole. In addition to providing a means of documenting trajectories, this allows the production of a scale diagram and/or computerized animation.

Many police departments issue Remington 870 12-gauge shotguns to their officers. The most frequently issued round is the Federal 00 buckshot-buffered load. Accordingly, the pellet patterns produced by any shots to doors, walls, etc. should be measured in order to approximate the impact angle and muzzle-to-target distance. As discussed in Chapter 6, the general rule of an inch of pellet-pattern diameter (width in the case of oblong patterns) to a yard of muzzle-to-target distance can be used for the purpose of beginning a search for evidence of shooter position. The calculation of approximate angle of impact based on the width and length of the overall pattern and/or several well defined individual pellet holes further define the area to be examined.

Footwear impression evidence is frequently an afterthought at a crime scene after what might be categorized as a parade of individuals walking through the scene. Such activity at a scene can cause the obliteration of footwear impression evidence by officers and other responders who move through a scene in the early stages of an investigation. To reduce or prevent alteration of footwear evidence, a scene must be sealed off as soon as possible and entry should be strictly controlled.

Officers' footwear impressions can be used to establish the positions of officers and other individuals involved in shooting incidents. If uninvolved individuals move through a scene, impressions of their footwear should be obtained at the scene for elimination purposes. This approach minimizes time wasted on taking footwear impressions that do not belong to the participants in a shooting by allowing on-scene evaluations to be made. Otherwise, all visible footwear impressions must be considered in the reconstruction until appropriate eliminations can be made.

Clothing and/or uniforms of officers involved in shooting incidents should be taken into evidence and carefully examined for bullet and pellet holes, GSR, blood, rips and tears, and other possible trace evidence to assist in reconstructing the shooting. Simply photographing the officer wearing the clothing is inadequate to properly document related evidence.

The proper documentation of bloodstains at a scene includes taking overall photographs and close-up photographs that include appropriate identifiers and scales. Dividing stained areas into zones and using both vertical and horizontal (x and y) scales simplifies documentation and subsequent interpretation. Additionally, representative samples must be collected for analysis.

Tire tread impression evidence can also be a consideration in an officer-involved shooting reconstruction. As with footwear impression evidence, photographing with the camera at 90 degrees to the impression and casting with dental stone provides appropriate documentation. Making elimination impressions of uninvolved tire treads requires taking all four tire impressions on paper. A technique developed by the author involves spraying a heavy coat of silicone release agent onto the tire tread surface and then driving along a piece of heavy paper taped to a piece of smooth plywood. The silicone spray provides an invisible image of even the finest detail on the tire tread that is developed by immediately brushing with a magnetic wand and magnetic fingerprint powder.

Unintentional Discharge of Weapon

A number of potential mechanisms allow unintentional discharge of a weapon. They include:

- Poor weapon design
- Carelessness
- Inadequate training and/or ongoing weapon familiarity

- Sympathetic firing (involuntary muscle response)
- Loss of balance
- Startling the carrier of the weapon

Poor weapon design can cause or contribute to unintentional firing. When police departments replaced revolvers with semiautomatic weapons, the incidences of unintentional firing increased as a result of the ease of firing a semiautomatic pistol as compared to a revolver (when fired double action). The necessity for the shift from 6 shot revolvers to 15- or 16-shot semiautomatic pistols could be debated since most police shootings involve fewer than 6 shots fired by an officer. Semiautomatic pistols, however, are here to stay. Two issues should be considered in designing semiautomatic weapons for police use.

The first consideration is trigger pull. Trigger pull for a police issue semiautomatic pistol should be in the 8- to 12- pound range for maximum safety. Trigger pulls at or below 6 pounds are used by some departments but heavier trigger pulls are recommended. New York City Police special order 12-pound trigger pulls for all their Glock™ semiautomatic pistols in an effort to minimize the potential for unintentional firing by officers. Any discharge of a weapon by an officer of the New York Police Department initiates a firearms discharge review panel inquiry.

The second consideration for semiautomatic pistols is the length of travel of the trigger while under resistance before the weapon fires. The length of trigger travel can be just as important a consideration in unintentional firing as trigger pull. Weapons with very short trigger travels under resistance, say, a tenth of an inch or less before firing occurs, are very unforgiving. Having a longer trigger travel under resistance prior to firing of 3/8 to 3/4 inch does not appear to present any tactical disadvantage and offers added assurance against unintentional discharge. In comparing trigger pull to trigger travel, a higher trigger pull does not compensate for a very short trigger travel. Thus, the combination of higher trigger pull and longer trigger travel is probably the best bet for law enforcement use.

Carelessness and human error are probably responsible for more unintentional shootings than any other cause. An old saying notes that a "lot of people have been shot with 'unloaded' guns." Police officers can be as careless as other people. Failure to follow basic firearm safety rules happens from time to time. In a very tragic case the author reviewed, a police officer shot and killed a fellow officer during a training exercise in which no live ammunition was supposed to be present. The shooting occurred in the presence of a class of police cadets who were there to observe how to disarm a suspect. In spite of well known and long-established safety rules to the contrary, the officer who fired the fatal shot had not had his weapon inspected to ensure that it contained no live ammunition prior to the start of the exercise. Other than police academy training sessions, few officers receive ongoing extensive firearms training. Regular and frequent training with a weapon makes a user familiar with its inherent characteristics to the point that, during a critical incident, the operation of the weapon becomes second nature.

Sympathetic or involuntary firing is the pulling of the trigger and firing of a gun as a result of an intense contraction of the non-gun hand. This most often occurs when an officer has a gun in one hand while trying to handle a suspect with the other hand. According to studies conducted by Dr. Roger M. Enoka at the Cleveland Clinic, an average force of 100 pounds can be applied by the grip of a 20- to 30-year old male.

A sympathetic nervous response when one hand is tightly contracted imparts up to 20% of the force to the other hand. Further research has shown that approximately 30% of the force is exerted by the index (trigger) finger. Thus, 6 pounds of force can be applied to the trigger finger when the opposite hand is used to tightly grip someone or something. This is why an officer is trained not to hold a weapon and have his finger on the trigger when handling another person. Of course, altercations with suspects do not always follow the book. In any officer-involved shooting in which a struggle occurred and an officer fired shots, unintentional firing must be considered a possibility.

Similarly, if an officer is moving toward a suspect with gun drawn and he stumbles or trips, an involuntary trigger pull can result. This is another reason officers are trained not to keep their fingers on the trigger until it is appropriate to do so. This is often an uncertain issue, however, and a decision that an officer must make on the basis of perceived danger at a given moment. When a suspect is unintentionally shot by an officer, the second guessing inevitably runs rampant.

Another common reason for the unintentional discharge of a weapon by an officer results when he or she is startled while having a finger on the trigger. This can result from a variety of events but a common one is in response to the discharge of a weapon by a fellow officer who is nearby. For example, when several officers have a suspect at bay and all the officers have their weapons drawn and at the ready, an inadvertent discharge by one officer often sets off firing by the others. The author has observed this in a number of police-involved shootings.

Accidental Discharge of Weapon

Accidental discharge of a weapon is distinguished from unintentional discharge in that accidental discharge is indicative of a weapon malfunction. Thus, accidental discharge is a mechanical malfunction while unintentional discharge has no mechanical aspect (except for the possibility that a weapon has a much lighter trigger pull than the department standard). Mechanical malfunctions that result in accidental discharges of officers' weapons are rare. This is because modern police-issued weapons such as Glocks, Sig Sauers, Berrettas, and Smith & Wessons, have sophisticated, reliable safety mechanisms and are not prone to malfunctions.

Any questions about the possible malfunction of an officer's weapon that resulted in accidental discharge can be answered by the department's armorer. An armorer is skilled in the maintenance and repair of issued weapons and usually serves as the "go to" individual for this kind of situation. If a department does not have an armorer on staff, a firearms examiner at a crime laboratory will often have comparable expertise in this particular area.

Suicide by Cop

The phenomenon known as suicide by cop occurs when individuals wish to die but are unwilling or unable to carry out the act on their own. Synonymous terms include police-assisted suicide and self-precipitated suicide. A number of possible motivators are involved in suicide by cop:

- Avoidance of incarceration or other consequence
- Proving some emotional point
- Venting rage
- Suicide
- Component of homicide–suicide
- Cry for help
- Intent to avoid insurance policy exclusion of suicide
- Avoiding spiritual or religious prohibition of suicide
- Seeking an effective method
- Need to save face

Suspects bent on forcing police officers to shoot them often provide the officers with a number of indicators during the initial stages of confrontations, for example, a suspect may:

- Ask to be shot
- Indicate he "won't be taken alive"
- Express a desire to die
- State that "jail is not an option"
- Cite the Bible's Book of Revelations and mention resurrection
- Express hopelessness

In addition to verbal indicators, the following actions of a suspect can be indicative of his intent to force officers to shoot:

- Demonstration of weapon
- Pointing weapon at police
- Shooting at police
- Counting down time to kill hostages
- Forcing a confrontation
- Self-mutilation in presence of police
- Failure to make escape demands
- Refusal to negotiate
- Continued aggression after sustaining wound

A number of background issues of individuals who become involved in confrontations with police may indicate intentions to commit suicide by cop. A person intent on this type of suicide may:

- Have killed a significant person in his life (parent, spouse, child, etc.)
- Have killed a prized pet or destroyed valued possessions
- Have recently disposed of money or property
- Face shame
- Face certain imprisonment
- Have left a suicide note
- Have a history of clinical depression
- Have been given a terminal diagnosis
- Suffered two or more traumatic losses (loss of job, divorce, loss of loved one)
- Experienced previous police contact related to suicide issues

All officers are called upon to deal with a number of circumstances and types of individuals that present extra potential for suicide by cop, for example:

- Domestic violence calls
- Armed robbery calls
- Calls about a "person with a gun"
- Mentally disturbed individuals
- Known suicidal individuals
- Barricaded individuals
- "Three strikes" criminals

When reconstructing a shooting involving a police officer, some consideration should be given to the possibility that suicide by cop is involved. While the presence of the indicators listed here does not guarantee that a case is a suicide by cop, further investigation of that possibility is certainly warranted. The "why" aspect of a shooting reconstruction is not always answerable, but it is a relevant aspect of reconstruction that should be explored, particularly in officer-involved shootings.

Case Studies

Attempted Suicide by Cop

The author was involved in the investigation of a clear case of attempted suicide by cop that did not reach its intended conclusion only because of poor shooting by the officers involved. A man hijacked a taxi from the airport of a large western city and began driving the taxi north on an interstate highway. Police officers proceeded to engage in a low speed chase such as the 1994 chase involving O.J. Simpson for about 60 miles. Eventually, seven police vehicles became involved.

The decision was finally made to place tire shredding spikes on the road and block all entry and exit ramps. The suspect drove over the spikes and continued for a short distance before coming to a stop. Upon exiting the taxi, the suspect found himself facing seven officers with drawn weapons who had taken cover behind their vehicles. The officers were within approximately 40 yards of the suspect. One of the lead officers had a dash-mounted video camera that recorded both the chase and the shooting that followed.

The man was standing by the taxi with his right arm down at his side holding a chrome handgun. Officers repeatedly ordered the suspect to drop his weapon but he ignored them and started to raise the weapon in the direction of the officers. The officers opened fire and the man went fell to the ground. As he lay on the ground, the man again raised his weapon toward the officers and again was met with a hail of gunfire.

Following the second barrage, the man's arm went to the ground. Officers then approached the man, and found him very much alive and begging them to "Shoot me, please shoot me." The man had been hit in the shoulder by one bullet (probably while he was standing) and in the arm by a ricochet as he lay on the ground. In all, the officers fired more than 40 shots. The videotape from the camera in the police vehicle clearly showed most of the officers' rounds striking the ground well in front of the man during both engagements. Had the officers been better shots, the man would have no doubt gotten his wish for suicide by cop. Following an embarrassing display of the tape on the evening news, the officers involved were assigned to remedial firearms training. The man lived and was convicted of attempted murder of a police officer.

Charles Whitman and the University of Texas Tower Incident

The author was attending classes at the University of Texas during the summer of 1966 when Charles Whitman barricaded himself at the top of the University of Texas tower with a large cache of guns and ammunition. As the author left his dormitory and headed for class, he was met by the sounds of gunfire coming from the mall area near the tower. As he came into view of the mall, bodies lying in pools of blood were visible.

The author moved back around a corner of the building to take cover just as a Texas ranger took up a position directly at the corner with a 30-06 rifle with a scope. The author positioned himself behind and about 10 feet away from the ranger. As shots from the tower continued, the ranger took aim and fired several rounds before two Austin police officers, Houston McCoy and Ramiro Martinez, made their way up the tower elevator and shot and killed Whitman.

Whitman managed to kill 14 people and wound 31 more before McCoy and Martinez killed him in what constituted an incredible act of bravery on their part. Most of the victims were shot with a Remington model 700 bolt action rifle in 6 mm caliber with a telescopic sight. Whitman also fired a 30 caliber semiautomatic carbine without a scope.

After Whitman's body was removed from the tower, it was learned that he had killed his mother and wife a day earlier. He made no demands and had no contingency plan for escape. He clearly wanted to die in a big way and did so. An autopsy revealed that Whitman had a walnut-sized brain tumor. This caused some to speculate that he must have "snapped" as a result of the tumor and academic pressure (he was a graduate student in the school of architecture). This does not appear to have been the case, based upon the meticulous plan he contrived and carried out.

Exercises

Indicate whether the following statements are true or false.

1. Suicide by cop may be indicated by a number of signs with which officers and investigators should be familiar.
2. Unintentional firing results from mechanical malfunction.
3. Accidental firing is a fairly common occurrence.
4. A barricaded individual is a likely candidate for suicide by cop.
5. Charles Whitman gave multiple indicators as to his suicide by cop intentions.
6. An officer can safely handle a suspect with one hand while holding a gun on the suspect with the other hand.

7. Tripping or being startled while holding a gun and having a finger on the trigger can result in unintentional discharge.
8. A lighter than normal trigger pull can contribute to unintentional discharge.
9. A police armorer is an appropriate individual to ask to carry out an examination for possible malfunction of an officer's weapon.
10. Officers' weapons do not need to be examined in a police shooting unless malfunction is suspected.
11. All officers present at a shooting should be sampled for gunshot residue even if there is no question as to who fired shots.
12. The loading status of officers' weapons should be determined as soon as possible during a shooting investigation.
13. Footwear impressions at a shooting scene must be evaluated and compared to officers' footwear.
14. Cartridge case locations can be used to establish officers' positions as long as shot directionalities are known.
15. Officers may deliver their weapons to the armorer or crime laboratory at some convenient time following a shooting incident in which they were involved.

Answers: 1 - T, 2 - F, 3 - F, 4 - T, 5 - T, 6 - F, 7 - T, 8 - T, 9 - T, 10 - F, 11 - T, 12 - T, 13 - T, 14 - T, 15 - F.

Suggested Readings

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13 Case Analysis

General Considerations

Shooting incident reconstruction requires a "holistic" approach. That is, all aspects of the events leading to the shooting and those that follow it must be considered in analyzing a case. Simply looking at the physical evidence alone may not provide an investigator the proper insight required to decipher the events of the shooting. The possible motivation for a shooting can sometimes shed light on how a shooting took place. Certainly knowing something about a person's medical history, financial status, and martial situation can assist in trying to distinguish homicide from suicide.

A common mistake that investigators make in trying to reconstruct shootings is to try to apply "stop-action" or "frame by frame" principles to a shooting incident. A shooting is a dynamic event that frequently involves movements by various persons. Shooting incidents often occur in a very brief span of time. When they involve multiple shots, trying to determine the shot order and the exact body positions for those involved as each shot was fired is often an impossibility and also usually unnecessary.

Individuals involved in shootings, including officers, have experienced are very high stress. Recollections of the number of shots fired, positions during the shooting, and other details are often unclear. A fairly common mistake made by witnesses to shootings is to transpose the position of the gun based on visual perceptions and their own dominant hands. In other words, a person facing an individual who holds a pistol in his left hand perceives the weapon as being to his or her right. If that individual is right hand-dominant, the dominance tends to further cultivate the notion that the weapon was in the shooter's right hand rather than left hand.

Few individuals accurately report numbers of shots fired. The reasons should be obvious: the stress of the shooting and the concentration on survival that are involved. Thus, it should come as no surprise when individuals present at a shooting report varying numbers of shots fired, none of which are accurate.

Time frames associated with shooting incidents constitute another area that frequently gets misstated. Individuals may, for example, report hearing shots fired "seconds" apart when, in fact, the shots were all fired within a single second. Total elapsed time for a shooting may be reported as "several minutes" when the actual time involved was only a matter of seconds. The investigator must consider these reports but weigh them against other aspects of the case and recognize their propensity for inaccuracy.

The mental states and physiological conditions of individuals reporting shooting events must be ascertained and considered. Individuals who are under the influence of alcohol or other drugs at the time of a shooting should generally be considered unreliable. Mentally ill or retarded individuals cannot be relied upon to provide valid information in a shooting incident and would not be allowed to testify in court.

Shot Accounting

One of the most important aspects of on-site and off-site shooting reconstruction is shot accounting. The technique involves reconciling the number of fired cartridge cases, fired bullets, bullet holes (in inanimate objects), and bullet wounds. An investigator should make every effort to do as much as possible to settle these issues prior to leaving the scene by making a thorough search for bullets, fragments, and fired cartridge cases.

All weapons recovered at the scene must be unloaded and loading diagrams prepared to document their status, as described in an earlier chapter. Ultimately, it will be necessary to establish the magazine capacities of all semiautomatic and automatic weapons involved in an incident in an effort to determine the maximum number of rounds that could have been fired:

Magazine capacity + chamber – total number of rounds remaining in weapon = maximum number of rounds that could have been fired

This, of course, assumes no reloading was involved during the shooting. If additional magazines were used, obviously their contents must also be considered.

