

A Simplified Guide to Explosives Analysis

Introduction

A backpack left on a crowded city street. A gunman's apartment. A meth lab in an abandoned building. These are all areas where explosives have been found – ready to detonate, endangering lives and property. In today's law enforcement environment, officers are more sensitive than ever to the possible existence of explosive devices.

The bomb squads who respond to these situations are highly trained to identify explosives and to dispose, disrupt or render them safe. In a situation where an explosion has occurred, investigators will scour the area to piece together clues to help identify the type of device used and gather all available physical evidence or witness testimony that could help lead to the bomber. Fragments of circuit boards, fingerprints, even pieces of pet hair have been used to help narrow the investigation and nab a perpetrator.

Principles of Explosives Analysis

Explosives are used for a variety of legitimate applications from mining to military operations. However, these materials can also be used by criminals and terrorists to threaten harm or cause death and destruction.

Bombs can be either explosive or incendiary devices, or a combination of the two. An explosive device employs either a liquid, a powder, or a solid explosive material; an incendiary device is flammable and is intended to start a fire.

Explosives are classified according to the speed at which they react. High explosive materials, such as dynamite, Trinitrotoluene (TNT), C-4 and acetone peroxide, react at a rate faster than the speed of sound in that material (TATP), causing a loud detonation. These substances are tightly controlled to ensure they are not easily procured.



C-4 high explosive



Plastic explosive

A low explosive material, such as gunpowder, smokeless powder or fireworks, burns much slower. Low explosives are often used as propellant. A low explosive must be confined to explode. *Note: In the case of a low explosive, this is referred to as a “deflagration,” not detonation, since the reaction occurs at a rate below the speed of sound, in the material.ⁱ*

¹ *Practical Bomb Scene Investigation*, James T. Thurman, 2011, Taylor and Francis Group, LLC

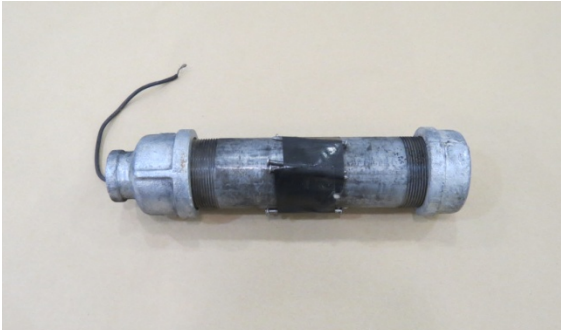
Bomb Blast Effects

The effects of an explosion are created through the action of several rapidly occurring events. The most damaging phase of the explosion is the initial blast wave that radiates rapidly outward from the epicenter. This wave of highly compressed air inflicts the primary damage to structures and people.

The initial blast wave, also called shock waves, violently expel fragments of the casing and shrapnel such as nails or screws that may have been added to the device. In addition to the shrapnel from the device, when an explosion occurs in or near a building, fragments from high-velocity glass shards or other building materials can be a large contributor to injuries.

The blast may also produce high heat and a fireball that could start secondary fires or explosions. In most explosions the seat of the explosion should be apparent, but structural damage and physical damage to vehicles can be used to approximate the location of the seat of the explosion.

Common Explosive/Incendiary Devices



Common pipe bomb

One of the most common explosives encountered by a bomb squad is a pipe bomb. A pipe bomb is a section of pipe that usually contains a low explosive powder mixture. The ends are capped and a fuse is inserted into the explosive powder. Upon explosion, the bomb sends shards of the pipe outward at a rapid speed. If a bomb has a hard casing, such as a steel pipe, large fragments may be found around the blast site. If a bomb has a soft casing, it will generally leave smaller fragments behind.

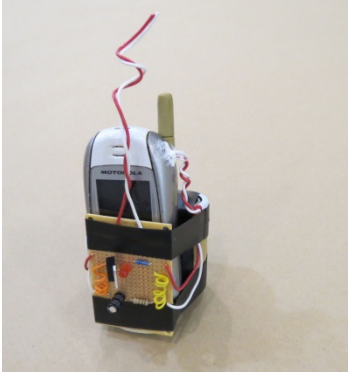


Pipe bomb device

Improvised explosive devices (IED) – The term “IED” has become commonplace since U.S. involvement in the Iraq and Afghanistan wars. These homemade devices can be delivered in a myriad of different designs – from letter bombs to roadside bombs. IEDs employ at least

four key components: a power supply, initiator, explosive material and a switch. A typical IED carries an explosive main charge with electrical fusing system that can contain components from a device such as a mobile phone or garage door opener.

