DESTRUCTIVE ENTRY

Destructive entry (or forced entry) is a non-covert method of entry characterized by damage to or destruction of a lock, safe, or surrounding objects, such as a door, window, or wall. It is by far the most common method of entry and is frequently used by law enforcement and military personnel for rapid entry to a residence or facility. As you might have guessed, there are many ways to destroy things. Techniques are classified by their method of destruction in terms of the physics of the operation but often overlap and complement one another. All destructive techniques use energy or force to damage, displace, weaken, or destroy components. Once components of a lock, safe, door, window, or wall lose structural or molecular integrity their ability to resist compromise is considerably reduced. The general categories of destructive entry are: chemicals, compression, impact, shearing, temperature, tension, and torsion.

While the techniques discussed might seem advanced, the majority are rather simple when put in perspective; doors are kicked in, padlock shackles are cut, locks are drilled, et cetera. Techniques are categorized to help the investigator identify, define, and study new attacks. While tool designs differ greatly the tool marks and forensic evidence they leave behind may help investigators quickly identify the techniques used to gain entry.

Chemicals are used to affect the molecular structure of components. Chemicals, namely acids, can corrode, disintegrate, or dissolve components. Like temperature, chemicals often leave components vulnerable to other attacks.

Compression is the use of pressure against a component in complementary directions. Essentially, the opposite of tension. It causes distortion, compaction, or breakage of components. Compression is most often used to reduce the strength of materials so that other methods can be used.

Impact is the use of pressure and shock against a component. Striking and explosives are most common. Impact has a wide variety of results including fracturing, breakage, deformation, and compression. Some methods of bypass use impact to retract the locking bolt, most of which are destructive. Explosives are one of the most dangerous methods of destructive entry and use has dwindled with time as safer alternatives, such as drilling, have become popular.

Shearing is the use of pressure on a component placed betweeeen two edges. Cutting, chopping, and drilling are included in this category. Drilling is the most popular method of destructive safecracking and removal of locks by a locksmith. In general, drilling is probably the easiest, fastest method of destructive entry.

Extreme temperature can be used to affect the molecular structure of components. High temperatures can vaporize, burn, melt, or re-temper components. Re-tempering can leave components soft or brittle, thus vulnerable to many other attacks. Low temperatures are less common, but can be used for similar purposes.

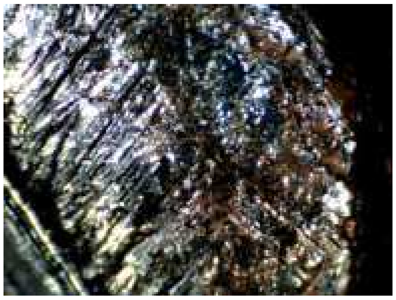
Tension is the use of pressure on a component in opposite directions. Stretching, pulling, prying, bending, or ripping are included in this category.

Torsion is the use of rotational pressure (torque) on a component. Twisting and torque and included in this category. Causes shearing, compression, and deformation of components.

Destructive entry is fairly straightforward in terms of method of entry, so the focus is on tool mark identification. The forensic locksmith must be wary of destructive techniques used as a method of hiding covert or surreptitious entry. A thorough investigation will reveal covert techniques and can potentially rule out destructive entry as the method of entry due to improbable direction, angle, or position of tool marks.

The most common attack against padlocks is cutting the shackle, either in half or clean off. Almost all low to medium security non-shrouded padlocks are susceptible to this attack. This attack is a form of shearing, and the two edges of the bolt cutter are clearly seen in the displacement of the shackle material.

A closer examination of the tool mark reveals that a red substance is present in the area where the bolt cutter was used. This could be a variety of things; paint, dirt, grease, or rust. We might be able to match this material to the tool if a bolt cutter is found in a suspect's possessions.



Drilling, a form of shearing, is the most common method of destructive entry against all types of locks. It is frequently used by locksmiths to remove locks when they cannot be opened non-destructively. In this photo, the plug of a KIK cylinder has been drilled at the shear line, allowing the plug to freely rotate.