The autopsy report should be consulted to determine the number of entry and exit wounds and the number of bullets recovered. The possibility of multiple wounds caused by a single bullet must be considered when the wound count does not coincide with the shot count. Obviously, shots fired result in more wounds than missed shots.

In the case of fragmented bullets, the total weight of all fragments recovered can be compared to the weight of an intact bullet in order to estimate the number of bullets represented. In reviewing numerous shooting cases worked by various agencies over the years, the author often experienced the perplexing situation of having no clue as to what the bullet evidence described in reports actually meant. *Projectile* is a favorite "catch-all" term used by many agencies. By definition, a projectile is simply a body in motion. Thus, a projectile could be anything flying through the air, from a bullet to a Volkswagen. A communication problem arises when scene investigators apply the term to various types of bullet fragments, such as jacket or core fragments, and then use the same term to describe an intact bullet. An individual reading an evidence list is left with no idea what was collected. To ensure consistent and accurate reporting, the following definitions of terms are suggested:

Bullet Correct term for an intact and complete lead, copper or jacketed lead bullet.

Bullet fragment Correct term for a bullet that is not entirely intact due to loss of some portion of the jacket and/or core but is still recognizable as a bullet.

Bullet core The inner lead portion of a jacketed bullet.

Bullet core fragment A less-than-complete bullet core.

Bullet jacket A complete steel, copper or brass bullet jacket without a core.

Bullet jacket fragment A less-than-complete bullet jacket.

Metal fragment Term that should be used when a question exists whether a fragment actually originated from a bullet jacket or core.

Using "fired" to describe one of the above components is usually unnecessary because it can be assumed that all components are the products of firing.

If investigators used these terms in the manner suggested to describe bullet evidence, a great deal of confusion could be avoided. Attempts to describe bullet evidence using a variety of other terms can sometimes be downright humorous, if not ridiculous. In a case reviewed by the author several years ago, the following descriptions were used in a report documenting the bullet evidence:

Item 1 – projectile
Item 2 – projectile (intact)
Item 3 – slug
Item 4 – projectile (outer)

The actual evidence the investigator was attempting to describe was:

Item 1 – partial jacketed bullet
Item 2 – jacketed bullet
Item 3 – bullet core
Item 4 – bullet jacket fragment

The confusion resulting from the use of such nondescript terms should be obvious. The bottom line for the investigator responsible for documenting bullet evidence is simple – call it what it is!

Generally, not as much confusion surrounds descriptions of cartridge cases with the possible exception of shot shells. The most common term for a fired cartridge case is *casing*. This term is also sometimes used interchangeably for cartridge cases and shot shells. For the sake of clarity, it is recommended that fired cartridge cases be called just that and that fired shot shells be described that way as well. The use of terms like *projectile* and *casing* has been firmly entrenched in police agencies for decades and continues today. As more investigators recognize the benefits of using clearly understandable terminology in referring to firearms evidence, perhaps these terms will slowly fade away.

Another common problem that frequently arises is the use of multiple designators for firearms evidence items. In a typical scenario, a crime scene investigator assigns designators to evidence collected in the field, the medical examiner them to ammunition components collected at autopsy, and the crime lab uses its own designation system for all submitted items. When the laboratory report is issued, it can appear as if the intent was to create utter confusion about the sources of the evidence. To avoid such confusion, it is recommended that the original item designators (numbers and letters) and descriptions of sources be included as parenthetical entries if new designators are assigned to evidence.

As an example, suppose a pathologist recovers a bullet designated "Gunshot wound #4 – left anterior forearm." Further suppose that an investigator receives this bullet for transport to the crime laboratory and lists it on the evidence submission form as "Item 2 – bullet from autopsy." When the firearms unit receives the item, it is then assigned the designator "Q1 bullet." The firearms report may contain a statement that, "The Q1 bullet was identified as having been fired from the Q7 pistol." This will be very clear to all concerned if only one shot is involved in the incident. However, what happens if multiple rounds are involved? In those situations, the different designators assigned by various agents will create confusion. The recommended remedy is to use this type of description: "The Q1 bullet (M.E. #4 – from left anterior forearm) was identified as having been fired from the Q7 pistol." [M.E. means medical examiner.] This verbiage clearly describes the evidence and the source.

Table 13.1 Shot Accounting Chart

Shot Count

Bullets/fragments found at scene	5 (2 on floor, 3 in east wall)
Cartridge cases found at scene	9 (all on bedroom floor by door)
Entry wounds in victim	5 (3 bullets recovered at autopsy)
Exit wounds in victim	2
Total shots believed fired	9
Unaccounted for (missing) bullets	1

Bullets

CSI #	ME #	Lab #	Source	Description	Result
EEH-1	ME-2	Q3	NE floor, BR	Jacketed bullet	ID as fired from Q8

Cartridge Cases

CSI #	ME #	Lab #	Source	Description	Result
EEH-8	—	Q12	BR floor	Fed 40 S&W	ID as fired from Q8

It is frequently useful for an investigator to produce charts that summarize all the ammunition component evidence. Such charts can be presented in court to assist jurors in understanding how many shots were fired. Table 13.1 is an example of a shot accounting chart. Note that the bullet and cartridge case tables have been abbreviated.

In the example shown, one bullet was unaccounted for. Charts like this one make it easy to grasp the inter-relationships of the ammunition component evidence. All evidence designators used should be included for clarity (see the bullet and cartridge case sections of the table).

Recognizing Staged and Misrepresented Crime Scenes

Staged crime scenes are those in which evidence has been altered and/or the scene has been rearranged in some manner. Misrepresented crime scenes involve individuals who give false statements about the events involved. An investigator should be on the alert to a number of indicators of possible staged or misrepresented crime scenes:

- Postmortem lividity in wrong location
- Dried or coagulated blood that should not be so
- Blood stains going in the wrong direction
- Voids where blood should be
- Blood stains where blood should not be
- Fired cartridge cases missing or out of place
- Bullet trajectories inconsistent with stated shooter positions
- Weapons in unusual positions

- Gunshot residue results inconsistent with stated shooter positions
- Bullet hole appearance inconsistent with stated muzzle-to-target distance
- Trace evidence results inconsistent with stated shooter positions
- Latent print/DNA examination results contrary to those predicted or expected

Postmortem lividity can indicate the repositioning of a body. In a case the author was involved in, a woman was found shot to death by officers called to the scene by her boyfriend. The man claimed to have called 911 immediately after seeing his girlfriend "shoot herself" behind her right ear with a 44 Magnum revolver. He stated that she did so while standing in the bedroom closet facing outward toward him. He also said that after she fell face-down to the floor, he did not move her prior to the officers' arrival. The officers immediately noticed postmortem lividity on her buttocks (she was clad in a thong) as she lay on her stomach. Because the officers arrived within 8 minutes of the 911 call, no lividity should have been present. Regardless of the time involved, lividity on her buttocks was a clear indication that she had been on her back for a sufficient period for lividity to develop and that her body had been subsequently moved.

In a similar case, a man called 911 to report that he had just shot his father during an altercation at their home. The man was asked if his father was still alive and he responded that he was "not sure." The man said that his father was lying on the floor on his side. The 911 operator advised the man to roll his father over onto his back and begin mouth-to-mouth resuscitation. When officers arrived approximately 10 minutes after the call, they found the father lying on his back as expected. However, postmortem lividity on his right side clearly indicated a significant delay in calling 911 and rolling the father over onto his back.

Additionally, the officers noted a very large pool of blood around the body that was coagulated and had crusted along the outer margins. All these observations clearly indicated that the scene was staged as far as the time frame for the shooting was concerned.

In an example of how blood voids and stains going in the wrong direction can reveal a staged crime scene, a man was shot in the chest by his estranged wife after he allegedly tried to stab her. A butcher knife was found in his left hand. The palm of his left hand was covered with blood (Figure 13.1). Little or no blood appeared on the knife handle and none was present on the blade. The back of the man's left hand showed bloodstains consistent with expirated blood. No explanation as to why no blood transfers and expirated blood were found on the knife held in the man's left hand was apparent. Also, a dried bloodstain on the back of the hand holding the knife was going in the wrong direction (Figure 13.2). The crime scene was clearly staged. When confronted

Figure 13.1 Bloody hand holding knife.

Figure 13.2 Bloodstain traveling in wrong direction.

with this and other evidence, the woman ultimately confessed that she placed the knife in her estranged husband's hand after she shot him.

Missing or "displaced" cartridge cases can sometimes reveal alteration or misrepresentation of a scene. A man was charged with firing shots at some young people in a Jeep as they drove by the front of his residence in a rural area. His statement to police indicated that he had been "hunting skunks" in his front yard at dusk when he heard what he thought were shots coming from an approaching vehicle. He said that he "hit the deck" to avoid what he thought were incoming rounds and in so doing, "may have accidentally fired a shot." A single fired cartridge case was found in the vicinity where the man said he dropped to the ground.

The driver of the Jeep was struck by a single bullet that entered his skull behind his left ear. When the Jeep was carefully examined, a bullet strike of apparent recent vintage was found in the rocker molding directly below the driver's seat. An additional bullet was recovered from the driver's side rear tire. Elemental analysis of the bullet from the victim, the bullet from the tire, and representative bullets from a box of cartridges found in the man's residence under a search warrant revealed they were all consistent with the same lot of ammunition.

The father of the victim testified that he kept a watchful eye over the Jeep in order to keep abreast of any "modifications" that his son might have made as many teenagers are apt to do. He had looked at the Jeep just before his son left in it for the last time and was 100% sure it had no bullet impact in the driver's side rocker molding prior to the incident. Thus, three shots appeared to have been fired.

Since it was highly unlikely that the man knew that he hit the Jeep twice in addition to shooting the boy in the head, it appeared that he picked up two cartridge cases and left one in order to support his story of a single unintentional shot. Neither of the two passengers in the Jeep heard shots because of a loud radio and the fact that the dead driver turned the ignition switch on and off as they drove in order to cause the Jeep to backfire — which explained the defendant's thinking that he heard shots coming from the Jeep.

At trial, the prosecutor made the point to the jury that the man clearly fired intentionally at the youths and then staged the crime scene by removing two fired cartridge cases. The jury convicted the man of first degree murder. Had the two shots that struck the Jeep not been found, the man may well have gotten away with the murder. At the least, he would have probably only been convicted of a lesser charge such as manslaughter.

In another case involving ammunition components that appeared out of place, the author was asked to reconstruct a shooting inside a residence. The shooter claimed that the decedent was standing at the end of a hallway pointing a weapon at him as he entered the residence through an outside door. The shooter said that he fired in self-defense upon seeing the decedent with a gun. He stated that he fired twice, striking the decedent in the upper torso. Both bullets exited the decedent's body. The shooter said that the decedent moved into an adjacent room and collapsed after being shot. The decedent's final resting place was approximately 10 feet from where the shooter said the decedent had been standing when shot.

A fired cartridge case identified to the shooter's pistol was found in the hallway behind the location where the defendant was standing at the time of the shooting, as claimed by the shooter. A second fired cartridge case was found inside the room where the decedent collapsed. It also was identified to the shooter's pistol. One of the bullets that exited the decedent was found on the floor beside his body. A second bullet was also found on the floor in the same room, diagonally across from the entry between the room and the hallway where the shooting allegedly took place. Figure 13.3 is a sketch (approximately to scale) of the scene.

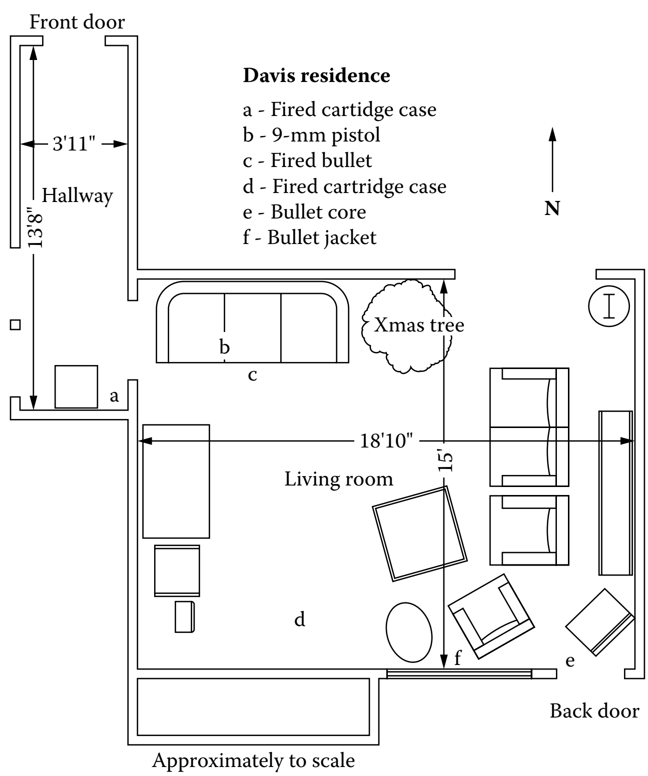

Figure 13.3 Shooting scene.

Clearly, the bullet and cartridge case locations do not appear to fit the shooter's account of the incident. The flooring in the hallway was tile and the cartridge case at location (a) could have rolled or been kicked to that location. The bullet at location (c) could have been caught up in the decedent's clothing and fallen there. Much more difficult to reconcile with the shooter's version of events, however, were the positions of the bullet core (e), bullet jacket (f), and cartridge case (d) because the room contained wall-to-wall carpet along with a large area rug, making any significant rolling of the bullet core, jacket, or cartridge case very unlikely.

The bullet core, bullet jacket, and cartridge case locations were consistent with a shot fired with the weapon inside the plane of the entry between the hallway and the room. This position would have the potential for an ejected cartridge case to ricochet off the adjacent wall and land in position (d) and also allow for the bullet core and jacket to end up at positions (e) and (f), respectively. When confronted with the evidence concerns, the shooter had a "sudden recall" and allowed as to how he had "probably" fired the second shot as the decedent backed into the room while still holding the gun. The gun was found on a couch several feet from the decedent.

When weapons appear to be out of place based on the purported events of a shooting, one must be very certain before eliminating a particular position as a possibility. The author has noted weapons in seemingly suspicious locations only to later ascertain that no foul play or staging of the scene was involved. In one shooting incident a question arose whether a man shot himself while seated in the driver seat of his vehicle after the weapon was found under the driver's seat. The fatal injury was a contact shot to the right temple. The decedent was right handed and the weapon belonged to him. The vehicle was parked on a dirt road and the roadway and ground in the area were very soft. No footwear or tire impressions were observed leaving the scene.

A series of drop tests was conducted using a similar vehicle. The idea was to simulate the decedent shooting himself and then allowing the weapon to fall out of his hand. Due to the presence of a center console in the vehicle, the weapon occasionally landed under the front edge of the seat. Any movement of the decedent's feet could have conceivably pushed the gun further back in the position where it was found.

No fingerprints were found on the gun. Blood spatter was present on the muzzle of the weapon; none was found on the decedent's right hand. However, it is well known that blood spatters appear on hands in such shootings in fewer than half the cases. No clear answer based on the physical evidence was forthcoming.

In conclusion, when crime scenes appear to have been altered, the first step is to ascertain whether the perceived change(s) to the scene are intentional or unintentional on the part of the suspect. The most common alterations to scenes in the author's experience resulted from the activities of first officers to arrive at scenes, emergency medical personnel, and others involved with life saving efforts. Bodies have been repositioned, bloodstains produced, trace evidence transferred, cartridge cases and bullets moved about unintentionally. It is, therefore, always a good idea to interview all the first responders to a shooting scene regarding what took place prior to the arrival of the investigators.

In a case that really makes the point, the author spent several hours mapping cartridge case locations on a roadway in a police shootout only to learn that a helicopter had set down at the scene in order to transport the wounded defendant to a distant hospital. A video camera inside a police unit captured the landing on tape. When the tape was reviewed, the wash from the helicopter could be seen blowing cartridge cases about the scene as if a giant egg beater had been used.

Off-Scene Analysis of Crime Scene Data

A number of steps relating to the reconstruction of a shooting are best conducted off-scene, including shot accounting, trajectory analysis, and cartridge case location analysis. As previously noted, shot accounting involves reconciling the number of fired cartridge cases with the number of recovered bullets or bullet fragments, the number of bullet entries in inanimate objects, and the number of victim entry wounds. While this can obviously be accomplished at the scene if only one or two shots are involved, more complex shootings involving multiple shots, multiple shooters and/or multiple victims may be better dealt with at the office after examining all the evidence. This is particularly necessary when many fragmented bullets are involved. The fragments must be examined for trace evidence, weighed and checked for physical matches (jigsaw puzzle fits of fragments) in order to estimate the total number of bullets represented and their sources.

The linear and angular components measured for each bullet trajectory must be incorporated into scale diagrams for evaluation as to shooter position. Two views (side or profile view and top or overhead view) should be prepared unless three-dimensional views can be produced via computerized animation or scale models. Photographic images may be used to accomplish the same task if feasible. Scenario evaluation can begin after the diagrams are prepared. Figure 13.4 shows overhead and side views of a scene prepared for scenario evaluation. In the case illustrated, the shooter claimed that two shots had been fired from a pantry area during a struggle, one striking and penetrating the refrigerator and the other penetrating the victim's skull. As can be see in the figure, the explanation is logical based on the overhead view, but does not work when the side view is considered. Thus, the explanation is refuted. A scenario

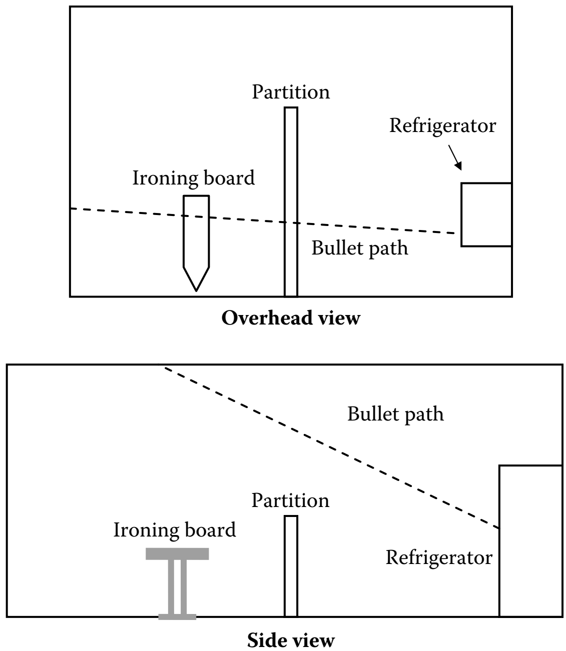

Figure 13.4 Overhead and side views of shooting scene.

may be declared invalid if one perspective does not fit. Conversely, it must fit both the top and side perspectives to be judged a valid explanation.