Common IEDs:



Remote controlled IEDs often use radios or cell phones as the triggering device.



Victim-operated IED (VOIED) fusing systems require someone or something to complete an electronic circuit such as stepping on two pieces of metal wire, held apart by an insulator.



A VOIED using two metal strips wired, but separated by matchboxes achieve the same effect as the saw blades above and show the diversity of materials that IED triggers can be made from.



A car that has been struck by a relatively small IED offers much information about the device and possibly the network that designed, built and delivered the device.

Incendiary devices – A common incendiary device used by rioters to start fires is the Molotov cocktail. A Molotov cocktail is a glass bottle containing a mixture of flammable liquids; a rag or fuse is attached and lit just before the bottle is thrown. This ignites the liquid upon impact.

Applications

Why and when is Explosives Analysis used?

A bomb squad may be called in to investigate a variety of situations, from a backpack left on a street corner to a bomb threat called in on a public building or workplace. The number one job of bomb technicians is to identify potential threats and render them safe. Bomb squad personnel can determine the type of explosive and the scope of the threat. This information may also help law enforcement determine whether a circumstance is a coordinated terrorist threat or an isolated incident.

During the aftermath of the shooting in Aurora, CO, the bomb squad had to deal with the shooter's intricately booby-trapped apartment. After several days of examining the scene, technicians safely extracted 30 home-made IEDs from the apartment. Water was used to disable a control box, then the bombs were carted out in buckets of sand, and brought into an unpopulated area where they were detonated. The shooter had set the bombs to explode via a series of trip wires when someone opened the door of the apartment.

While high-profile incidents such as the bombing of the Murrah Federal Building in Oklahoma City in April 1995, or the Boston Marathon bombing in April 2013 receive widespread attention, the majority of explosives incidents involve residential properties,

mailboxes and vehicles.¹ Vandalism and revenge are the most frequent motives cited for these acts.

2 *A Guide for Explosion and Bombing Scene Investigation*, National Institute of Justice, June 2000.

A key goal of an explosives investigation is to determine whether the explosion was an accident or was set off deliberately with criminal intent. In addition, explosives analysis often provides key information during an arson investigation.

How It's Done

Evidence That May be Collected

A detailed investigation of a blast site will reveal crucial clues to lead the investigation. By thoroughly documenting the condition of the scene, including any structural damage and injuries or fatalities, investigators can slowly piece together what occurred.

Fragments of an exploded device will often be left intact, including switches, wiring, timers and circuit boards. If the timer was made from a unique type of watch, for instance, that information could help narrow the search for who created the device or where it may have come from.



After an explosion, residue from the explosive that was used will be left behind. To identify the type of explosive used, investigators may use an ion mobility spectrometer (IMS), a handheld chemical detection device, to identify residues that may be present around the blast site.

For large-scale incidents, the area of investigation may be expansive. The bombing of the Pan Am Flight 103 over Lockerbie, Scotland in 1988 created the largest crime scene in the world. It stretched for more than 1,200 square miles. By painstakingly piecing together the wreckage that was found in this area, investigators identified trace amounts of explosives that helped confirm the incident was indeed caused by a terrorist attack. Two hundred seventy people died that day – 259 on the plane and 11 residents of Lockerbie.

In addition to collecting physical evidence, video footage may be available from security cameras or from witnesses' cell phones. Investigators will also interview witnesses and victims to gather crucial details.

How the Evidence Is Collected

If an undetonated device is located, it must first be rendered safe. A bomb should never be moved from where it was found because it could detonate. This should only be conducted by a qualified bomb technician. Safety is the primary consideration; damage to a structure can be repaired, but injury to a person could be life-altering or fatal.

To examine the type of explosive, bomb technicians use remote robotic equipment to take pictures of the device, or even to detonate the bomb. Robots are commonly fitted with a device that can shoot a high velocity jet of water into the device, disrupting it. The bomb squad technician can then move in to confirm the area is safe and law enforcement can begin an investigation.