On the Forensic Investigation page we discuss the need to tape any openings in locks recovered at the crimescene. In the photo, a large amount of metal is present inside the lock, a product of drilling. This material is preserved because it may contain evidence useful to the investigation, such as shards of a broken drill bit.

Drills are much like firearms in terms of forensic evidence. Bullets fired from a gun have striae based on the barrel used; the same goes for drill bits used in destructive entry. In the photo, the spiral striae left by the drill bit can clearly be seen in the plug of the lock.

Impact is a versatile method of destructive entry that is extremely effective against windows, doors, and walls. In the photo, a padlock has been hammered until the shackle broke. The direction of the break can tell us what angle it was being struck from. Additional tool marks will likely be found on the body of the padlock.

In this photo, the body of the padlock shows tool marks in places where the hammer impacted the lock. The crescent shaped marks are numerous and can be measured to determine the size and shape of the hammer used. At least three different points of impact are visible.

Heavy damage to the face or keyway of the lock can mean many things. A thorough investigation of tool marks, including angles and positions, helps to reveal how entry was accomplished. In this photo the keyway has been considerably widened and gouged so a tool can be inserted, probably a screwdriver or chisel.

In addition to damage to the keyway, the upper pin chambers have been completely sheared off, leaving the plug and broken cylinder free to rotate in the lock. This attack appears to be torsion applied counter-clockwise to the plug through the use of a screwdriver.

The pins inside this lock show heavy damage from where the screwdriver or chisel was forced into the keyway. Examination of what is left of the tip of the pin shows no indication of covert entry techniques. Because of the force used, tool marks on the pins are rather distinct and may later be used to link suspects to the crime.

European profile cylinders are held in place by a screw that extends through the center of the cylinder. Because the cam is beneath this point, it is the thinnest part of the lock and thus the easiest to break. In this photo, a european profile cylinder has been snapped in half (forced to the left) using common hand tools.

The basis of this attack is that there is enough of the cylinder extending through the door, as little as a few millimeters, and a tool used to grab and apply force to the lock. In this photo, tool marks can be seen where the tool was used to grab the front of the lock.

The cam of the lock can also be examined to determine which way the lock was snapped. This is generally not important, but the lock may have been snapped at an angle that is impossible when the door is closed, indicating fraud or misdirection from the real method of entry.

Many destructive attacks against low security padlocks break the shackle because, relative to the body, it is the weakest component. In this photo, the padlock shackle is broken in two places, with one piece being stuck beneath the locking bolt.

A thorough examination of both the shackle and the padlock body helps to identify the specific technique used. In this photo, the body of the padlock shows excessive distortion in the form of twisting, indicative of extreme torsion being applied to the padlock body.

Tool marks for the torsion tool are found on the edges of the padlock. Marks appear to be rather fresh, thus the most likely candidates for the attack in question.

A closer inspection of the tool mark shows a series of parallel teeth marks, probably from the use of a plumber's wrench or tongue-and-groove pliers. Marks can be used in tool mark comparisons done with tools found in a suspect's posessions.

Simulating lockpicking is common in insurance fraud or when the insurance holder is worried about coverage. These people rarely understand lockpicking and just jam a screwdriver in the lock to make marks. In most cases, material removal and tool marks are present at the front of the cylinder but not past the first or second pin.

The pins in simulated lockpicking will have a large amount of material removal and tool marks that are not consistent with any type of covert entry, including lockpicking or key bumping. Marks will usually not be found on the pins in the back of the lock, too.

Chemicals are powerful because they can fundamentally alter metals to leave them vulnerable to many other attacks. In this case, brass pins are dark red/brown because of NO_2 fumes released when concentrated nitric acid contacted the brass components. Nitric acid has the effect of eating away the copper in brass.