Cartridge case analysis need only be done using the top perspective unless a potential issue concerning obstacles such as low hanging structures or objects must be addressed. As discussed in the section on cartridge case analysis, the direction of fire must be known and the cartridge case locations must be logical to allow an investigator to make meaningful statements about probable shooter position. Scale diagrams can sometimes provide useful insight into the reliability of witness statements about shootings.

Homicide-versus-Suicide Issues

The question of homicide versus suicide frequently arises at shooting scenes. A number of misconceptions and misunderstandings have persisted among some investigators through the years:

Common Misconceptions

- If no gunshot residue is found on the hands of the victim, the death is a homicide.

- Finding gunshot residue on the back of a hand and not on the palm means suicide, while the reverse situation (residue on the palm and not on the back of the hand) means homicide.
- Absence of blood spatter on the hands of the victim of a contact headshot indicates the case is a homicide.
- Failure to leave a suicide note indicates a homicide.
- A female who suffers a head shot was probably murdered because women never shoot themselves in the head.
- Multiple gunshot wounds indicate a homicide.
- A shot not to the head by a male suggests a homicide.

The best response to all these statements is probably Herb MacDonnell's "Absence of evidence is not evidence of absence." Not finding evidence can never be treated as absolute proof of a particular occurrence or, put another way, a negative finding cannot be used to make a positive statement.

A negative test result for gunshot residue on the hands of a suicide victim can be attributed to issues such as faulty sampling technique, analytical error, failure of the weapon to produce detectable residue, or environmental factors present during and after a shooting. Likewise, positive results for gunshot residue on surfaces of the hand can depend on how the sampling was done as well as other factors such as postmortem handling.

Back spatter from a contact wound to the head from a large caliber weapon such as a 9 mm or 38 Special can certainly be expected. Studies by Vincent Di Maio of the Bexar County Institute of Forensic Science in San Antonio, Texas, indicate that no visible blood spatter is produced on the gun hand most of the time. An investigator should carefully inspect the weapon for blood spatter consistent with a gunshot. If spatter is widely distributed over the surfaces of the gun, the absence of blood on the hands would certainly raise a question. Even in this kind of situation, however, the only scientifically valid conclusion is that no blood was found.

Failure to find a suicide note in a case of self-inflicted gunshot death is the norm rather than the exception. Suicide notes are found in only about a third of the documented cases. Conversely, finding a suicide note would certainly necessitate verification of its authenticity.

The body location chosen for a self-inflicted gunshot often becomes a subject for debate. While it is certainly true that men most frequently select the head rather than the body and the reverse is true for women, the reverse situations certainly occur, albeit less frequently. The same can be said for a right hand-dominant individual who is found with a contact wound to the left temple or a left hand-dominant individual with a contact wound to the right temple. It happens! Certainly, one should look carefully at all aspects of the incident and keep in mind that "using the wrong hand" does not, in and of itself, indicate homicide.

The author has seen a number of cases over the years involving multiple shots fired by an individual intent on suicide. It is not uncommon for an individual to sustain a grazing wound to the head as a result of flinching at the last moment or because the weapon was held at too steep an angle. This often precipitates an additional shot or even multiple shots. Even self-inflicted shots to the back of the head are not entirely unheard of. In any event, the investigator should be cautious about declaring that homicide *must* be involved based merely on multiple shots inflicted.

Importance of Obtaining Participant Information

A number of facts should be learned about participants in the interest of reconstructions of shooting incidents. While the previous section may appear to downplay the importance of hand dominance, it is still an issue that must be considered. Other physical factors of importance are summarized below. The need to acquire some or all of this information for shooting reconstruction purposes will vary with the circumstances:

- Dominant hand
- Height
- Weight
- Visual acuity
- Hearing acuity
- Physical limitations
- Shoe size
- Waist measurement
- Arm length
- Weapon position (height held above ground, elevation of muzzle, cant to left or right)
- Inseam length
- Neck size
- Hat size

The majority of these features will be important when a live or animated reenactment is conducted. Weapon position descriptions can most often be established in officer-involved shootings because officers typically have established shooting stances. Gang members often use the "gangsta" sideways orientation when using handguns and an investigator must be able to confirm that. Otherwise, the information may represent speculation. In any situation, the likelihood that one scenario is more logical than others may well rest with one of these physical factors.

Characteristics like hearing and vision acuity become especially important when witnesses profess to have seen or heard certain activities leading up to and during shootings. This is especially true in officer-involved shootings where questions typically arise as to the justification for use of lethal force based upon the officer's perception of threat from a would-be assailant or whether the officer properly identified himself. Establishing visual acuity in such situations usually requires subpoenaing medical records to establish whether a witness requires corrective lenses and, if so, whether they were use at the time of the incident. Establishing hearing acuity is usually best accomplished by carrying out hearing tests as soon as possible following a shooting.

Shots Fired into Vehicles

The analysis of shots fired into a vehicle is entirely dependent upon proper documentation of bullet trajectories within the vehicle. First, the length, width, and height of the vehicle must be measured and any other measurements of importance (windshield, door openings, and window openings) should be made. While it is possible to obtain these measurements from a manufacturer, direct measurement eliminates questions about variations such as different sized tires, for example.

As with all inanimate objects of suitable thickness and construction, the x, y linear coordinates and the X, Y angular coordinates must be determined carefully. A convenient standard reference point such as the vertical plane of the rear of the vehicle must be established and all horizontal (x) linear measurements referenced to that point. The ground is typically used for vertical (y) linear measurements. If one or more tires are flat and it can be determined that the tires became flat after the shots were fired into the vehicle body, the vehicle must be leveled to its approximate original height before the vertical (y) measurements are taken. Otherwise, the vertical (y) measurement must be taken both ways (level and with deflated tires on the ground). The same applies to the X and Y angular measurements because a flat tire and a fully inflated tire can produce different apparent vertical angles.

All of the various linear and angular measurements should be referenced to imaginary vertical or horizontal planes, as appropriate. As already stated, one example is the plane of the rear of a vehicle. This measurement is important because few vehicles have flat body and window surfaces. It is also extremely important to make a sketch that illustrates the method by which the angle was determined. Figure 13.5 shows how to measure the lateral (x) angle of a trajectory rod passed through a bullet hole in a windshield. A simple sketch or notation of the exact angle recorded should appear in the examiner's documentation. Noting only that "X = 23 degrees" can easily become meaningless weeks, months and, especially, years later when someone attempts to ascertain what was actually measured, as discussed earlier.

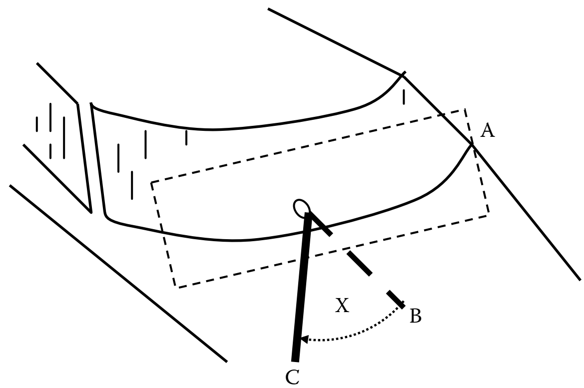

Figure 13.5 Measuring X or lateral angle of trajectory of a shot through a vehicle windshield relative to a perpendicular (B) to the vertical plane of the front of the windshield (A).

It is also important to determine the angles of inclination of windshields and rear and side windows when bullet holes are present. The following summary of the special considerations associated with the documentation of bullet holes in vehicles should be used as a checklist by the investigator or examiner responsible for collecting and analyzing the data.

Vehicle Bullet Hole Documentation and Trajectory Analysis

1. Measure and record the general vehicle dimensions (overall length, width, and height).
2. Measure and record specific vehicle dimensions (door and window openings, etc.).
3. Measure and record angles of inclination of windshield, rear window and/or side windows if perforated by bullets (easily accomplished with an angle gauge).
4. If one or more tires are deflated, determine the need to level the vehicle for purposes of taking trajectory rod measurements.
5. Determine x and y linear positions of the bullet holes (x should be determined relative to some convenient fixed point such as the plane of the front or the rear of the vehicle; y is typically the height above the ground).
6. Insert trajectory rods into bullet holes (properly orient rods as described in Chapter 4) and determine the X and Y angular coordinates.
7. Document trajectory rod positions with overhead and side (profile) view photographs.

8. Prepare scale drawings based upon the linear and angular measurements made for the bullet holes.
9. Analyze the feasibilities of various shooter positions based upon the scale drawings and information obtained from involved persons.

Using this methodical and detailed approach will enable an investigator to include certain scenarios and exclude others. Moreover, it allows all interested parties to visualize the shots into the vehicle. The additional use of three-dimensional diagrams may add to the reviewer's perspective of the shooting.

Case Studies

Case 1

An officer-involved shooting in a rural community resulted in the death of a woman. An officer shot her after he approached her stopped vehicle from the front. According to the officer, the woman started her vehicle and tried to run him over after she first stopped. The officer and two other units followed the woman after observing weaving of her car as she drove down the road. When she turned into a residential area, the officer turned in the opposite direction to head her off as the other two units continued to follow her.

The officer pulled his unit across the road with the emergency lights flashing and waited for the woman to arrive. As she pulled around a curve and sighted the officer, she came to a stop approximately 30 feet in front of the officer's unit, whereupon the officer exited his vehicle and began to approach the woman's vehicle on foot. According to the officer, the woman then put the car in gear and tried to run him over, forcing him to shoot. The woman was struck in the cheek by a fragment from the bullet that struck the windshield. A second fragment penetrated her abdomen. The woman survived following surgery and the officer was charged with attempted murder.

As part of the defense effort, a reenactment of the officer's position at the time the shot was fired was conducted. An individual representing the woman sat in the driver's seat. A dowel rod was then placed through the bullet hole in the windshield and the actor in the driver's seat held the end of the dowel rod to his cheek in the approximate position of the woman's wound. This was done to represent the trajectory of the shot fired by the officer. To establish the position of the officer, his stated shooting stance during the shooting was measured for height of the muzzle above the ground. This measurement was then used to determine where the officer would have been along the line of trajectory represented by the dowel rod from the windshield to the actor's cheek. The reenactment put the officer within a few feet of the front of the vehicle and clearly in danger.

This scenario no doubt poses a few questions about the validity of the reenactment and the resultant reconstruction. Questions such as how closely the actor's physique matched the woman's are certainly important here. The woman was 5 feet, 4 inches tall and weighed 120 pounds while the actor was 6 feet, 2 inches tall and weighed 240 pounds. This disparity meant that conclusions about the officer's position could not be considered reliable. The greater weight of the actor clearly affected the amount of compression of the driver's seat cushion. The longer torso of the actor would, likewise, subject the reconstruction results to question. Exactly how much deviation resulted is open to argument. The important point is that a true representation of the shooting was not accomplished.

Case 2

An officer fired at and shot a man as the man was exited his vehicle following a traffic stop. The man was rendered a paraplegic as a result of the shooting. The officer justified his use of lethal force by stating that the man carried a rifle in his right hand and raised it toward the officer. The officer stated that the man grabbed the driver door frame with his left hand as he exited. When the man moved around the door, the officer said he saw the rifle in the man's right hand with the muzzle pointed down toward the ground. The officer stated that he ordered the man to drop the weapon at which time the man started to raise the muzzle, forcing the officer to fire. A 22 lever action rifle with a broken stock was found at the scene. The officer said the broken stock occurred when he kicked the weapon away from the man following the shooting. The man admitted having the rifle in his truck but denied exiting with it in his hand.

At the criminal trial, a physician testified that the defendant had no use of his right arm at the time of the shooting due to a previous accident and could not have possibly been holding the rifle in his right hand when he exited his vehicle. The officer was either wrong about which hand carried the rifle or was altogether wrong about the rifle. His insistence as to which hand was where caused the jury to acquit the man of attempted murder of a police officer. Clearly, the physical limitations of the man should have been revealed in a thorough investigation of the man and the incident.

Case 3

In the highly publicized case of the U.S. Naval Academy midshipman Diane Zamorra who was accused of aiding and abetting her Air Force Academy boyfriend in the murder of a girl the boyfriend confessed to having a fling with, a physical limitation served as part of the defense effort. According to the prosecution's theory, Zamorra was secreted in the trunk of her boyfriend's vehicle behind the fold-down rear seat back when they went to pick the victim up. According to the state, once the vehicle stopped in a secluded area, Zamorra pushed the seat down and jumped out to attack the girl from behind. Zamorra allegedly struck the girl on the side of the head with a 10-pound dumbbell. This, the state alleged, was accomplished using the left hand.

At trial, the defense presented a surgeon who operated on Zamorra's left hand several months prior to the incident. The surgeon testified that there was no way that Zamorra could have lifted a 10-pound dumbbell with her left hand or swung it from left to right because of surgical implants. Supportive testimony from a pathologist indicated that the deceased victim's head wounds were inconsistent with injuries from a dumbbell. Although this battle was presumably won by the defense, the war was lost in that Zamorra was convicted of capital murder and sentenced to life without parole. The family of the victim requested that the death penalty not be sought. Nevertheless, Zamorra's physical condition should have undergone a thorough investigation prior to trial.

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Ballistics

14

Introduction

The term *ballistics* is often used improperly and interchangeably with *firearms identification*. Ballistics is the study of projectile motion while firearms identification deals with the examination and comparison of weapons and ammunition components. Obviously, determining whether a bullet or cartridge case was fired from a particular weapon has nothing to do with projectile motion per se. Ballistics is certainly one aspect of shooting incident reconstruction that must be dealt with, particularly in cases involving long range shots and bullet trajectories in flight. Questions about bullet behavior upon target impact are also ballistics issues as are questions regarding weapon failures such as those resulting from excess internal pressures.

The study of ballistics is generally approached from three perspectives: internal ballistics, external ballistics, and terminal ballistics (wound ballistics is a subdiscipline of terminal ballistics). Internal ballistics concerns bullet behavior and related aspects prior to the exit of the bullet from the muzzle of the weapon. External ballistics encompasses bullet behavior upon exiting the muzzle and prior to final target impact. Terminal ballistics deals with bullet behavior upon impact with a target.

Internal Ballistics

A quick review of some of the basic principles of metallic cartridge case discharge is in order as we begin our discussion of internal ballistics and the behavior of bullets within the confines of a gun barrel. Two events are required to ensure that a bullet will move down a barrel in the most efficient manner. First, a primer must be detonated by the impact force of a firing pin or striker. The flame created by the detonation of the priming mixture must then enter the confines of the cartridge case and ignite the powder charge. This ignition creates combustion gases that rapidly expand equally in all directions.

As a result of this expansion, the brass cartridge case expands to seal the rear of the chamber. This is extremely important for both the safety of the shooter and the efficiency of the round. No gases should move rearward toward the shooter. In an extreme situation, this could result in blowout of the primer or even weapon failure. The case expansion that seals the chamber literally occurs in a split second. What is even more remarkable is that the case returns to its original shape (more or less) in another split second as evidenced by the fact that the fired cartridge case can be extracted from the chamber. If the fired cartridge case did not contract, it would be tightly jammed in the chamber and could not be extracted easily. These two dynamics represent a remarkable bit of physics in action.

Similar sealing takes place at the muzzle end when the bullet expands to seal the bore. This expansion is known as obturation. Failure to seal the muzzle end of the bore results in blow-by of gases. This ultimately erodes the barrel surfaces and makes the weapon inaccurate to say the least.

Joshua Shaw, who immigrated to the United States from England in 1814, is credited for the first design of a metal cup for holding a priming mixture. A piece of metal foil was used to cover the priming mixture. The foil was then shellacked in place and the assembly was placed on the nipple of a percussion cap pistol or rifle. With the advent of the self-contained brass cartridge case and its combination with Shaw's primer cup, the modern metallic cartridge was born. Modern center-fire cartridges are typically made of brass due to the ability of brass to expand and contract upon discharge as described above. The primer cup is held in a primer pocket centrally located in the head of the cartridge case as shown in Figure 14.1.

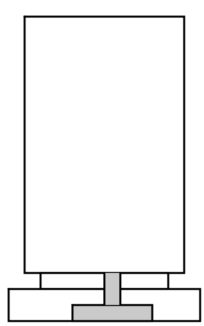

Figure 14.1 Typical metallic cartridge case design. Cutaway view showing primer pocket and flash hole (in gray).

In addition to the single flash hole device designed in England by Colonel Edward Boxer (Figure 14.1), a double flash hole design was developed by Colonel Hiram Berdan at the Frankfurt Arsenal in Philadelphia. NATO 9-mm ball ammunition is typical of Berdan's twin flash hole design as are many center-fire cartridges manufactured outside the U.S.. Most U.S.-manufactured center fire ammunition follows the Boxer style with a single flash hole.

The only possible implication for this in shooting reconstruction relates to demonstrating consistency via comparisons of cartridge cases found at a shooting scene with those taken from a suspect. Berdan-style cartridge cases are less common in the U.S. and their presence or absence could add to the weight of circumstantial evidence of similar cartridge case design.