A bomb squad technician may also use a portable X-ray tool to examine a suspicious package to determine if it contains an explosive. X-rays are commonly used in airports to examine luggage to ensure baggage does not contain explosive devices.

Before being transported from the scene, all physical evidence is photographed, packaged, placed into containers, labeled and secured. Evidence could even be lodged in the bodies of victims or a suicide bomber. The body can be examined via X-ray images and the evidence retrieved if necessary.

If a community doesn't have its own specialized unit to handle explosives, it will have an agreement with a nearby bomb squad to handle these types of situations.

Who Conducts the Analysis?

Several professionals may be involved in examining explosives evidence or a destructive device. A chemist who is specially trained examines items for explosive residues. This practitioner may work in concert with explosive device specialists who have knowledge of electrical components, expertise in device reconstruction and an understanding of post-blast damage.

In circumstances involving terrorist IEDs, the devices are analyzed by the FBI's Terrorist Explosive Device Analytical Center (**TEDAC**). TEDAC is located at the FBI Laboratory in

Quantico, Virginia. IEDs collected from around the world are sent to TEDAC for forensic examination.

How the Analysis Is Performed

Once a device is rendered safe, it can be analyzed like any other piece of evidence to search for leads regarding who was responsible for creating and deploying the device. If large fragments of the device are retrieved, DNA or fingerprints may be present that analysts can attempt to match to a suspect. DNA profiles are compared to records in the FBI's national Combined DNA Index System database, "CODIS".

Post-blast explosive residues can be analyzed using a variety of techniques such as infrared spectroscopy, gas chromatography/mass spectrometry, energy dispersive X-ray analysis, Raman spectroscopy and other techniques.

Explosive devices can be searched against several national databases that are maintained to identify trends in the manufacture of explosives, and track bomb and device designs employed by serial bombers and terrorist groups. These databases include the FBI's Terrorist Explosive Device Analytical Center, the ATF's Arson and Explosives National Repository and the National Fire Incident Reporting System.

Frequently Asked Questions

What kind of results should I expect from explosives evidence analysis?

During the analysis, scientists will confirm the type of explosion that occurred, and identify the type of explosive material and any explosive precursors such as diesel fuel or ammonium nitrate used in fertilizer, that may have been used. Ideally, an explosives analysis will provide enough information so that the origin of the device can be determined.

What are the limitations of the analysis?

Even if bomb squad technicians and forensic scientists can gather extensive evidence, there aren't always signatures left behind that can lead to the person responsible. For large scale vehicle bombs, such as the one used in Oklahoma City, the size of the bomb made it difficult to identify the fusing system. Another limitation is inclement weather. Rain can wash away explosive residues and make analysis difficult.

How is quality control and assurance performed?

During an explosives examination, the analyst's work is reviewed by a laboratory technical manager who ensures that proper protocols are followed; the technical manager reviews reports and conclusions.

To help standardize explosives analysis methods, the Technical Working Group for Fire and Explosions (TWGFEX) publishes recommended guidelines for **Forensic Identification of Post-Blast Explosive Residues** for use by forensic practitioners.

The management of forensic laboratories puts in place policies and procedures that govern facilities and equipment, methods and procedures, and analyst qualifications and training. Depending on the state in which it operates, a crime laboratory may be required to achieve accreditation to verify that it meets quality standards. There are two internationally recognized accrediting programs focused on forensic laboratories: The American Society of Crime Laboratory Directors Laboratory Accreditation Board (www.ascl-d-lab.org) and ANSI-ASQ National Accreditation Board / FQS (www.forquality.org).

What information does the analysis report contain?

If the explosive is identified, this information will be included in the report. The report may also contain details regarding how the device was constructed and how the device functioned. If items of investigative value are developed, this information will be included in the report.

A post-blast report would include pictures, a site diagram with measurements, location, circuitry, explosive (weight and type), components and pieces collected, fingerprints, DNA samples, residue analysis, unique features, links to other IEDs, etc.

The chemical analysis report would provide information on the types of explosive residue and precursors located at the site.

Are there any misconceptions or anything else about this topic that would be important to the non-scientist?