A closer examination can confirm the use of nitric acid by identifying trace evidence left by the chemical reaction between nitric acid and brass. The scattered blue particles are cupric nitrate and zinc nitrate, a byproduct of the chemical reaction.

LOCK DISASSEMBLY

This page discusses different ways to disassemble a lock as well as vivisect it for laboratory investigations. Different jurisdictions have different preferences as to how evidence is handled and examined, but these techniques are chosen because of their minimal impact on evidence and the forensic process.

In order to do laboratory examinations, components must first be properly removed from the lock. This can be a simple or arduous task depending on the lock in question. In most cases the forensic locksmith will *not* be given a working key to a cylinder, and must open it in another way. Obviously, the investigator cannot pick or bump the lock open. When disassembling the cylinder, all components must be kept in their original position, order, and, if possible, alignment. The best way to accomplish the first two items is by using a pinning tray to organize components as they are removed from the lock. In the case of wafer and lever locks, components should be laid out according to their proper position and order.

In all cases it is essential that the lock and door are thoroughly examined before being disassembled. Clues as to method of entry and tools used may be better seen when the lock is mounted, where the lock can be examined alongside the door and other surroundings.

See the Tools and Workspaces page for more information on tools used during disassembly of the lock.

The absolute best method of disassembly of the lock is taking it apart without damaging it or using a key to open it. In pin-tumbler cylinders this means proper removal from the door and then removal of the pin-chamber screws, casings, or cover. In combination, lever, and warded locks this usually means simply removing the lock from the door and removing any casing screws. Most American locks are easy to disassembly in this way, but many European profile locks do not have exposed pin-chamber screws or casings.

Rapping is a non-destructive method of opening a pin-tumbler cylinder without affecting internal components. Rapping is similar, in function, to key bumping, but without the forensic implications. To rap a lock: light torque is applied to the plug or cam with one hand, the other hand uses a rubber mallet to gently hit the bottom of the cylinder, cause kinetic energy to transfer to top pins. If all top pins jump above the shear-line the plug will turn. Unlike bumping, rapping leaves no forensic evidence because it does not use a key to transfer kinetic energy. This method is not terribly effective, but it is worth trying because it does not affect forensic evidence inside the lock.

Shimming is a non-destructive method of opening a pin-tumbler cylinder that uses a thin piece of metal to separate pin pairs at the shear-line. Shimming is mildly invasive, but generally does not leave forensic evidence in places that are normally accessible by compromise tools. To shim a lock, a blank key and a shim are obtained. The blank key is inserted into the lock, then a shim is inserted from the *back* of the lock, between the plug and cylinder. The blank key is slowly withdrawn while light pressure is applied to the shim. As the pin pairs reach the shear-line the shim slips between them, trapping top pins above the shear line. This process repeats until the shim separates all pin pairs and the plug is free to rotate. The photo shows a shim partially inserted between the plug and cylinder.

Destructive methods are not popular to initially disassemble the lock, but may be required in the case of padlocks or when use of a key or shim is not preferred. A working knowledge of the anti-drilling, cutting, and other security features of the lock is an absolute necessity to properly disassemble the lock as well as protect the well-being of the forensic locksmith. The lock is destroyed only enough to remove the internal components and nothing more. Pictures and documentation must be done throughout every step of the process to ensure that it can be verified and was done properly.

One place where destructive methods are very useful is in the vivisection of lock components. This is not a big issue with lever, combination, and warded locks, but pin-tumbler and wafer based cylinders provide a wealth of information when their plugs are dissected. The preferred method for vivisecting the plug is into thirds, not cut down the middle as may be expected (see photo). Cutting into thirds is preferred over halves because the top portion of the keyway is never touched by components, including the key, and is considered virgin territory where forensic evidence may be present. See the lockpicking page for more information of possible marks in this area. To cut the plug, a fine-tooth hacksaw or jeweler's saw is used.