Priming mixtures were originally based on potassium chlorate and later on fulminate of mercury. The problems associated with these mixtures were significant. Potassium chlorate is corrosive to steel. Fulminate of mercury forms an amalgam with brass that, over time, causes it to become brittle and prone to cracking. Most modern primers are based on lead styphnate, although lead-free primers are available from a number of manufacturers (see Chapter 8).

After a primer is detonated and the resultant flame passes through the flash hole or holes, the gunpowder is ignited. Modern "smokeless" powder consists of either nitrocellulose (single base) or nitrocellulose in combination with nitroglycerin (double base). Originally, a "black powder" consisting of a mixture of charcoal, sulfur, and potassium nitrate was used. The disadvantages of this formulation were its corrosive nature and the production of a large quantity of smoke upon combustion. Most modern weapons are designed for smokeless powder although black powder weapons are still produced and black powder shooting is a popular hobby. The author has reconstructed several shootings involving the use of black powder weapons. One common black powder substitute is Pyrodex® which offers the black powder shooter a non-corrosive alternative.

As mentioned in Chapter 8, modern gunpowder also contains various stabilizers and plasticizers so that the combustion occurs at a predictable and controlled rate. A major consideration regarding rate of combustion is powder shape or morphology. Smokeless powder typically exists in flake (disk), ball, flattened ball, and tubular configurations. The rate of combustion increases with an increase in surface area. This is exactly analogous to selecting wood to start a fire. To achieve a rapid, very hot fire, lots of small pieces (kindling) are used instead of intact logs. The issues to be considered relating to gun powder are:

- Morphology (flake/disk, ball, flattened ball, tubular)
- Coatings that control burning rate
- Single base or double base
- Smokeless or black powder

In addition to the primer and powder charge, other variables associated with the study of internal ballistics include chamber capacity of the weapon, barrel length, caliber, and bullet design and dimensions. Powder chamber capacity is defined as the number of grains of water that a cartridge case can hold. This is a standard capacity measurement used in ballistics determinations. Bullet design considerations include diameter (caliber), overall length, and weight. Obviously, characteristics like length and weight figure into the friction that a bullet will display inside the confines of a gun barrel. Barrel length is another important consideration. In general, the variables that effect internal ballistics are:

- Chamber capacity
- Amount of powder
- Burning rate
- Diameter, length, and weight of bullet
- Barrel length and caliber
- Primer (uniformity of ignition)

Firing a cartridge involves nine internal ballistics events:

- Trigger is pulled
- Hammer strikes primer
- Priming mixture explodes
- Powder is ignited
- Gases are produced and expand
- Bullet or shot starts down barrel; cartridge case expands to seal breech
- Bullet obturates to seal bore
- Gas pressure builds, then decreases
- Bullet exits barrel

A few notes regarding weapon functioning are in order here. If the cartridge case is not square with the breech face, the pressures created upon combustion can cause torque which prevents the bullet from entering the bore in proper alignment (i.e., axis of bullet = axis of bore). This can produce a significant deviation in the impact point. With revolvers, this effect is manifested by "shaving" of the bullet as it moves from the misaligned chamber into the barrel. This can produce fragments that can result in injuries to individuals within close proximity.

Ideally, the build-up of pressure within the bore maximizes just prior to the exit of the bullet. Different barrel lengths would, theoretically, benefit from different burn rates. Commercial ammunition must take into account

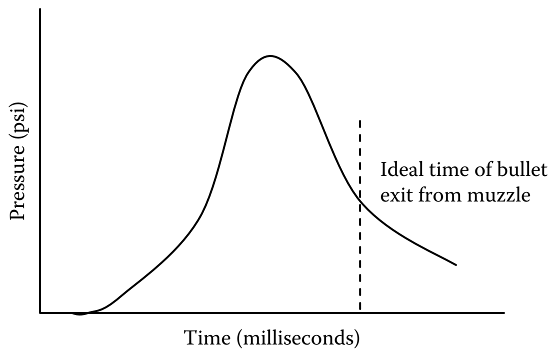

Figure 14.2 Internal barrel pressure curve.

all possible common barrel lengths. Thus, more than adequate powder is present for short barrels. The good news for shooting reconstruction is that this ensures that partially burned and unburned powder particles will emanate from the muzzle and allow muzzle-to-target distance determination. Figure 14.2 depicts a typical pressure curve; the pressure (in pounds per square inch) is plotted against time (in milliseconds). The volume of gas produced is huge compared to the volume of the unburned powder (about 4700 times as great). To illustrate the amount of pressure generated inside a bore, modern 308, 556, and 223 caliber rifles attain pressures of over 50,000 pounds per square inch within milliseconds of discharge.

The longer the barrel, the more pressure exerted against the bullet, hence the higher the velocity of the bullet. Velocity may be altered by changing the burning characteristics of the powder or by using more powder (a longer case). A familiar example is the 38 Special versus the 357 Magnum.

Maximum velocity is reached just past the peak pressure point. The corresponding barrel lengths associated with various commercial loads to achieve maximum velocity vary as would be expected. For example, with a 22 long rifle, peak pressure is attained in about 16 inches. If the barrel is longer than 16 inches, friction between the bore and the bullet actually retards the round. For a 308 round using commercially available ammunition, a barrel length of 30 to 36 inches is required to obtain complete combustion and peak pressure. This barrel length is generally too long for tactical use. Therefore, some loss in performance is accepted in order to gain practical efficiency for law enforcement use.

In theory, the shorter the barrel (or the lighter the bullet), the faster the required burn rate to ensure maximum barrel pressure just prior to bullet departure. Obviously, as the pressure rises, the bullet will be imparted with greater velocity. Given these basic principles of internal ballistics, it is obvious that weapons such as a snub nose 44 Magnum fail to capitalize on the inherent energy in the large powder charge present due to their short barrels and low expansion ratios.

When a bullet exits the mouth of a cartridge case and strikes the rifling, the effect can be likened to striking the chamber end of the barrel with a hammer. According to Newton's third law, an equal force will be generated at the butt of the handgun or long gun. This force is manifested as longitudinal vibrations within the barrel.

Spin stabilization of the bullet within the confines of the barrel is the dynamic that allows the bullet to maintain a trajectory upon exiting the muzzle. The twist direction may be clockwise or counter-clockwise, depending on the barrel rifling characteristics. Also, the rate of twist of the barrel will determine how fast the bullet rotates upon muzzle exit. Barrel rate of twist is given designations such as "1 in 12" or "1 in 6." This means the bullet completes one rotation about its long axis for every 12 inches or 6 inches, respectively, of barrel length.

As a rule, the longer and heavier a bullet is in any given caliber, the faster the twist needed to stabilize it. A typical round involves 150,000 to 200,000 revolutions per minute. If a bullet base is not square with the plane of the muzzle upon exit, an "axial error" will cause the bullet to go off target. This is overcome, to a large degree, by a boat-tail design (Figure 14.3) considered superior to other base designs.

The firing pin spring pushes forward with a force of approximately 25 foot-pounds on the average. Newton's third law dictates that a comparable force be applied rearward. Thus, a bullet produces equal forces forward and rearward. The net effect is, of course, recoil. The point is that the recoil effect is the same as the bullet impact effect. The recoil effect is diminished by the

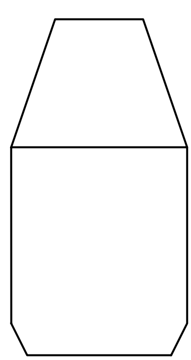

Figure 14.3 Boat-tail bullet base design.

greater mass of the weapon as compared to a bullet. In terms of the significance in shooting reconstruction, bullets do not knock people down, spin them around, or stop them in their tracks as they run forward, even though Hollywood would have us believe otherwise. On the other hand, people react to being shot in a variety of ways. As someone once pointed out, if you stick someone with a pin, he may jump into the air and scream, but the action is simply a reaction to the pin, not to the mass of the pin or the lack thereof.

One of the poorly conceived arguments for a shot from the "grassy knoll" in Dallas when President Kennedy was shot, was that his head could be seen snapping back from a bullet that struck from the front in the 8-mm movie film taken by Abraham Zapruder. On close examination of the digitized version of the film run in slow motion, the viewer can clearly detect a brief lapse between the obvious bullet impact from the rear and the backward movement of the head. The movement was likely an autonomic nervous response that followed the bullet impact to the back of the head.

The misconception that bullets and shot pellets cause various movements of human bodies arises rather frequently in shooting incidents. An investigator should understand the physics involved in order to be able to explain to a jury and to others why the portrayals in the movies and on television are incorrect. The explanation must be tempered, however, with the statement that people may definitely react in various ways to being shot.

A rather dramatic, although unorthodox, illustration of these principles was provided in a video titled "Deadly Weapons" produced by Anite Productions in California a number of years ago. In one segment attesting to the proficiency of a particular brand of bullet proof vest, the designer shoots another individual in the chest with a 308 at point blank range. The individual shot was, of course, wearing one of the designer's vests. The impact of the 308 military ball round failed to move the recipient off his one-leg-in-the-air stance: one picture can be worth a thousand words!

A frequent issue in shooting reconstruction is the use of rifles and shotguns with sawed-off barrels. The net effect on velocity depends on how much of the barrel was removed and the size of the cartridge case in relation to the barrel diameter (caliber or gauge). This involves a factor known as expansion ratio: the ratio of the capacity of the powder chamber to the capacity of the chamber plus the bore. Weapons with high expansion ratios (small cases in relation to bore diameter) tend to lose less velocity than do weapons with low expansion ratios (large cases in relation to bore diameters). The best way to obtain a quantitative determination of the effect of sawing off a barrel is to perform chronographic studies using the weapon and ammunition involved.

External Ballistics

External ballistics has been recognized and explored for thousands of years. The word *ballistics* can be traced to ancient Greece. The Greeks used it in relation to throwing machines used around 300 B.C. Some of the best known scientists (Leonardo da Vinci, Galileo, Sir Isaac Newton, Francis Bacon, Leonard Euler) delved into the study of projectiles in motion and helped develop ballistics as a true science.

Galileo was a ballistics consultant to the arsenal in Venice and conducted his well known experiment of dropping cannon balls from the Leaning Tower of Pisa to prove that bullet trajectories are parabolic. Although a brilliant scientist, Galileo failed to consider the significant effect of air friction on all bodies in motion. This coupled with his inability to determine muzzle velocities prevented him from accurately calculating trajectories.

Benjamin Robins' invention of the ballistic pendulum in 1740 allowed reasonably accurate muzzle velocity determinations. This, along with Newton's invention of the calculus and his understanding of gravitational effects, allowed trajectories to be calculated. Robins came to the then amazing conclusion that the effects of air friction (drag) were considerably greater than gravitational effects on projectiles put into motion. Air friction or drag *slows* a bullet while gravity *pulls* it to earth. Gravity produces a constant acceleration on a body in motion at the rate of 32 feet per second (fps). This acceleration continues until impact with the target (or ground) occurs. The idea, of course, is to hit the target, not let the bullet go to ground. The effect of gravitational acceleration over time can be illustrated as follows:

After 1 second velocity = 32 fps
After 2 seconds velocity = 64 fps
After 3 seconds velocity = 96 fps
After 4 seconds velocity = 128 fps
And so on

Ballisticians use a number of terms when discussing external ballistics. A shooting reconstructionist should be familiar with these terms:

Back curve Portion of trajectory below the critical (kill) zone beyond the point blank range

Ballistic coefficient Measure of a bullet's ability to resist air friction and maintain velocity and energy in flight (signified by a number)

Bore centerline Visual line of center of bore

Bullet trajectory Parabolic path of flight of bullet

Critical zone Known as the "kill-zone," a 6- to 8-inch diameter area for humans and big game

Initial point Range at which bullet trajectory first crosses line of sight (approximately 25 yards downrange)

Line of sight Visual line from sight to target

Maximum ordinate Maximum height of bullet trajectory above the line of sight (usually slightly beyond the mid-range point of the trajectory)

Maximum point blank range Maximum distance at which the bullet remains in the critical zone (no more than an 8-inch drop for a man-sized target)

Mid-range trajectory Bullet height half-way to the zero range

Minute of angle (MOA) One sixtieth of a degree; equates to approximately 1 inch of pattern spread (group) at 100 yards

Yaw Angle between the longitudinal axis of a projectile and the line of the projectile's trajectory

Yawing Rotation of a non-stabilized or destabilized bullet about its longitudinal axis; most severe consequence is tumbling

Zero range Maximum range at which line of sight and trajectory intersect

Most of these concepts are represented by the bullet trajectory diagram (Figure 14.4). Prior to spin stabilization or as a result of impact with an intermediary target, a bullet yaws in flight. With time and distance, this yawing can

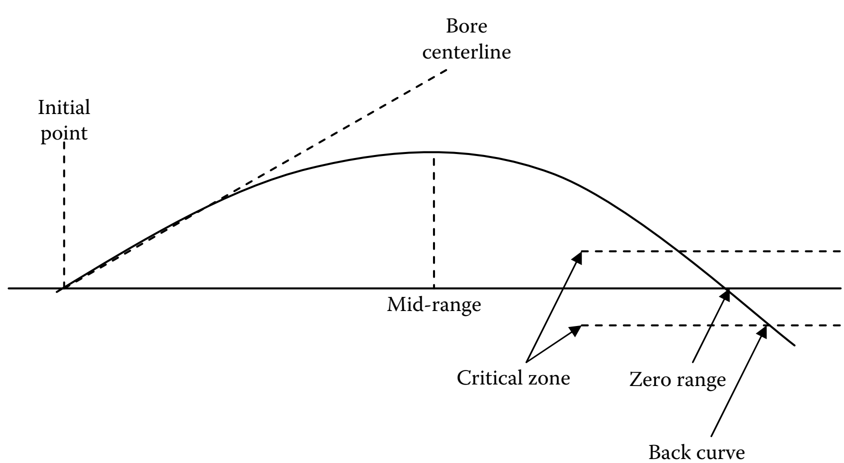

Figure 14.4 Bullet trajectory diagram.

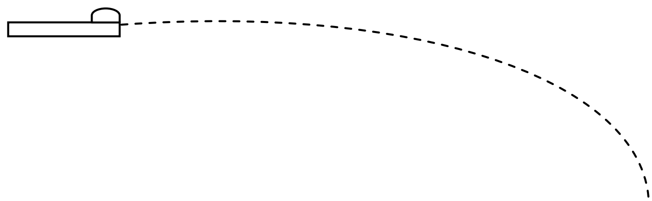

Figure 14.5 Effect of gravity on bullet trajectory (shot fired parallel to ground).

become pronounced enough to produce tumbling. It can be recognized by the characteristic "keyhole" entry. Yawing also takes place within the human body (see next section). If the barrel of a gun is held parallel to the ground and fired, this effect is a parabolic trajectory to earth as shown Figure 14.5.

If we eliminate drag and consider only the effects of gravity, a bullet fired parallel to the ground and one simultaneously dropped from the same height above ground would strike the ground at the same time because gravity will act equally on both bullets; the fired bullet would land farther away. To illustrate the comparative effects of drag and gravity on a bullet in flight, consider the following example. If we could eliminate the effect of gravity, a 30 caliber, 165 grain bullet fired parallel to the ground would travel just under 2 miles. The same bullet fired in a vacuum (no drag effect) would travel 43 miles and strike the ground at the same velocity it left the muzzle with!

The concept of a "standard bullet" to allow comparison of various bullet designs (shapes) was introduced in the mid-19th century along with the *ballistic coefficient* term as a measure of bullet efficiency. Bullet trajectory for the standard bullet could be calculated and used to determine the proposed trajectories for other types and styles of bullets.

In 1965, Winchester published several bullet drag tables based on four standard drag models for four families of bullets. These models cover the majority of sporting bullets. Additional models have been derived for other bullets. These models are denoted by the letter G along with a number or letter. The G1 is a widely used drag model in the firearms industry. The reader is invited to pursue more in-depth reading on the subject in any of a number of fine ballistics texts published over the years. Thanks to modern computers and ballistics software (see Chapter 15), the calculation of bullet trajectories is quick and easy. Galileo and Newton would no doubt be duly impressed!

For shooting reconstructions involving close range shots (under 100 yards), external ballistics considerations are usually the subjects of academic discussions rather than having practical implications. The effect of a change in ballistic coefficient is relatively small, even at great range. For example, a flat-based bullet may be compared to its boat-tail cousin with few noticeable differences. For example, consider the comparison of the bullet paths of two 165 grain hollow point bullets (one flat-based and the other a boat-tail) with 2700 fps muzzle velocity and 225 yard zero range at 300 yards. The flat-based bullet is found to have a drop of 6.8 inches while the boat-tail bullet shows a 6.6-inch drop. This is basically insignificant, given the percent error associated with such measurements.

Environmental effects can be somewhat more pronounced. Ballistics tables are generally based upon standard conditions (0.0 altitude, 59 degrees Fahrenheit, 29.53 inches of mercury, and 78% relative humidity). Looking first at altitude effects in general, the higher the altitude at which the shot takes place, the higher the bullet will strike. This is why hunters re-sight in their rifles when they go to mountainous regions to hunt after they originally sighted in their weapons at low altitudes. As a rule, the bullet strike point will only change a fraction of an inch for each 1000-foot change in altitude. Shots fired uphill or downhill will strike high because gravity acts on a bullet only on its horizontal component, as illustrated in Figure 14.6.