In TV and popular films, a bomb squad technician may be depicted attempting to disable an explosive device by hand in a race against the clock. In real life, however, this is a very rare occurrence. When possible, disabling a bomb is conducted remotely for safety reasons. The only time a hands-on disabling would take place is when a device is attached to someone or in a situation when the area cannot be evacuated in a timely manner.

It's important to emphasize that people should never attempt to move a device that could be an explosive. Moving an explosive could detonate it causing severe damage to people and property.

Common Terms

A complete **glossary of terms dealing with fire and explosions** is maintained online by the Technical Working Group for Fire and Explosions (TWGFEX).

Base Charge – The main high explosive charge in a blasting cap.

Binary Explosive – Two substances which are not explosive until they are mixed.

Black Powder – A low explosive traditionally consisting of potassium nitrate, sulfur and charcoal. Sodium nitrate may be found in place of potassium nitrate.

Blasting Agent – A high explosive with low sensitivity usually based on ammonium nitrate and not containing additional high explosive(s).

Blasting Cap – A metal tube containing a primary high explosive capable of initiating most explosives.

Bomb – A device containing an explosive, incendiary, or chemical material designed to explode.

Booby Trap – A concealed or camouflaged device designed to injure or kill personnel.

Booster – A cap-sensitive high explosive used to initiate other less sensitive high explosives.

Brisance – The shattering power associated with high explosives.

C4 – A white, pliable military plastic explosive containing primarily Cyclonite (RDX).

Cannon Fuse – A coated, thread-wrapped cord filled with black powder designed to initiate flame-sensitive explosives.

Combustion – Any type of exothermic oxidation reaction, including, but not limited to burning, deflagration and/or detonation.

Deflagration – An exothermic reaction that occurs particle to particle at subsonic speed.

Detonation – An exothermic reaction that propagates a shockwave through an explosive at supersonic speed (greater than 3,300ft/sec).

Detonation Cord (“Det-Cord”) – A plastic/fiber-wrapped cord containing a core of PETN or RDX.

Detonator – A device used for detonating many types of high explosives.

Double Base – A smokeless powder which contains both nitroglycerine and nitrocellulose.

Dud – An explosive device which has undergone a complete arming and firing cycle but has failed to explode. It should be noted that this is a very dangerous situation.

Dynamite – Originally, a mixture of nitroglycerine and an absorbent filler now used to designate an entire class of high explosives.

Electric Match – A metal wire coated with a pyrotechnic mixture designed to produce a small burst of flame designed to initiate a low explosive.

Electric Squib – A metal wire surrounded by a pyrotechnic mixture and encased within a metal tube which produces a small jet of flame designed to initiate a low explosive.

Explosion – A rapid expansion of gases resulting from a chemical or physical action that produces a pressure wave.

Explosive – A chemical substance or mixture capable of producing an explosion.

Explosive Compound – A single chemical compound capable of causing an explosion.

Explosive Mixture – A mixture of chemical compounds capable of causing an explosion.

Explosive Ordnance Disposal (EOD) – Bomb squad; term generally used more for a military context.

Explosive Precursor – Any chemical material that can be mixed with one or more other chemical substances that consist of fuels and oxidizers that result in the intended production on an explosive.

Explosive Train – A series of combustible or explosive components arranged in order of decreasing sensitivity designed to initiate explosives.

Frag – Any item(s) produced and cast away from an explosion.

Fuel – Any substance capable of reacting with oxygen or oxygen-carriers (oxidizers).

Fuse – A fiber-wrapped cord of black powder used to initiate blasting caps or low explosives.

Fuze – A mechanical, chemical, or electrical device designed to initiate an explosive train.

Gunpowder – See “Black Powder”.

High Explosive – Generally a chemical substance or mixture capable of detonation.

Hoax – A “dummy” device intended to appear as a bomb but not containing an explosive.

Improvised Explosive Device (IED) – A non-commercially produced device designed to explode.

Incendiary – A compound, metal or mixture capable of producing intense heat.

Inert – A simulated explosive or device that contains no explosive, pyrotechnic, or chemical/biological agent.

Initiator – The part of an explosive train which starts the reaction.

Low Explosive – Generally a chemical compound or mixture that can deflagrate without the addition of atmospheric oxygen.

Main Charge – The main or final explosive in an explosive train.

Munitions – Any and all military explosives.