Though it may seem natural to use a working key to aid in disassembly of the lock it is generally frowned upon. The last object to enter the lock was that key and it may have destroyed or created evidence. Use of a key may only be done in situations where destructive methods are not allowed and there is no other way to disassemble the lock.

KEY ANALYSIS

While investigation of locks is important, it is more common that the keying system has been compromised. Much like the cryptography world, systems are not usually broken by some awe-inspiring flaw but instead by the simple act of obtaining the proper keys. The keys to a specific lock can yield just as much information as the lock itself, sometimes more so because of the possibility of hair, fiber, and fingerprint transfer when handling keys. While examination of locks is excellent for determining the method of entry, examination of keys is doubly excellent for the identification of suspects.

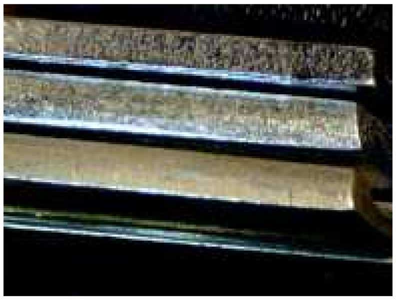
If you haven't already, visit the Normal Wear page to see how keys are affected by normal use.

"Cuts" refer to the pattern of cuts on the key bitting. The cuts interface with components and, if positioned properly, cause the lock to lock or unlock. The investigator is often asked if a key could have been used to open a lock. Analysis of cut depths, spacing, and keyway can answer this. The key is also evaluated to see if it can be jiggled or partially inserted to allow entry.

The keyway profile is the pattern of warding on the key. Many keys have a keyway code stamped to the bow. If not, it can be identified by comparing the keyway with a code book or database. Some advanced key machines can automatically identify a keyway via optics or lasers. Keyway identification allows the investigator to determine if the key fits the lock, thus is able to position components correctly.

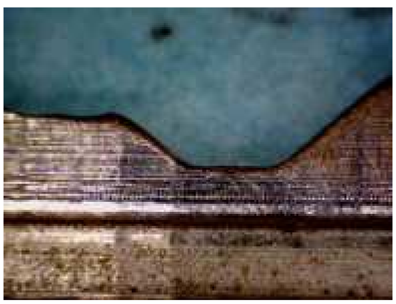
Many keys have codes that identify cuts and keyway. Bitting codes may be direct (literal) or indirect (obfuscated). In the case of indirect codes, the manufacturer may be able to determine to whom and where the key belongs. Other information may also be stamped on the key, such as the name of lock brand, key brand, or the locksmith/hardware store that produced the key. All of which may be used to identify a suspect.

The material of a key can identify factory original keys, and in some cases specific third-party manufacturers. Certain manufacturers use proprietary alloys to increase longevity and strength of their keys, some of which can be traced back to them. The photo shows three different keys, each made of a different material.

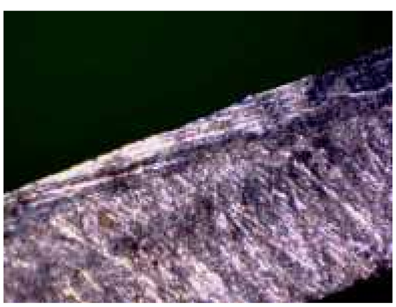


The plating on a key also provides some clues. Manufacturers usually plate factory-original keys *after* they are cut, while locksmiths and hardware stores will remove the plating of a blank key when making cuts. The plating material may also be used to identify the key blank manufacturer.

Keys can be duplicated in many ways, but the most common is duplication by hand or with a key machine. Identifying an original vs. duplicate key is an important function of the forensic locksmith. In addition, the forensic locksmith may be able to determine if the key was recently duplicated.