As a bullet leaves a barrel, the movement of air (wind) can alter the strike point with respect to the point of aim. A wind blowing at a right angle to the line of departure (cross wind) will have the greatest effect. Tail winds and head winds produce significant vertical deflection only for shots over approximately 600 yards. As an example of wind effect, a 308 Sierra 168 grain boat-tail hollow

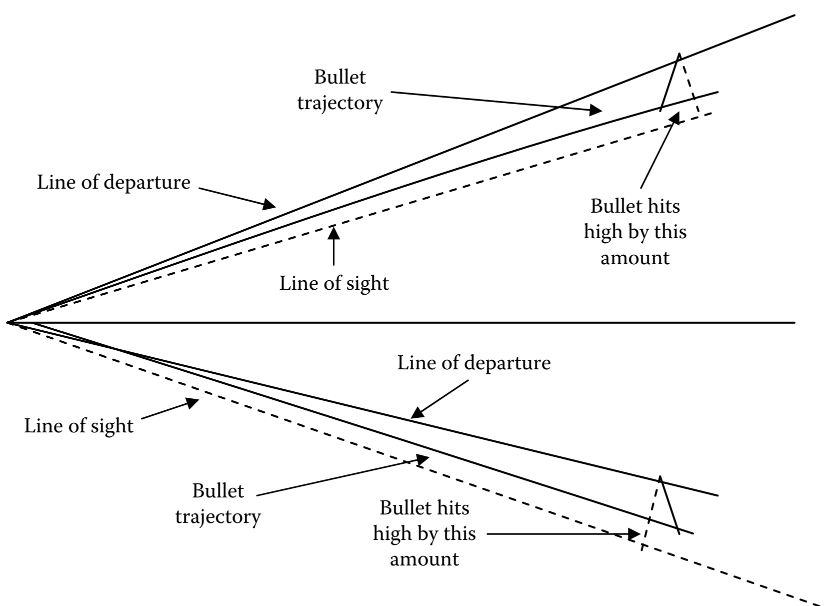

Figure 14.6 Uphill and downhill shots hit the target high.

point with a 10-mph right angle wind will be deflected over 3 inches at 200 yards. At 400 yards, the deflection will be over 13 inches. At 1000 yards, a 1-mph cross wind can deflect the same bullet more than 7 inches.

Temperature will affect both the muzzle velocity of a bullet and its trajectory. The ambient temperature is a factor for ammunition in storage. A gun barrel is also affected by temperature changes. A cold barrel will have a smaller internal diameter and a resultant increase in friction as compared to a hot barrel. As a rule, the hotter the temperature, the higher the shot will impact the target. For each 15-degree increase in temperature, a corresponding fractional increase in bullet rise will be produced.

If shots are fired in the rain, the resultant increase in humidity and air density causes the bullet to impact its intended target lower than would otherwise be the case. The change is generally quite minimal, however, and only a consideration for long range shots of the order of 1000 yards or so. A similar result is produced for shots fired when snow is falling.

All these issues mean little in the contexts of most shooting incidents because shootings generally involve close range shots. Even in the cases of police sniper shootings, shots of under 100 yards are the norms. Accordingly, if a rifle is zeroed in for 200 yards, the potential environmental effects on bullet impact are negligible. For those occasional cases involving long distance shots, appropriate consideration must be given to these effects. As will be discussed in the next chapter, ballistics software provides us with a simple solution to this rather complex problem.

Terminal Ballistics

Terminal ballistics covers bullet behavior upon impact. For shooting reconstruction, it is important to understand terminal ballistics for both inanimate and human targets. In the case of human targets, *wound ballistics* is the subcategory of concern. Again, the reader should be familiar with certain terms.

Armor piercing Bullet constructed of hardened steel or containing a steel core

Fragmentation Disruption of a bullet into smaller fragments

Full metal jacket Bullet nose is fully encased by a jacket (open base)

Full metal case Both the base and the nose of a bullet are fully encased by the jacket; typical of military bullet construction where expansion is not desired

Hollow point A cavity in a bullet nose designed to produce expansion (typical hunting bullet)

Minimum perforation velocity Minimum velocity required for a projectile to perforate human skin; largely depends on projectile shape and mass; ranges from about 200 to about 300 feet per second

Permanent cavity Cavity in tissue created by passage of a bullet (does not contract after bullet passage)

Temporary cavity Cavity resulting from temporary tissue displacement following bullet passage (collapses after the bullet passes through)

Penetration depth Final depth to which a bullet penetrates

Note that several common terms do not appear on this short list, most notably, *killing power* and *stopping power*. The reason is that these terms are erroneous and have no place in a legitimate discussion of terminal (wound) ballistics. The reader should recognize how misleading these terms are after reading the following section.

In general, tissue damage is proportional to the size of the bullet and the energy transferred. Thus, the old prediction about the outcome of a gunfight ("whoever has the gun with the biggest hole in the end wins") seems appropriate. Tissue damage is a permanent effect and, thus, an important consideration in terms of lethality. However, even the most disruptive heart wound cannot be relied upon to prevent aggression until 10 to 15 seconds have elapsed.

In terms of immediate incapacitation, the "principle of the two Ps" (placement and penetration) of a bullet is vital. For a bullet to cause immediate incapacitation, it must impact the appropriate area of the body (the first P: placement). After it strikes the target in the right location, it must penetrate the tissue to an appropriate depth (the second P: penetration). The two areas of the body where bullet impact produces instant incapacitation are the spinal cord and the brain stem. Thus, a shooter must be capable of placing a shot to the brain stem or spinal cord area and the bullet must be capable of passing through intermediary tissue and bone to reach these vital regions.

Massive disruption of the heart and/or major blood vessels of the torso will cause circulatory collapse and, ultimately, death but no immediate incapacitation. An aggressor can do a lot of damage in 5 to 10 seconds. For this reason the FBI abandoned the 9-mm in favor of the 40 caliber after a well known bank robbery shootout in Miami years ago. In that incident, FBI agents fired their 9-mm handguns and hit the aggressors but the aggressors kept coming, fueled by sheer determination rather than alcohol or other drugs. A number of agents lost their lives in that incident and lack of proper firepower was cited as a contributing cause.

When a bullet strikes and passes through human tissue, crushing and stretching of the tissue result. Tissue crushing produces what is commonly

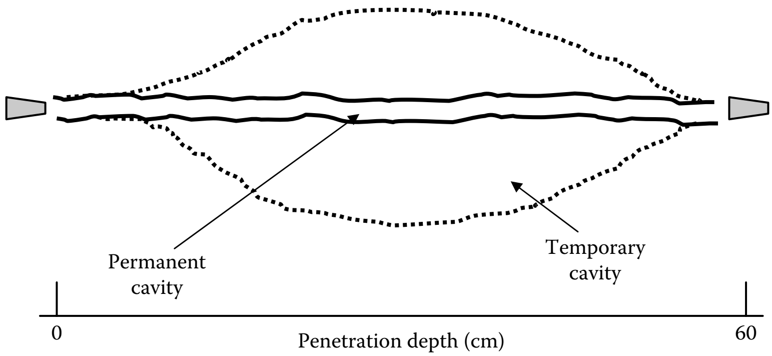

Figure 14.7 Temporary and permanent cavities in tissue.

referred to as a *permanent cavity*. The outward, centrifugal stretching that takes place is responsible for a temporary cavity. A temporary cavity does not persist and eventually collapses back to its original configuration. The *permanent cavity* produces the lethal effect of a gunshot. Figure 14.7 and Figure 14.8 illustrate permanent and temporary cavities. Note that the tumbling shown in Figure 14.8 produced a more pronounced permanent cavity and caused the bullet to land base first (180-degree change in orientation). Tumbling is the result of yawing that begins upon impact and becomes so severe that a bullet will ultimately reverse itself if sufficient tissue depth is available. Military 7.62 NATO bullets and the stubby 7.62 × 39 bullets are well known for this while the M-16 round (223) has a reputation for the propensity to fragment inside a body (Figure 14.9). Note the relative differences in penetration depth for these different bullet behaviors.

A case in which the author was involved reveals what an investigator might see as a result of yawing upon impact with tissue. The author was

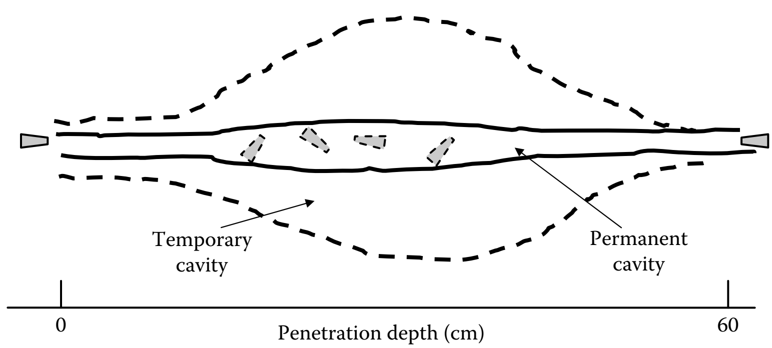

Figure 14.8 Temporary and permanent cavities in tissue (tumbling bullet).

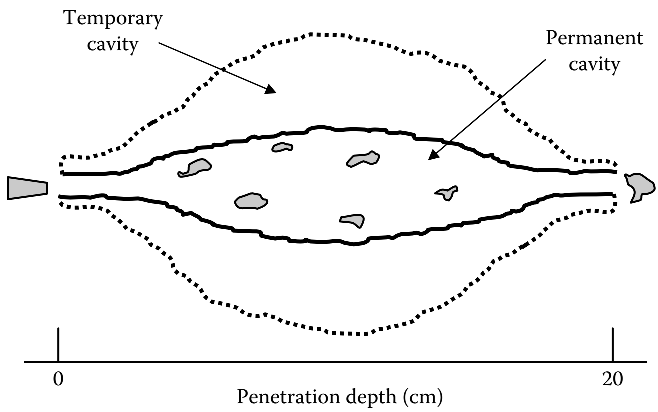

Figure 14.9 Temporary and permanent cavities in tissue (fragmenting bullet).

investigating a shooting in a South American country. A driver was shot to death as he sat in his vehicle parked at a curb. The shots were fired from the front passenger compartment as evidenced by fired cartridge locations and the general trajectories of the shots. One bullet perforated the man's neck. A bullet was found in the "B" pillar on the interior side of the vehicle in line with the neck wound. The bullet was lodged in the pillar base first. Clearly, the bullet reversed itself as it passed through the victim's neck. The bullets fired into the victim were full metal case 9 mm.

Studies of bullet behavior in human tissue are simulated with 25 × 25 × 50 cm blocks of 10% gelatin calibrated to reproduce the crush and stretch found in living tissue. The results of test firings into gelatin blocks are transposed onto scale drawings called wound profiles (Figure 14.7 through Figure 14.9). By studying and comparing these wound profiles, it is possible for a wound ballistics expert (pathologist) to determine what type of tissue disruption to expect in a particular anatomical location. Also, the gelatin block studies allow the depth of penetration for the bullet or load under study to be determined.

Common Misconceptions Regarding Wound Ballistics

A number of misconceptions regarding wound ballistics should be explored. These misconceptions are generally based upon half-truths and need to be fully discussed so that their limitations will be clearly understood.

High velocity bullets are more devastating than low velocity bullets. High velocity rounds tend to be lighter and more prone to fragmentation and fragmentation produces tissue disruption. Low-velocity rounds, on the other hand, tend to be larger and heavier, producing deeper penetration and greater tissue destruction (larger permanent cavities).

The larger the temporary cavity, the more devastating the resultant wound. Kinetic energy deposit alone produces no wounding effect. The transfer of kinetic energy is responsible for production of a temporary cavity. Temporary cavity tissue displacement can disrupt blood vessels and even break bones in rare instances, but elastic tissues such as bowel walls, muscles, and lungs are somewhat resistant to damage. Solid organs such as the liver are not, however. The loss of kinetic energy stops a bullet — an event preferred to exiting the body, particularly in officer-involved shootings.

A bullet must expand as much as possible and as soon as possible to be effective. The key issue is penetration, not expansion. While expansion is desirable, the depth of penetration is vital in terms of immediate incapacitation. Any bullet that will not reliably penetrate 10 to 12 inches of soft tissue is inadequate.

Bullets passing through only soft tissue maintain their trajectories. Gelatin studies and case evaluations clearly show that yawing takes place upon impact with tissue and tumbling often results both within the body and upon exiting. Thus, bullets do not have to impact bone in order for destabilization to occur.

It is clear that many variables are associated with wound ballistics and one should consider the specifics of the case at hand rather than relying on broad generalities. An individual charged with reconstructing a shooting should seek the assistance of a qualified forensic pathologist in evaluating issues pertaining to wound ballistics, particularly in predicting whether an individual had mobility following bullet impact and for how long. At the least, a review of the autopsy report to determine whether injuries to the spinal cord or brain stem were produced is a requirement for a shooting reconstruction expert.

Another common misconception is that a bullet designed to expand must not have impacted its intended target if expansion did not take place. The best known example of this principle is, of course, the so-called pristine bullet from the assassination of President Kennedy. The bullet first passed through President Kennedy's neck, entering from the rear, before passing through Governor Connolly's shoulder and wrist and entering his thigh. A subsequent study of this shot concluded that the bullet was tumbling as it entered Governor Connolly due to yawing that began inside the President's body. Much discussion centered on the lack of expansion or "significant" damage to that bullet. The fact is that visible damage was found on the nose of the bullet, although no expansion was apparent. Such "pristine" bullets are found in shooting incidents from time to time. Hollow point bullets sometimes impact relatively soft materials, such as sheet rock, that fill the nose cavity and prevent expansion. The same result can occur from impact with human tissue. Thus, the presence of a bullet that has not expanded should not necessarily be taken as evidence that it did not pass through some individual or some object.

In a case the author investigated, an unexpanded, 9-mm, hollow-point bullet was found on a gurney beside the body of a deceased male. The man sustained a perforating wound that entered the right posterior shoulder, traversed the chest cavity and exited the left chest just below the nipple. He was wearing a heavy sweat shirt with a thick, embroidered emblem on the front. A small defect in line with the exit wound was found on the inside of his shirt in the area of the emblem — obviously an inside-to-outside hole due to the outward protrusion of fibers. The hole, however, was too small for the bullet to have passed through, even with fabric stretching. Apparently the bullet traversed the man's body, lost most of its energy, but still managed to partially perforate the sweat shirt emblem. In the absence of visible expansion, another "pristine" bullet was born.

Sound Suppressors

Sound suppression is really not part of the study of ballistics, but it is somewhat related because sound suppression is concerned with the rapid expansion of gases produced during the combustion of gunpowder. The reader will note that the term "silencer" has not been used because it is an impossible term. The only way to totally silence a firearm is simply not to fire it.

The sounds that combine into the noise of discharge have a number of sources. The falling of the hammer and the working of the action are mechanical sounds associated with discharge. The rapid expansion of gases from the combustion of the gunpowder, as already mentioned, produces a major portion of the noise generated. The sonic boom created when a bullet breaks the sound barrier is an additional source of noise. Sound suppression involves stopping or reducing the report of as many of these events as possible.

A muzzle-mounted device intended to suppress sound is intended to reduce the rate of gaseous expansion and the associated sound. Other steps are required to eliminate or reduce the remaining sounds. Locking the action of a semi-automatic weapon is a way of eliminating the sound of the action, but it means that only one shot will be possible since locking the action eliminates automatic reloading. It is presumed that the reader recognizes, contrary to old classic movies, that the report of a revolver cannot be feasibly suppressed because of the cylinder gap.

Eliminating sonic boom merely requires firing subsonic ammunition — ammunition with a muzzle velocity slower than approximately 1100 feet per second. Such ammunition is available through a number of commercial sources. A popular round for law enforcement use is the 9-mm 147 grain subsonic round. This particular round is subsonic not by design, but as a consequence of maximizing bullet weight for tactical purposes and the subsequent reduced powder charge resulting from reduced space in the 9-mm case.

The main source of sound is produced by the rapid expansion of the combustion gases. Any slowing down of these gases has the effect of reducing the audible sound. For shooting reconstruction purposes, an investigator really must be on the alert at the crime scene because all sorts of make-shift devices can serve as sound suppressors in addition to more sophisticated forms. Among the objects that the author has encountered over the years that were placed over the muzzles of handguns and long guns in an effort to reduce reports are the following:

Two-liter plastic soft drink bottle (empty)
Two-liter plastic soft drink bottle filled with fiberglass insulation
Two aluminum beer cans connected end to end with duct-tape
Loaf of French bread
Potato
Pillow
Towel
Blanket

Perhaps surprisingly, all of these items served to reduce the audible report to an extent. Both the loaf of French bread and the potato exploded and left debris all over both the victims and the shooters. The potato left numerous small white fragments on the victim's shirt and eyeglasses. Upon examination of the particles with a polarized light microscope, the well-known "Maltese cross" interference figure characteristic of starch was observed. This observation prompted the use of the starch–iodine color test for which a positive response was obtained. The lead investigator was advised that what appeared to be potato fragments were found on the decedent's clothing. When the investigator confronted the suspect with this fact, the suspect admitted to cramming a potato onto the muzzle end of the barrel of his handgun in an effort to "silence" it. Unfortunately, his weapon of choice was a 357 Magnum revolver, making his potato suppressor only an academic point of discussion. The suspect said he saw the idea on "Hawaii Five-O" a popular television program popular in the 1960s.

An investigator should look closely for the remnants of improvised suppressors. Cans and bottles with tell-tale holes and soot deposits should be collected for laboratory examination. Any trace evidence that appears out of place or otherwise questionable should be collected and evaluated. Soot deposits on pillows, towels, blankets, and other textiles are good indications of an attempt to reduce the report of a weapon, especially when bullet holes are present.

The use of more sophisticated suppressors is usually revealed by examination of the fired bullets. Commercially produced and home-built suppressors of more sophisticated design often use baffles and disks that the bullet must pass through. They frequently leave tool marks along the bearing surfaces of bullets fired through them. The tool marks are frequently reproducible, allowing the determination that the bullets have come in contact with the same object.

Case Study

The author was requested to reconstruct a triple homicide in which all three victims died of multiple gunshot wounds. Fired 22 long rifle cartridge cases were recovered at the scene. The head stamps on the cartridge cases identified Fiocci, an Italian ammunition manufacturer. At autopsy, the pathologist recovered nine 22 long rifle bullets. Each of the six intact bullets recovered (three were severely distorted) bore an area of longitudinal tool marks on the bearing surface. Tool mark comparison revealed that each bullet had been marked as a result of contact with the same object. The marks were inconsistent with having been produced by the interior surfaces of a gun barrel. The class characteristics of the bullets (numbers and widths of lands and grooves and direction of twist) included those of Ruger MK I and MK II pistols.