Ordnance – See “Munitions”.

Oxidizer – A chemical compound that supplies the oxygen in a chemical reaction.

PETN – Pentaerythritoltetranitrate, a high explosive used in many applications.

Plastic Bonded Explosives (PBX) – A high explosive in a pliable plastic matrix (e.g., C4, Det Flex)

Plastic Explosives – Common term for PBX.

Primary High Explosive – A high explosive sensitive to heat, shock, spark, and/or friction.

Primer – See “Initiator”.

Primer cap – A small metal device containing an impact-sensitive primary high explosive commonly found in ammunition or used in initiators.

Pyrotechnic Fuse – See “Cannon Fuse”.

Pyrotechnic Mixtures – An oxidizer/fuel mixture which produces bright or colored lights, heat, fogs, or acoustic effects.

Report – A loud sound produced by an explosion.

Safety Fuse – A water-proof coated, thread-wrapped cord filled with black powder designed to be used to initiate a non-electric blasting cap.

Secondary High Explosive – A less-sensitive high explosive initiated by another explosive.

Shaped Charge – An explosive device which is designed to direct or focus explosive energy into a narrow jet. The created plasma has a synergistic effect increasing the heat and energy on the target area.

Shrapnel – Objects which are attached to the outside or included inside a device to increase the blast damage and/or injure/kill personnel. The device/container walls themselves can also function in this manner.

Single Base – A smokeless powder which contains nitrocellulose but does not contain nitroglycerine or nitroguanidine.

Smokeless Powder – A low explosive used in ammunition as a propellant, which can be single-, double-, or triple-based

TNT – Trinitrotoluene, a commonly used explosive that is especially useful because of its low risk for accidental detonation.

Triple Base – A smokeless powder which contains nitrocellulose, nitroglycerine, and nitroguanidine.

Resources and References

You can learn more about this topic at the websites and publications listed below.

Resources

Overview of FBI Bomb Technician tools and techniques: <http://www.fbi.gov/about-us/capabilities/fbi-bomb-tech-graphic>

Overview of FBI Post-blast investigation training:
<https://www.youtube.com/watch?v=8y8QcSCWh8g>

Technical Working Group for Fire and Explosions: <http://ncfs.ucf.edu/twgfex/>

FBI Investigation of the bombing of Harvey's Casino in Nevada:
<https://www.youtube.com/watch?v=1YTmDEQWY2A>

National Geographic Channel website about bombing of Pan Am 103 over Lockerbie, Scotland: <http://natgeotv.com/uk/air-crash-investigation/lockerbie>

References

A Guide for Explosion and Bombing Scene Investigation, National Institute of Justice, Washington, DC: June 2000. <http://www.nij.gov/pubs-sum/181869.htm>

“Official: Trap in Colorado suspect’s home had 30 homemade grenades, gasoline” CNN: <http://www.cnn.com/2012/07/24/justice/colorado-theater-shooting/index.html> (accessed 8/20/13).

Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings, FEMA, 2003. <http://www.fema.gov/library/viewRecord.do?fromSearch=fromsearch&id=1559>

Thurman, James T., *Practical Bomb Scene Investigation*, Taylor and Francis Group, LLC, 2011

Explosive Examiners Job Description, Technical Working Group for Fire and Explosions: http://ncfs.ucf.edu/twgfex/docs/exp_exm_job_desc.pdf (accessed 8/1/13).

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Forensic Evidence Admissibility and Expert Witnesses

How or why some scientific evidence or expert witnesses are allowed to be presented in court and some are not can be confusing to the casual observer or a layperson reading about a case in the media. However, there is significant precedent that guides the way these decisions are made. Our discussion here will briefly outline the three major sources that currently guide evidence and testimony admissibility.

The *Frye* Standard - Scientific Evidence and the Principle of General Acceptance

In 1923, in *Frye v. United States*^[1], the District of Columbia Court rejected the scientific validity of the lie detector (polygraph) because the technology did not have significant general acceptance at that time. The court gave a guideline for determining the admissibility of scientific examinations:

*Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while the courts will go a long way in admitting experimental testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be **sufficiently established to have gained general acceptance** in the particular field in which it belongs.*

Essentially, to apply the “*Frye* Standard” a court had to decide if the procedure, technique or principles in question were generally accepted by a meaningful proportion of the relevant scientific community. This standard prevailed in the federal courts and some states for many years.

Federal Rules of Evidence, Rule 702

In 1975, more than a half-century after *Frye* was decided, the Federal Rules of Evidence were adopted for litigation in federal courts. They included rules on expert testimony. Their alternative to the *Frye* Standard came to be used more broadly because it did not strictly require general acceptance and was seen to be more flexible.

The first version of Federal Rule of Evidence 702 provided that a witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

- a. the expert’s scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
- b. the testimony is based on sufficient facts or data;
- c. the testimony is the product of reliable principles and methods; and
- d. the expert has reliably applied the principles and methods to the facts of the case.

[1] 293 Fed. 1013 (1923)

While the states are allowed to adopt their own rules, most have adopted or modified the Federal rules, including those covering expert testimony.

In a 1993 case, *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, the United States Supreme Court held that the Federal Rules of Evidence, and in particular Fed. R. Evid. 702, superseded *Frye's* "general acceptance" test.

The *Daubert* Standard - Court Acceptance of Expert Testimony

In *Daubert* and later cases^[2], the Court explained that the federal standard includes general acceptance, but also looks at the science and its application. Trial judges are the final arbiter or "gatekeeper" on admissibility of evidence and acceptance of a witness as an expert within their own courtrooms.

In deciding if the science and the expert in question should be permitted, the judge should consider:

- What is the basic theory and has it been tested?
- Are there standards controlling the technique?
- Has the theory or technique been subjected to peer review and publication?
- What is the known or potential error rate?
- Is there general acceptance of the theory?
- Has the expert adequately accounted for alternative explanations?
- Has the expert unjustifiably extrapolated from an accepted premise to an unfounded conclusion?

The *Daubert* Court also observed that concerns over shaky evidence could be handled through vigorous cross-examination, presentation of contrary evidence and careful instruction on the burden of proof.

In many states, scientific expert testimony is now subject to this *Daubert* standard. But some states still use a modification of the *Frye* standard.

[2] The "Daubert Trilogy" of cases is: **DAUBERT V. MERRELL DOW PHARMACEUTICALS, GENERAL ELECTRIC CO. V. JOINER** and **KUMHO TIRE CO. V. CARMICHAEL**.

Who can serve as an expert forensic science witness at court?

Over the years, evidence presented at trial has grown increasingly difficult for the average juror to understand. By calling on an expert witness who can discuss complex evidence or testing in an easy-to-understand manner, trial lawyers can better present their cases and jurors can be better equipped to weigh the evidence. But this brings up additional difficult questions. How does the court define whether a person is an expert? What qualifications must they meet to provide their opinion in a court of law?

These questions, too, are addressed in **Fed. R. Evid. 702**. It only allows experts “qualified ... by knowledge, skill, experience, training, or education.” To be considered a true expert in any field generally requires a significant level of training and experience. The various forensic disciplines follow different training plans, but most include in-house training, assessments and practical exams, and continuing education. Oral presentation practice, including moot court experience (simulated courtroom proceeding), is very helpful in preparing examiners for questioning in a trial.

Normally, the individual that issued the laboratory report would serve as the expert at court. By issuing a report, that individual takes responsibility for the analysis. This person could be a supervisor or technical leader, but doesn't necessarily need to be the one who did the analysis. The opposition may also call in experts to refute this testimony, and both witnesses are subject to the standard in use by that court (*Frye, Daubert, Fed. R. Evid 702*) regarding their expertise.

Each court can accept any person as an expert, and there have been instances where individuals who lack proper training and background have been declared experts. When necessary, the opponent can question potential witnesses in an attempt to show that they do not have applicable expertise and are not qualified to testify on the topic. The admissibility decision is left to the judge.

Additional Resources

Publications:

Saferstein, Richard. **CRIMINALISTICS: AN INTRODUCTION TO FORENSIC SCIENCE**, Pearson Education, Inc., Upper Saddle River, NJ (2007).

McClure, David. Report: Focus Group on Scientific and Forensic Evidence in the Courtroom (online), 2007, <https://www.ncjrs.gov/pdffiles1/nij/grants/220692.pdf> (accessed July 19, 2012)

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