A suspect was developed and a search warrant issued for his residence specified that the search was to include any 22 caliber weapons and ammunition, associated components, materials, accessories, and/or documents pertaining to such items. The search warrant also listed suppressors, suppressor components, and/or documents pertaining to suppressors, based upon the autopsy bullet examination results. As a result of the search effort, the following items were recovered:

Receipt for purchase of a case of Fiocci subsonic 22 long rifle cartridges
Receipt for purchase of a Ruger MK I semiautomatic 22 pistol
Factory advertising flyer that included listings for tubes for making suppressors

No weapon was ever recovered nor were any subsonic Fiocci rounds or suppressor components. The investigators had no way to determine that the fired bullets and cartridge cases were actually from a subsonic round.

The suspect had owed one of the deceased victims several thousand dollars and payment was overdue. The other two victims were probably at the wrong place at the wrong time; no link was ever established between them and the defendant.

This case was circumstantial case in every respect. No weapon was recovered and investigators had no way to put the defendant at the crime scene, although he had the opportunity to be there and could not irrefutably prove he was elsewhere. Somewhat surprisingly, he was convicted of capital murder and given three death sentences. Obviously, the jury felt that the fact that the documentation of the defendant's purchase of a Ruger MK I pistol whose general rifling characteristics were the same as those on the bullets from the victims, his purchase of subsonic ammunition, and display of apparent interest in suppressors were sufficient to conclude that he was guilty beyond a reasonable doubt.

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15

Firearms and Ammunition Reference Collections and Other Resources

Firearms and Ammunition Reference Collections

Firearms and ammunition reference collections are vital components of law enforcement firearms identification sections. These collections allow direct inspection of items for comparison to questioned items found at shooting scenes or recovered during autopsies. Another important benefit of firearms reference collections is the ability to acquire replacements for missing or broken parts for weapons suspected of having been used in shootings. Identifying a weapon and ammunition used in a shooting is a fundamental aspect of shooting reconstruction.

The most extensive firearms reference collections in the United States are maintained by some of its largest law enforcement agencies. The reference collections of the Los Angeles County Sheriff's Office, New York City Police Department, Federal Bureau of Investigation, and Bureau of Alcohol, Tobacco, and Firearms (ATF) contain thousands of items including multiple examples of virtually every common firearm as well as many examples of rare weapons. Similarly, these agencies also maintain large collections of ammunition components. Local law enforcement agencies involved in the reconstruction of shootings can usually contact their state agencies, the FBI, or ATF regarding ammunition or firearms identification questions that require the availability of a reference collection. This information is available on CD to law enforcement agencies.

Databases and Software

Many databases are available to assist an individual tasked with reconstructing a shooting incident including stand-alone databases on compact disks (CDs) and main frame-housed databases available via the Internet. Regular upgrades are required in order to keep data on CDs current. Many of the main frame-housed databases are accessible by law enforcement professionals only.

All of available databases offer an investigator the capability to rapidly search needed information for shooting reconstruction purposes. These databases include information that would otherwise be difficult and time-consuming to find and review.

Probably the most familiar database to law enforcement investigators is the FBI Combined Law Enforcement Information System or CLIS file on general rifling characteristics (GRC). The FBI created this database a number of years ago and continues to maintain it. CLIS GRC files consist of rifling data for bullets and firing pins and extractor and ejector data for cartridge cases. These data are largely contributed by various law enforcement agencies throughout the country. Using CLIS GRC files allows an investigator to predict what types of weapons may have been used in a shooting via the generation of a list of possible candidates. For example, if a bullet is recovered from a victim and a fired cartridge case is located at the scene, the general rifling characteristics (number of lands or grooves, direction of twist, rifling dimensions) of the bullet and the type of firing pin impression and relative orientation of extractor or ejector marks on the cartridge case may be determined. A search of the database will then provide a list of potential candidates. It is rare that only one or two candidates will arise from such a search. In some cases, lengthy lists are generated. Keep in mind that the CLIS GRC files *do not include every weapon*, and contain only those that were entered into the system. Nonetheless, the system provides useful information that can potentially include or exclude certain weapons. The FBI provides law enforcement agencies with this data on CD and distributes annual updates. Figure 15.1 is a typical CLIS GRC data page for a search based on a 22 long rifle bullet of unknown manufacture.

Scott Doyle of the Kentucky State Police has developed, without a doubt, the most impressive, comprehensive, and useful public access website relating to firearms identification. In addition to containing a wide variety of firearms identification data and information about interactive components, Doyle has compiled a database of trigger pull information that is available to anyone accessing his website: www.firearmsid.com. This information permits comparisons of trigger pull test results to those found for similar weapons in the database and provides a way of assessing how well the obtained results fit into "the general population" and, thus, determining the significance of an apparent departure from a manufacturer's specified value.

General rifling characteristics file

REC #1 Caliber: 22 Cartridge: 22LR Rifling- (P) or (C): C

Manufacturer: UNK Model: UNK

Number of lands and grooves: 8 Direction of twist: R FA type: R

Land width min: 0.8 max: 1.0 Groove width min: 0.6 Max: 0.7 In

Firing pin: NA Extractor: NA Ejector: NA Breech/bolt: NA

File to search [G] [M] [T] [K] [O] : K Data to (P)rinter or (S)creen: P

LAB DATA FILE (KFILE)

Cartridge FA type Manufacturer model Dir Twt NO LG

LND min max GRV min max Fir pin Ext Ejr

BOB ID #1

Remarks:

Figure 15.1 General rifling characteristics file entry for a 22 long rifle bullet of unknown origin.

Doyle also compiled a general rifling characteristics file that may also be accessed through his website. Similar to the CLIS GRC file, Doyle's file contains rifling characteristics data for a large number of weapons and serves as a useful adjunct to the CLIS GRC file. Doyle has received several well deserved awards for his outstanding contributions to the field of firearms identification and shooting reconstruction through his website.

The Association of Firearm and Tool Mark Examiners (AFTE) also maintains a website with links to valuable firearms information and databases: www.afte.org. The site is accessible to members only. The links may be found by entering the member section and entering a password. Two databases of particular utility for shooting reconstructions are the serial number search database and the shotshell wadding search database. Other databases of value for shooting reconstruction found on the AFTE website include:

- Firearms cross reference search
- AFTE glossary
- *AFTE Journal* search
- Recalls and warnings section
- Safety bulletins
- "Potpourri"

The firearms cross reference search provides cross references for weapons manufactured for various distributors and bearing different markings from the same manufacturer or bearing the same markings but from different manufacturers. Cross referencing can be invaluable in trying to identify a particular weapon's manufacturer.

The AFTE glossary is a compilation of firearms and ammunition terms that are generally accepted in the field of firearms identification. It is important to use correct terminology in the preparation of written reports and while testifying at depositions and in court. Use of the AFTE glossary lessens chances for confusion and projects a more professional image on the part of the presenter.

The *AFTE Journal* search allows individuals to perform literature searches in efforts to understand or reconcile issues associated with shooting investigations. This resource allows quick access to published works in various general and specialized areas of shooting incident reconstruction.

The recalls and warnings section consists of postings of warnings from factories and from examiners who share concerns relating to the use of certain weapons and ammunition. This information can be important when attempting to determine whether accidental discharge is a factor in a shooting incident. It can also be of value for evaluating other safety issues. The same areas of interest are covered in the safety bulletins section of the website.

The "potpourri" section, as the term implies, is a collection of generally unrelated, esoteric considerations involving firearms and tool marks. From time to time, an investigator may find something pertinent to a shooting under investigation here.

Although the members section of the AFTE website and the above described resources are available only to AFTE members, a nonAFTE member engaged in law enforcement can usually have the benefit of this information as a result of contacting a local, state, or federal firearms unit and requesting assistance. Most firearms units include AFTE members who are usually glad to assist by performing needed searches.

Another useful source of information relating to firearms and ammunition components is *Gunsights Pro 3.0*, the latest release from Forensic Technology. This firearms reference software contains image viewing tools that allow close inspections of over 2700 firearms. Thus, searches through reference texts for full views and schematics have become practices of the past. This software must be purchased from Forensic Technology. Other offerings from this vendor include *Gunsights LE* and *F.R.T. Firearms Reference.* The *Gunsights LE* is designed for law enforcement practitioners rather than firearms examiners and contains generalized data about more than 2000 firearms. The *F.R.T. Firearms Reference* software is a comprehensive reference table including some 21,000 entries. These three packages allow searches for potential weapons listed as results of searches of CLIS GRC files and/or Scott Doyle's files based upon rifling characteristics of ammunition components found at shooting scenes or recovered at autopsy.

Long-time AFTE member and advisor George Kass of Okemos, Michigan is the undisputed "go-to guy" for information and exemplars of ammunition. Kass does business as Forensic Ammunition Service and specializes in the unusual and the obscure. He also write a text on the identification of rimfire ammunition head stamps that is available online at www.rayrilingarmsbooks.com. Kass can be contacted online at forammo@aol.com.

Most major weapons and ammunition manufacturers also maintain websites that offer investigators a wealth of information. For example, the Glock Firearms Corporation website, www.glock.com, contains pertinent data on all Glock firearms. The Federal Ammunition website, www.federal.com, contains ballistics data and other information about all its products.

In summary, the absence of a firearm in a shooting incident requires an investigator to attempt to determine what type firearm may have been used. This becomes the first hurdle in attempting a shooting reconstruction in a so-called no-gun case. When fired bullets and cartridge cases are recovered, an examination of their markings may allow a database search that in turn produces a list of potential candidates. These candidates may be then viewed and examined through the aid of commercially available databases or databases made available to law enforcement agencies by the AFTE, ATF, FBI, and other agencies.

Vehicle Information

It is often necessary to obtain information about vehicles involved in shooting incidents that cannot be easily found or was not a consideration at the time of the initial investigation and subsequently became an issue. In such cases, it is possible to locate a similar vehicle model for examination or obtain required data from the manufacturer. Most new car dealership service departments can access this information and are usually very cooperative in providing it to law enforcement.

In a case described in Chapter 1 (see Figure 1.7) an issue arose concerning the turning radius of a Chevrolet extended cab pickup truck. An officer had been standing beside the driver door of the vehicle while attempting to question a possible drug user who sat inside the vehicle in the driver's seat. According to the officer, the driver started the vehicle and turned the wheel toward him. This led the officer to fire shots as a result of "being in fear for his life." It was necessary to know the turning radius of the truck and the information was acquired by contacting General Motors through the parts department staff at a local dealership. The data was confirmed by testing with

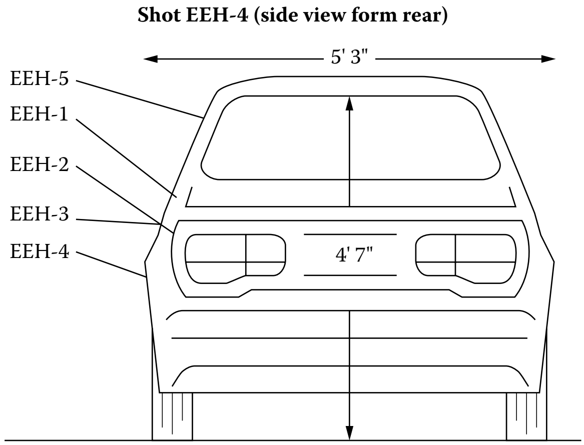

Figure 15.2 CADZone vehicle, profile view.

a similar truck. An investigator can usually obtain similar information from the same types of sources whenever necessary.

A number of software packages include both specific and generic vehicle images and diagrams. Whenever shots are fired into a vehicle, it is important to prepare diagrams that show both top and profile views of the vehicle with trajectories extended out to the maximum possible shooter position. Trajectory information is usually determined on the basis of shooter height and the reported position of the weapon. Positions that require the shooter's hands to be extended above his head, for example, would be excluded, barring specific information to the contrary. Figure 15.2 and Figure 15.3 are samples of the vehicle diagrams that can be produced using *Crime Zone* software.

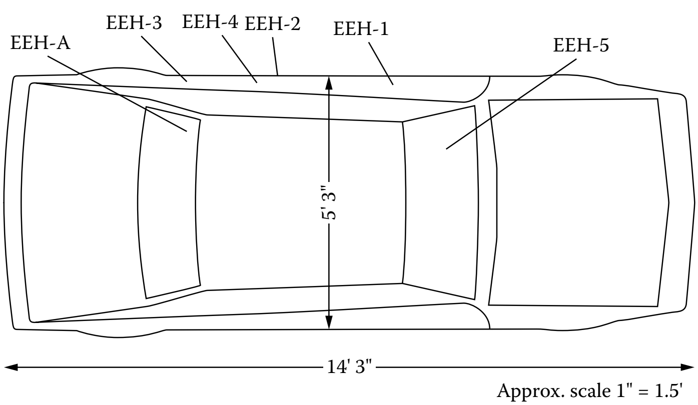

Figure 15.3 CADZone vehicle, top view.

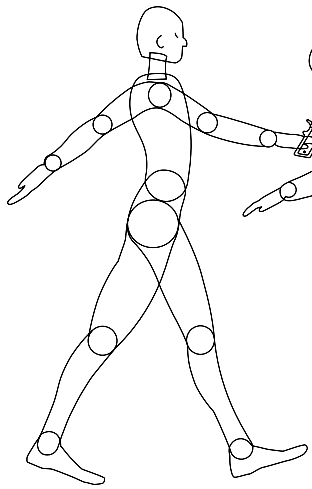

Figure 15.4 CADZone human forms

This software also includes scene diagrams as well as human figures, weapons, and a wide variety of other objects. The software is marketed by CADZone, Inc. of Beaverton, Oregon. Its website is www.cadzone.com. The company recently introduced a three-dimensional version that is very impressive. Vehicles, human forms, and other objects may be sized to fit circumstances of a particular shooting. The human forms may be set to virtually any position as a top view or profile in two dimensions and any position in three dimensions. Figure 15.4 and Figure 15.5 show of examples of generated human forms. CADZone software is powerful but somewhat user unfriendly. It require extensive training in

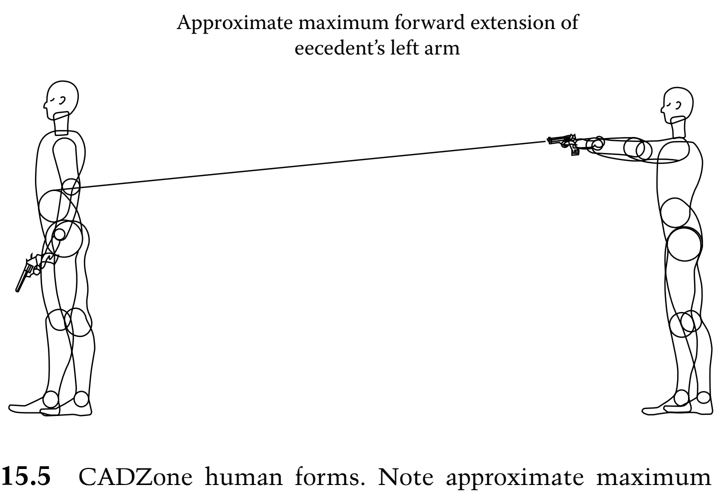

Figure 15.5 CADZone human forms. Note approximate maximum forward extension of decedent's left arm.

order to develop total proficiency. It lacks the intuitive nature of other software programs, but is capable of producing outstanding diagrams after a degree of proficiency is attained.

Architectural Information

It is sometimes important to determine standard architectural dimensions for various structures, streets, sidewalks, and curbs, especially when access to a scene is limited or impossible. John Wiley & Sons, Inc. offers an architectural graphic standards CD-ROM that contains most of the information pertaining to such structures. Additionally, the CD-ROM portrays male and female human forms and vehicles. This information allows determination of expected dimensions, angles, and spatial arrangement of a wide variety of forms based upon standard architectural measurements. Nothing can serve as a substitute for obtaining the desired dimensions from the item in question, but when that is impossible, this type of database is invaluable for shooting reconstruction purposes. In reality, it is seldom possible to anticipate every measurement that may be needed subsequently in a reconstruction effort.

Site-specific information is also available from city building code offices, street departments, state highway offices, architectural firms, and civil engineers. Building plans are usually on file with building code offices. Architectural and civil engineering firms maintain blueprints for structures they design.

Weather and Meteorological Data

The reconstruction of a shooting, particularly when conducted outdoors, often involves lighting considerations. An officer-involved shooting that occurred under low light conditions may require determining whether the officer could have seen the suspect well enough to discern a weapon in the suspect's hands. Ambient lighting conditions become critical in these cases. Obviously, the difference in available light on a clear night with a full moon and a cloudy night with no moon is considerable. Accordingly, any reconstruction or reenactment effort must take the lighting factor into account.

The presence of precipitation may have an impact on the reconstruction. The author worked on a case in which a glove had been worn during a shooting. The glove was tossed to the ground outside the building where the murders took place and remained undiscovered for two days. Rain fell for those two days and the glove was exposed to the rain. A question arose as to the number of shots fired by the suspect while wearing the glove. To attempt to establish the number of shots, the glove was to be analyzed for lead, barium, and antimony by flameless atomic absorption (FAA). The question was whether one or four shots had been fired while the glove was worn. It was necessary to know, as accurately as possible, how much precipitation had fallen on the glove in an effort to set up a simulation because the precipitation may have washed away some of the gunshot residue. Fortunately, weather information is readily available from the U.S. Weather Service National Climatic Center in Asheville, North Carolina. The phone number of the service is (828) 271-4800 and its email address is ncdc.info@noaa.gov.

The author reconstructed an officer-involved shooting in which the officer shot a suspect based on the officer's perception that the suspect had a gun in his hand. The shooting occurred at night on a street in a residential area. A check with the U.S. Weather Service National Climatic Data Center revealed a full moon and partly cloudy weather on the night of the shooting. To establish the degree of visibility the officer may have had and determine whether the shooting was justified, a reenactment was conducted. Since ambient light was the main issue, the reenactment was scheduled for the anniversary date of the shooting. This was possible because the reenactment was enacted for a civil suit against the police department and nearly a year had passed since the shooting had taken place.

Other issues were the street lights and lights from surrounding residences. The cloud cover was clearly a factor that could not be controlled, but conditions were partly cloudy on the anniversary night. Having the correct meteorological data allowed the reenactment to proceed under conditions that closely duplicated the actual shooting event. It was apparent from the reenactment that the officer would not have been able to see well enough under the scene conditions to confirm or eliminate the presence of a gun in the suspect's hands. Since the officer stated that the suspect extended his arms toward the officer and this fact was corroborated by a witness, the shooting was determined to be justified.

Ambient lighting conditions must be established for any shooting incident taking place outdoors at night. Crime scene photographs should be taken to document the lighting conditions. Written crime scene notes should document lighting, cloud cover, phase of the moon, and any other sources of light.

When shooting reconstructions are required and the lighting conditions at the scene were not properly documented, an investigator must rely on data from sources such as the U.S. Weather Service and the street department. Street department records should be consulted to obtain pertinent information about street lights in the area of the incident. For example, a record of a street light repair shortly after a shooting would suggest that the light may have been out at the time of the shooting. On the other hand, no repair history on street lights in the immediate area of a shooting would tend to indicate that the lights were working at the time of the shooting unless some reason exists (e.g., an established pattern of not replacing broken lights) to think otherwise.

Bullet Trajectory Data

Ballistics software can be purchased from numerous sources. Free downloads are available online as well. Long-time AFTE member and forensic firearms researcher, Ruprecht Nennstiel, of Wiesbaden, Germany, markets exterior ballistics software under the trade name *EBV4.* This sophisticated program is very suitable for shooting reconstruction. Additional information may be obtained from www.nennstiel-ruprect.de/eb/eb.htm.

For many years the author has used *Ballistic Explorer* software, marketed by Oehler Research, Inc. of Austin, Texas (www.dexadine.com). As is typical for exterior ballistics software, *Explorer* allows a user to produce graphs that show the following data:

- Combined distance from center
- Bullet drop
- Energy
- Momentum
- Time of light
- Bullet path
- Velocity
- Wind drift

The graphs provide excellent means to present exterior ballistics information to jurors and others. The user must know the particulars of the gun and ammunition as well as topographical data and wind conditions at the time of the shooting. The U.S. Weather Service National Climatic Data Center can provide such data for any location in the United States. Figure 15.6, Figure 15.7, and Figure 15.8 are sample graphs produced by this software.

As an example of how ballistics software can be of value, the author was asked to reconstruct a fatal shooting involving a 30-30 rifle fired at night from a distance of 250 yards. The defendant's version of the shooting was that he never saw the victim and was merely firing "pot shots" on a rural road. The reconstruction focused on how difficult a shot would have been if a shooter intentionally tried to hit the victim. The answer required determination of:

- Temperature at the time of shooting
- Elevation (above sea level) of shooter and victim

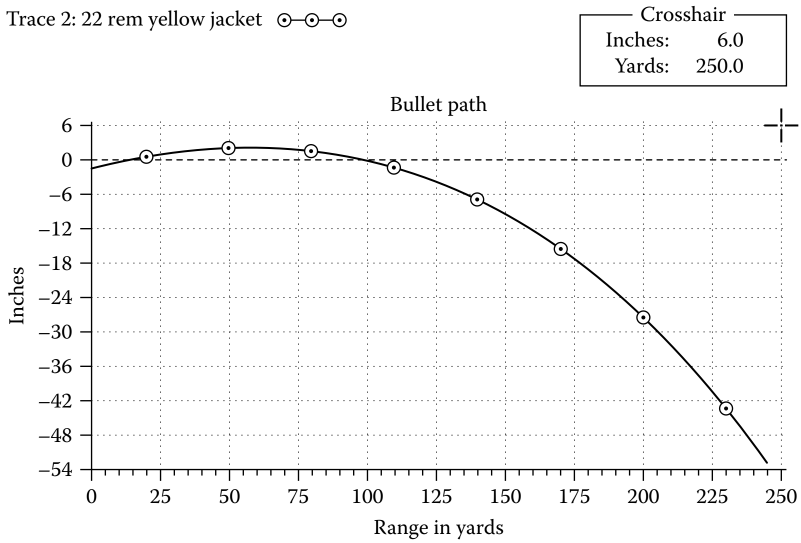

Figure 15.6 Ballistic Explorer graph of bullet path. (Courtesy of Forensic Science Associates. With permission.)

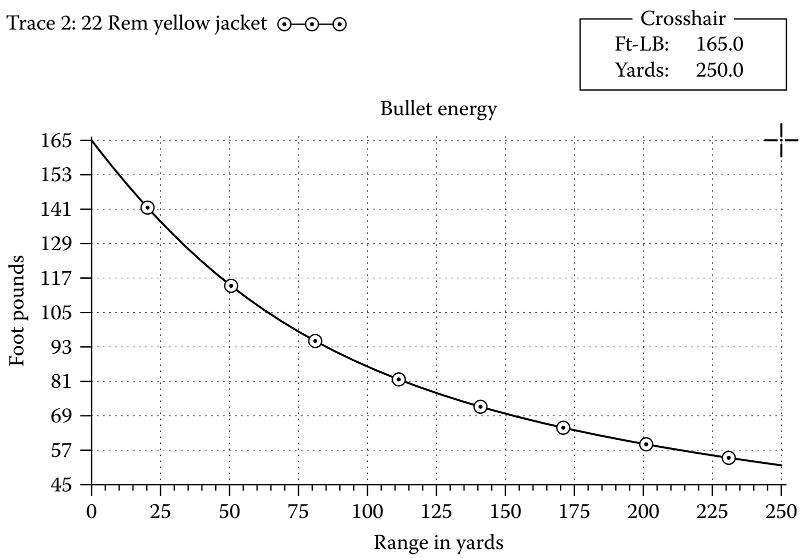

Figure 15.7 Ballistic Explorer graph of bullet energy. (Courtesy of Forensic Science Associates. With permission.)

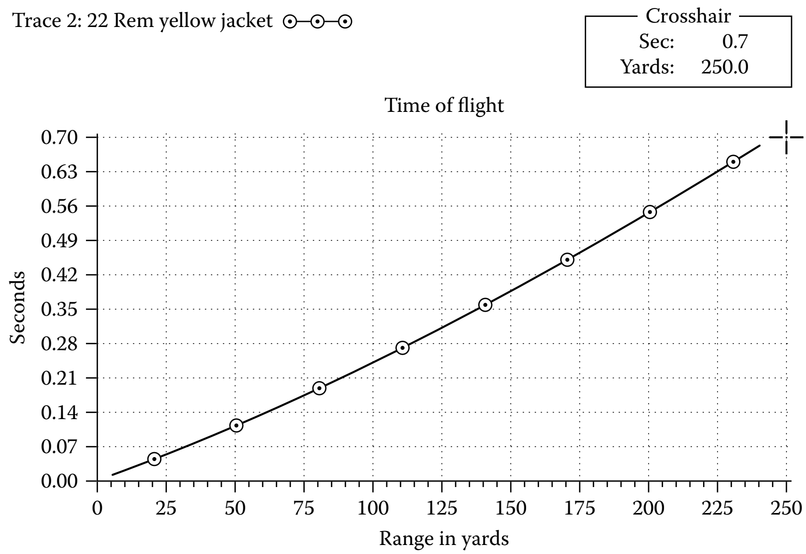

Figure 15.8 Ballistic Explorer graph of time of flight. (Courtesy of Forensic Science Associates. With permission.)

- Atmospheric pressure at the time of shooting
- Wind direction and velocity at the time of shooting
- Humidity at the time of shooting

The answers to all but one of the questions were obtained from the U.S. Weather Service. Elevation information was obtained via a Global Positioning System (GPS). As a side note, GPS systems are extremely useful for establishing positions in remote locations and in situations without available points of reference.

Additional data required for using ballistics software relate to the weapon and ammunition. The following information about ammunition is required:

- Bullet weight
- Ballistic coefficient
- Muzzle velocity

With regard to the weapon, the following information is required:

- Zero range
- Sight height

The investigator may then enter all this information into the software and generate data that may be graphically displayed as shown in the figures.

In the case involving the 30-30 rifle, the significant aspects were bullet drop and distance from center. Based on software results, the bullet would have dropped 14 inches at the 250-yard distance based upon being sighted in at 100 yards and holding dead-on. The wind at the time of the shooting would have pushed the impact point 5 inches to the left. The net result was that the shooter would have had to have held high and to the right to compensate for bullet drop and wind drift. With iron sights (no telescopic sight) in the dark, the shot was not likely to have been intentional, particularly for someone who was as unfamiliar with the gun as the defendant was. It cannot be said, however, that the shot would have been impossible. After all, the presence of a dead man confirmed that such a shot not only could happen, but did happen.

Imagery

Panorama Technologies Corporation Ltd. markets software known as *Crime Scene Virtual Tour* and based on 360-degree panoramic images that integrate crime scene details, an interactive map, texts, audios, links, and thumbnails into a tour that allows a viewer to control movements through the scene, zoom in on any object, and turn images to view them more clearly. This allows investigators and juries to "go back to the scene." Images and relevant text are viewed at the same time. The links and thumbnails allow additional pertinent information to be accessed along the way. The software requires no special training; only standard photographic knowledge is required to use it. A sample virtual tour of a crime scene may be accessed by going to the company's website, www.easypano.com. In addition to its use for courtroom presentations, a number of agencies have used it to train investigators. A number of companies can provide computerized animations and still images that may be tailored to the needs of an investigator. A search of the Internet will lead to a number of such service providers.

Crime Scene Software

Several excellent software packages are available for producing crime scene diagrams. *Crime Scene* is a CADZone product. *Crash Zone* is an excellent program for accident scene diagramming and is a companion to CADZone's *Crime Scene*. Others are *3D Eye Witness* and *Visio*. Another software product for crime scene drawing is *Diagram Studio* by Goodwin Systems, Inc. According to the manufacturer, the product is compatible with graphics printers and plotters and only requires 6 megabytes of hard drive space. Floor plans, street and directional maps, and directional routings are all producible with this software and it comes with complete flowcharting and diagramming templates and block diagrams. Linked text labels may be added and libraries may be accessed or created. Sample diagrams may be viewed and additional information obtained from the company website at www.diagramstudio.com.

The ultimate crime scene diagramming tool is the *Total Data Station* system that maps a crime scene using infrared light and downloads the data into software expressly designed to generate complete diagrams. Topcon Corporation of Japan manufactures a variety of total data-station systems. Its *Plane Offset Program* is advertised as offering "the most accurate method for locating building corners in the industry." This program computes a plane location by measuring three random points on a wall or other surface. The user can then sight another point and instantly compute it. The company website is www.topconsurvey.com.

A wide variety of hardware and software provide a shooting reconstructionist with many options. Readers are encouraged to explore the possibilities to determine what best fits their needs and budgets. Most of the software may be downloaded in trial versions from the Internet. This allows a potential purchaser to develop at least some familiarity with the various offerings prior to purchase. As always, references from other practitioners can save a lot of time and frustration when trying to decide what software or hardware to purchase.

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16 Report Writing, Demonstrative Evidence, and Courtroom Presentation

Standard Reporting Formats

Most police agencies use standard reporting formats. An agency's format does not always allow a lot of latitude as to how the written report will be structured. One of the biggest drawbacks to such formats in the author's opinion is that each section of the laboratory typically writes a report concerning only the evidence the section examined. A separate report covers the crime scene investigation and other reports are written on follow-up investigations. While this is an entirely appropriate approach, the lack of a summation report often requires the reader to attempt to collate all the results obtained and reach overall conclusions.

It is this writer's firm belief that a single document should incorporate and summarize all the findings of the various laboratory sections, the initial and follow-up investigations, and the autopsy report. This report should be a standalone document a reader can utilize to determine the physical evidence described and where it originated, test results obtained and, most importantly, what the results imply. Relationships of various items of physical evidence, although examined by different crime laboratory units or analysts, should be described and explained. The ties to the investigative evidence should be included, as should the findings articulated in the autopsy report.

Admittedly, this concept of an overall summation report presents a problem from the standpoint of who should write it. The lead investigator most frequently writes such reports in departments that use this approach. In officer-involved shootings, as part of the administrative investigation, a shooting review board usually issues a summation report. One of the most important aspects of issuing a summation report is that it ensures that all aspects of a shooting investigation are reviewed. This approach minimizes the chance of evidence or investigative aspects "slipping through the cracks."

In a questionable shooting death case the author reviewed, it was suspected that the handgun involved had fallen to the floor and a blow to the hammer caused it to discharge. The crime scene investigator noticed fibrous material adhering to the hammer spur and requested that the trace evidence section examine and identify the fibers. The investigator failed to obtain control samples of carpet fibers at the scene. The trace evidence analyst issued a report stating only that fibers were present. No summation report was issued. Had someone written a summation report after reviewing all aspects of the case, perhaps the inadequate trace evidence report would have been recognized and corrected.

Suggested Summation Report Format

The following is an outline of a suggested format for preparing a summation report on the reconstruction of a shooting.

Introduction — A brief synopsis of the incident that includes when and where the shooting took place and the general circumstances, including all participants' and witnesses' names and addresses.

Documentation —This section lists all written and photographic documentation that was reviewed and relied upon for forming opinions about the incident.

Physical evidence examined — This section should list and describe all physical evidence examinations conducted (including vehicle and scene examinations, shot accountings, and trajectory analyses) and summarize the findings. Supporting images, graphs and/or diagrams should be included.

Reenactment and other scenario related testing — All reenactments and other related scenario testing should be detailed and illustrated as appropriate with images, graphs and/or diagrams.

Results of investigative efforts —All investigative results should be described and ties to supportive physical evidence should be explained in detail.

Opinions — This section should put forth opinions derived from all aspects of the shooting investigation and/or reconstruction effort.

Conclusions — This section proposes the probable scenario and/or sequence of events for the shooting when feasible.

Attachments —Individual reports relied upon and other supporting documents may be attached.

The method of incorporating photographic images into the body of a report depends primarily on what the images are intended to show and what format is appropriate to the situation. While inserting images into the body of the report allows instant visual access, the small size required to do so may detract from the overall effectiveness. Placing full sized images at the back of a report as attachments facilitates maximum visual perception. The only minor drawback is that a reader must flip back and forth between the body of the report and the attached images.

A proposed scenario should be presented as "probable" or "likely" rather than as absolute fact, as discussed in Chapter 1. The fact that a proposed scenario fits the statements of witnesses and/or participants should be articulated in the conclusions section. Likewise, when a formulated scenario is at odds with witness and/or participant statements, the divergence should be stated as part of the conclusions.

One of the author's long-time friends and colleagues applies "fluff-versus-substance" test to report writing. Some reports consist of all substance — illustrative materials, diagrams and the like — and no "fluff." Conversely, some reports amount to all "fluff" and no substance. They abound with meaningless charts, graphs, and photographs that tend to stand alone rather than support meaningful conclusions. Obviously, the desired effect should be the inclusion of both "fluff" and substance, that is, a report that is professional in appearance, visually interesting, reaches scientifically valid conclusions, and clearly articulates these conclusions through the use of relevant visual aids.

Photographic Images, Drawings, and Diagrams

Drawings, diagrams, and photographic images are effective ways to transmit information in a succinct, understandable manner. To do so, however, requires that the images and drawings be clear and concise and not "too busy." The visual aid rule for a speaker is to limit each slide to one main point rather than covering multiple points from the same slide. The same rule is appropriate for drawings and images.

Photographs for inclusion in reports and for court presentations should be of appropriate quality and format. Photographs of shooting scenes should be taken following the same rules as those for general crime scene photography with a few additions. The general rules for shooting scene photographs can be summarized as follows:

- The first frame of a roll of 35-mm film or the first image recorded on a digital memory card should be the case identifier that notes the time, date, location, case number, and photographer.

- A photo log should be prepared and indicate what camera and lens were used and show the camera setting (f-stop and shutter speed or "automatic") for each image along with a description of the item photographed and its location within the shooting scene.
- Begin with overall photographs, then move to specific subjects. The rule of crime scene photography is that you cannot take too many photographs, but you can take too few. Take multiple photographs of each item of interest and bracket your exposures.
- Photograph evidence with and without a scale to eliminate concerns that a scale may possibly cover evidence in a photograph.
- Evidence should be photographed with the camera back in the same plane as that of the evidence whenever possible to eliminate distortion and thus allow accurate measurements to be made from the photographs with scales present.
- Use of a tripod and a remote shutter release is recommended. This may appear impractical due to physical constraints at shooting scenes, but it is the only way to ensure the best quality images.
- Bullet holes and other evidence at a scene should be assigned number or letter designators that are visible in all photographs and carried through in all documentation reports. This is the only sure system for identifying evidence and other items of interest within the shooting scene, covering them in reports, and using them during courtroom presentation.
- Stick-on arrows may be included to show directionality, particularly in close-up photographs (or added later if using digital imaging). This eliminates questions about orientation.
- Fill the frame with the subject matter while still allowing the scale and evidence designator to be visible in the image produced. Photographs of bullet holes and other evidence at the shooting scene should be taken at the closest point possible.
- Oblique lighting is required for photographing bullet holes in glass. This may be accomplished with available light in some instances but usually requires shading the subject matter and using a detachable strobe (flash) with a 4-foot sync cord held at a low angle.
- A ring flash is a useful accessory for macrophotography of small evidence items such as bullets and bullet fragments. A ring flash allows 360 degrees of illumination for taking close-ups of small items.
- Trajectory rods inserted into bullet holes should be photographed both from overhead and side (profile) perspectives whenever possible. The intent is to document both the x and y angular components of the trajectories represented by the rods.

By following these rules, an investigator will produce the best photographic documentation possible. Additionally, the ability to prepare full scale images and enlargements will be afforded. The question as to whether a 35-mm or digital format is best will not be argued here, but most departments across the country are converting to digital imaging. Some continue to use 35-mm film to back up digital images until questions about long-term storage of digital data are satisfactorily resolved.

With regard to preparing diagrams of shooting scenes for inclusion in reports and presentation in court, the general principles of crime scene diagramming should be followed:

- Indicate compass directions on diagrams. The northerly direction is typically indicated.
- Label a diagram "not to scale" if no scale is intended. Otherwise indicate the scale but label the diagram "approximately to scale" to avoid the common pitfall of having an item appear slightly out of scale even though the diagram was represented as drawn to scale.
- Indicate who prepared the diagram and the date of preparation.
- Include a legend if numerous items of evidence are to be included in a diagram.
- Use both overhead and profile perspective diagrams or a three-dimensional diagram if bullet trajectories are included.
- Images of actual evidence items may be inserted into a diagram if desired and appropriate. As with inserting images into the body of a report, consider the loss of detail caused by reduced image size.

The use of poster-size enlargements of photographic images and diagrams can help a jury better understand the nuances of a shooting reconstruction. This demonstrative evidence can be especially effective when placed upon an easel in the courtroom in view of the jurors and allowed to remain there for a significant period or even through an entire trial. Prosecutors generally welcome suggestions from investigators as to which images are particularly relevant to a shooting reconstruction.

As discussed in Chapter 1, computerized animation may be a consideration for courtroom presentation if the legal hurdle of hearsay objection can be overcome. The proliferation of this type of format in every aspect of society has paved the way for increased use in courtrooms. Juries tend to expect "dog and pony shows" as a result of all the movie and television dramas devoted to crime scene investigation. As a result, more consideration is now given to the inclusion of computerized animation in court proceedings.

A videotape of a shooting scene provides a real-life view of a scene and usually is not subject to the hearsay objections that computerized animations often prompt. Videotaping of shooting scenes should be a standard practice and a supplement to still photography. The same rules that apply to general crime scene videotaping also apply to videotaping shooting scenes:

- Begin with an oral introduction while focusing on a case identifying card that shows the date, location, case number, and photographer's name.
- Turn on the date and time functions and keep them on during the taping. This will allow viewers to see when taping is continuous and to identify starts and stops as well as confirm the time and date of the taping.
- The decision to narrate during the taping will largely depend on departmental procedures and preferences. One consideration is to narrate only for purposes of noting general orientation or location during the taping. Many jurisdictions prefer not to have the audio on during taping in order to avoid the unwitting recording of background statements by persons at a scene.
- Move the camera slowly, pausing for several seconds on items of evidentiary value. Generally, when a videocamera is panned across a scene, the tendency is to move too quickly. The videographer must move the camera very slowly in order to be effective.
- Use the zoom judiciously and zoom in and out slowly. Rapid zooming looks unprofessional and serves as a distraction.
- When moving from one area to another area to resume taping, using the fade feature on the camera allows the break in taping to take place smoothly.
- The ending of the tape should be stated on the audio and confirmed by focusing on an "end-of-tape" card. This show that no segments are missing at the end.

These steps help ensure that a videotape will be professional in appearance. The use of all or part of a shooting scene videotape in a courtroom can allow the jury to gain a better understanding of the scene and the inter-relationships of the physical evidence that still photographs simply cannot provide. Keeping the audio on during taping and narrating the scene to one degree or another can be done. The audio can always be turned off during courtroom presentation if required. A videotape with no narration whatsoever can be confusing, particularly related to a certain perspective of a view or a particular evidence item. For example, a drop of blood on a parking lot can be very hard to discern unless the viewer knows what the camera is focusing on.

Full-Scale Reproductions

On occasion, it is useful to create a full-scale reproduction of a room or other part of a shooting scene and set it up in a court room for the jury to view. Photographs alone, including video tapes, frequently do not allow viewers to appreciate the spatial relationships inside a scene. It is common, in the author's experience, to view scene photographs and then visit a scene and realize how different the actual inter-relationships of walls, doors and other objects are from what the photographs depicted.

Full-scale reproductions for courtroom demonstration can range from two-dimensional floor plans that use strips of tape to represent walls to full three-dimensional versions. Obviously, there are limitations to what can be set up in a court room, from both admissibility and practical standpoints. These considerations not withstanding, courtroom reproductions can provide a jury with a perspective that could otherwise only be obtained by visiting the scene.

The use of scale models is an alternative to full-scale models with the obvious advantages of portability and ease of setup. The downside of scale models is their inability to allow jurors to visually "get inside the scene" in the manner allowed by full-scale models.

The need for full-scale models as demonstrative exhibits in a shooting reconstruction presentation is clearly a decision that the prosecutor or defense attorney must make. However, it should be an option that the shooting reconstructionist considers and brings to the attention of the respective attorneys for their consideration. In the author's many years of shooting reconstruction experience and subsequent courtroom testimony, the need for full-scale models has, admittedly, been limited. However, it proved to be very effective when used.

In one case, it was important that the jury have a clear understanding of how small a bedroom in which a shooting took place was. Cardboard pieces were used to represent the floor of the room and 3-inch-wide strips of tape were used to create outlines of the bedroom furniture. The model was placed on the courtroom floor to allow the jury to see how confined the room was.

In another case, the chair on which the victim sat when he was shot was brought into the courtroom. Trajectory rods were inserted into the chair and a quasi-reenactment was conducted to allow the jury to see how near the defendant was to the victim when the shots were fired. In this case, walls and doors were not considerations.

As an alternative to setting up a full-scale reproduction in a courtroom, a full-scale reproduction can be set up elsewhere and a videotape made and played for the jury. One example of this involved a double homicide in which a young couple was found on the bedroom floor of their apartment lying side by side with their throats slit. Prior to trial it was decided that it was important that the jury understand just how confined the crime scene was in support of the theory that the murders were carried out execution style. Rather than producing a full-scale reproduction of the scene, the decision was made to use the apartment where the murders occurred. However, a new resident lived there and none of the original furniture was present. Using the crime scene diagram as a basis, measurements were obtained for the furniture in the apartment at the time of the murders and used to create cardboard mock-ups. The furniture in the apartment at the time of trial was moved out, with the cooperation of the then resident, and the mock-ups were put into place. A large pool of blood was simulated with a poster board cut-out. Individuals of similar size and appearance were used in a reenactment that was videotaped from different perspectives. The videotape was then played for the jury.

PowerPoint Presentations

PowerPoint presentations are making their way into courtrooms more frequently. PowerPoint presentations offer another way of presenting photographs and diagrams to juries. Crime scene photographs can be interspersed with reenactment images or crime scene diagrams for added explanatory quality. PowerPoint allows the insertion of arrows, lines, circles, and other effects to highlight certain parts of images. Presentations for courtroom use should be prepared according to protocols similar to those used for other visual presentations and the following suggestions should be considered:

- Begin with a simple title frame, for example, "Reconstruction of the Shooting of John Doe."
- Use a title for each image that simply defines what is being represented, for example, "Northwest bedroom as viewed from south door."
- Avoid "glitz." Save animation, sounds, and other features for other presentation forums.
- Limit each slide to one major point and limit the total number of slides in the presentation to those that are essential to presenting the major points. If a presentation becomes too lengthy, the jury can lose interest.
- Avoid the use of tables, charts or diagrams that contain. If too much information is presented in a single slide, major points can become lost among the unnecessary details.
- A summation slide (or slides) for the major points or conclusions is an effective way to conclude a presentation.

Court Testimony

As with any forensic investigation, it is one thing to carry out appropriate examinations and formulate conclusions about their meanings and a very different matter to be able to clearly articulate them in written form.

Providing oral testimony in a clear, concise, and understandable manner is another challenge and, perhaps, the most difficult. Many very good forensic scientists and investigators have difficulty being effective witnesses under the stresses of courtroom testimony. However, court testimony is where "the rubber meets the road." A thorough and well executed shooting reconstruction can be diluted and made to appear insignificant by inept courtroom presentation. A few reminders of the fundamentals of courtroom presentation include:

- Approaching the witness stand in a confident manner.
- Speaking clearly and confidently.
- Making eye contact with the jury while testifying.
- Avoiding exhibition of mannerisms or nervous habits.
- Answering questions posed by the prosecution and the defense with the same articulation and enunciation and with the same degree of courtesy and respect.
- Knowing your subject; not having to fumble excessively through reports and notes.
- Being prepared to defend your conclusions while acknowledging that other scenarios are also possible.

The last point above is worthy of discussion. As emphasized throughout this text, shooting reconstruction is the development of a likely or probable scenario as opposed to the only scenario in most cases. The investigator who presents a reconstruction of a shooting in court must be prepared to acknowledge other *possible* scenarios while maintaining the focus on the one deemed *most probable*. The sponsoring attorney should make the decision whether to present less likely alternative scenarios during direct examination along with the probable scenario. Nonetheless, it is likely that questions pertaining to alternative explanations for the events of a shooting will arise during courtroom testimony and the witness must be prepared to address them and explain why they are considered less likely.

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Glossary

Angle gauge A device used to measure vertical angles.

Angle of impact The interior (acute) angle of the axis of an impinging bullet with a target.

Angle of ricochet The angle of departure of a bullet or shot pellet from a substrate.

Annular rim The outer circumference of a cartridge case base (location of priming mixture in rimfire cartridges).

Antimony sulfide A component of most priming mixtures; acts as a fuel.

Ball powder Gunpowder with a spherical shape.

Ballistics The study of projectile motion, often confused with firearms identification.

Barium nitrate A component of most priming mixtures; acts as an oxidizer.

Bird shot A general term for any shot smaller than buckshot.

Bolt action A firearm in which the breech is always in line with the bore and manually reciprocates to load, unload, and cock; the two principal types are rotating and straight pull.

Bore The interior of a barrel forward of the chamber.

Breech face The part of the breech block or bolt which is against the base of the cartridge case or shot shell during firing.

Broach Rifling cutter that cuts all the grooves simultaneously.

Buckshot Lead pellets ranging in diameter from 0.20 inch to 0.36 inch normally fired from shotguns.

Bullet The projectile portion of a cartridge.

Bullet jacket The metallic covering over a bullet core.

Caliber The cross-sectional diameter of a barrel from land to land.

Calipers A device consisting of two moveable jaws or legs used to measure distance, thickness, or width.

Cartridge Ammunition component consisting of a cartridge case, bullet, powder charge (propellant), and primer.

Cartridge case A container for all other components of a cartridge.

Center fire Cartridge with a primer in the center of the base (head).

Chamber The rear part of the barrel bore that has been machined for a specific cartridge; revolver cylinders are multichambered.

Chamber marks Individual characteristics imparted to chamber walls during machining.

Choke Constriction in the muzzle end of a shotgun barrel.

Class characteristics The characteristics exhibited by an entire class or group.

Clip A separate device for magazine reloading.

Cock To place a firing mechanism under spring tension.

Concentric fracture Circular fracture of glass surrounding a point of impact.

Conchoidal fracture Fracture lines visible on the edges of broken glass that allow direction of force determination.

Contact shot A shot fired with the muzzle of the gun in direct contact with the substrate.

Core The portion of a bullet beneath the jacket.

Critical angle The angle at or below which a ricochet would be predicted.

Cylinder gap deposit Soot deposit resulting from gases escaping from the gap between the face of a revolver cylinder and the back of the barrel.

Cylinder halo Soot deposit on the face of a revolver cylinder around the margins of the chambers.

Disk powder An extruded form of gunpowder that is cut into small disks.

Distance shot Shot fired from a distance beyond which gunpowder particles can travel.

Double action A single pull of the trigger cocks and releases the hammer.

Double base powder Gunpowder consisting of nitrocellulose in combination with nitroglycerin.

Ejection The expulsion of a fired cartridge case or shot shell.

Ejector marks Marks left on the base (head) of a cartridge case or shot shell by the ejector during the process of ejection.

Ejection pattern The particular pattern that ejected cartridge cases produce upon firing a weapon from a given position.

Ejection port The port from which fired cartridge cases are ejected.

Falling block A single shot lever action mechanism in which the breech block slides vertically or nearly vertically down as the lever is worked.

Firing pin The part of a firearm mechanism that strikes the primer and initiates ignition.

Firing pin impression The impression left by the firing pin upon impact with the primer.

Flattened ball powder The gunpowder produced by compressing ball powder.

Function testing The examination of a firearm for operability and firing capability.

Fully automatic Weapon action; once cocked, a weapon continues to fire until the ammunition supply is exhausted if the trigger is pulled and held back.

Gauge The number of lead shot of a particular diameter to the pound (12 gauge means 12 lead shots of the bore diameter to a pound; 16 gauge means 16 shots to the pound; and so on).

General rifling characteristics The number, width, and direction of twist of rifling grooves.

Griess test A chemical test for nitrites; used to detect gunpowder residue around bullet holes.

Grooves Helical grooves in the interior of a barrel to impart spin to a bullet.

Gunshot residue (GSR) Gunpowder and primer residue resulting from discharge.

Hammer The part of the firing pin that imparts energy to the pin.

Hammer forging The process of forming the interior and exterior of a barrel by hammering.

Handgun Firearm designed to be hand-held.

High velocity impact spatter (HVIS) Blood spatter produced by bullet impact and/or muzzle blast.

Individual characteristics Accidental, random marks used to identify tool marks.

Intermediate range shot Shot fired at a muzzle-to-substrate distance sufficient to produce powder stippling (skin) or deposition (inanimate objects).

Instantaneous incapacitation The result of a bullet impacting the brain stem or spinal cord.

Knock-down power An erroneous and outdated term that has no meaning related to modern firearms and ammunition.

Laser protractor Protractor with a movable laser pointer that can be set to any angle ranging from 0 to 180 degrees.

Lateral angle of deflection The right or left deflection of a bullet from its original line of travel as a result of ricochet.

Lands The raised areas between grooves in rifled barrels.

Lead azide A chemical compound used in most priming mixtures.

Lever action Type of firearm action that utilizes a lever to move the breech mechanism.

Long gun Firearm designed to be fired from the shoulder.

Magazine An integral or detachable device used to contain and feed cartridges into the action of a weapon.

Micrometer Precision measuring device used to measure small distances and thicknesses.

Muzzle blast The rapid expansion of gases resulting from the combustion of gunpowder in the discharge of a firearm.

Muzzle imprint An abrasion of the skin having the general shape of the muzzle of a gun as result of the muzzle blast from a contact or near contact shot that forces the skin back against the muzzle.

Near contact shot A shot fired with the muzzle of the gun in close proximity to the substrate but not touching it.

NIBIN National Integrated Bullet Identification Network; a system for electronic comparison of bullets and cartridge case information entered into databases across the country.

Nitrocellulose powder A smokeless propellant whose principal ingredient is nitrocellulose.

Nitroglycerin A high explosive and component of double-based gunpowder.

Pellet Common term for small, spherical shot used in shot shells.

Plumb bob Cone-shaped metal object whose point is oriented to the ground, with the other end affixed to a line so that a perpendicular to the earth may be established.

Polygonal rifling Rifling with rounded edges instead of the usual square edges.

Powder Stippling The result of powder particles striking the skin and imbedding and/or leaving a burn or bruise.

Primer Shock-sensitive explosive mixture that initiates burning of a propellant.

Primer residue Compounds of barium, antimony, and lead; lead is absent from lead-free primers.

Propellant The powder charge inside a shot shell or cartridge case.

Pulverized glass Tiny particles of glass produced by bullet impact.

Radial fracture Glass fracture radiating outward from the point of impact.

Reenactment The use of actors, animated figures, scale models and/or mannequins to simulate an action or series of actions in a shooting incident.

Revolver Firearm that utilizes a revolving cylinder to hold and fire cartridges.

Ricochet A change in bullet direction of travel as a result of impact with a substrate.

Ricochet crease An indentation in a substrate resulting when a bullet or pellet strikes a substrate and is deflected off.

Ricochet mark A mark with no discernible depth resulting when a bullet or pellet strikes a substrate and is deflected off.

Sabot A subcaliber device that allows a smaller caliber bullet to be fired in a larger caliber weapon.

Safety glass Vehicle windshield glass consisting of two sheets of glass cemented around a piece of plastic.

Semiautomatic Weapon action that requires the trigger to be pulled for each shot but reloads itself automatically.

Shot accounting Determining the number of shots fired and their resultant impact sites.

Shooting reconstruction The development of a likely or probable sequence of events in a shooting incident.

Shot shell buffer White or black granular material included in some shot shells to occupy space or keep shot apart.

Single base powder Gunpowder consisting of nitrocellulose.

Slug Single projectile for a shotgun.

Sodium rhodizonate Chemical compound used to test for lead.

Soot Carbonaceous material resulting from the combustion of gunpowder.

Spin stabilization The clockwise or counter-clockwise rotation of a bullet produced by the rifling within the barrel of a firearm.

Suicide by cop The willful baiting of an officer into the use lethal force by an individual intent on achieving his own demise.

Suppression The reduction of the sound of discharge through some means, usually via a device affixed to the muzzle that slows the expansion of gases from the combustion of the gunpowder.

Tempered glass Glass with stress built in during manufacture to prevent sharp edges from occurring upon breakage.

Trajectory The path of a bullet or shot pellet in flight.

Trajectory rod Any type of plastic, metal, or wooden rod placed into a bullet hole to help determine the trajectory of the responsible bullet.

Yawing The side-to-side motion of a bullet about its long axis as a result of loss of stabilization in flight.

Zero-base protractor Protractor used for trajectory determinations; degree graduations begin at the base.

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