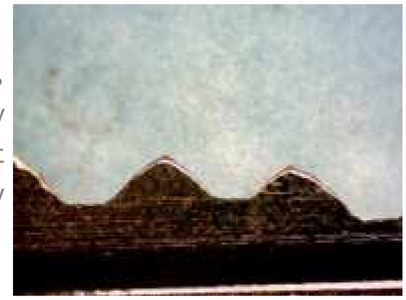
In this photo, the duplicate key is shown. Notice that the ramps and valleys of the key are slightly different than the previous photo. In addition, we see that the key is nickel-silver plated, with no plating on the cuts. Depending on the factory-original specifics, this may also indicate that it is a duplicate key.



When a key is duplicated with a stylus-based key machine a mark is left on the side of the original key. This is due to the stylus being gently dragged against the key, and resembles a long, straight, polished line. This cannot be confused with wear of the key because it is not in the direct center of the key.

Keys can be examined to determine the speed and blade design of the key machine was used to cut them. This photo shows a comparison of two keys, with the one of the left being cut with a lower speed key cutter. If a key machine is found with a suspect, it can be examined to determine if it was used to cut a specific key.

Possession of keys that are made by hand are, in a general sense, somewhat suspicious. In most cases hand made keys are easily identified by measuring the ramp angles, shoulder to first cut distance, and the distance between cuts. Hand-made keys generally have imperfect, jagged ramp angles and poorly spaced cuts.

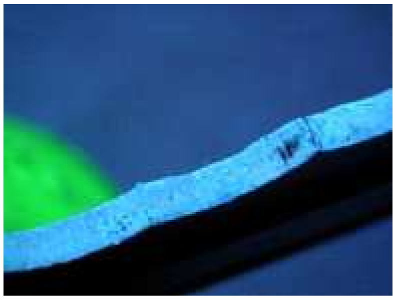


In this photo we see many groups of scratches, with slightly different angles, across the bitting of the key. This is consistent with the use of a file. Specifically, this is a flat file being used on the broad side. With a tool mark comparison we can determine the size, shape, and grade of the file(s) used.

In this photo we see a series of cuts with variable depth valleys and light material removal around the edges. This is consistent with use of a dremel. Again, tool mark comparison can determine exactly which dremel bit(s) may have been used. These can be linked with tools found in a suspect's possessions.

Sometimes marks will be left on the key as a result of normal or malicious use. When a key is duplicated with a cutter, the clamp to hold the original or the blank may leave a mark. In addition, some covert entry techniques may leave tool marks. In this photo we see a set of rather deep marks on the bow of the key.

Close up we see a distinct pattern on the largest tool mark. We can hypothesize what made this, and perform a tool mark comparison to confirm. This particular mark was made by a pair of vice grips being used to impression (via manipulation) a blank key. The key should also be examined for impressioning marks.



Keys that have been used in manipulation based impressioning may show impressioning marks along the key bitting. Close examination of the key for such marks may help to determine its intended purpose. In the photo, an impressioning mark is found by viewing the key under ultraviolet light.

In many covert entry techniques a key is used as a tool to affect entry. Keys with unusual marks or deformations can provide clues as to their use or intended purpose. In this photo, the shoulder of the key is deformed and compressed. This happens to be a bump key's shoulder, caused by impact against the face of the lock.

Various materials are transferred to the key during use. Generally hair, fiber, and fingerprints will be examined by a crime lab. The forensic locksmith, however, may examine the findings of the crime lab to identify the uses of materials found on keys. Here we see a light green residue, which happens to be modeling clay.

In this photo we find small traces of white wax left in the warding of the key. Both this and the previous image indicate that the key has been impressioned (via copying). Through further analysis we may be able to link these and other materials to those found in a suspect's possessions.

Keys should also be viewed under various light sources to attempt and fight any material residue that may not be visible with the naked eye (or naked microscope?). In this photo, a key is being viewed under ultraviolet light to discover traces of ultraviolet ink along the key bitting area, indicative of impressioning via manipulation.

DECODING

Decoding is a general term for a class of covert and surreptitious entry methods, all of which have the expressed purpose of decoding the proper position of components in a lock through an examination of the key or internal components. Decoding is probably the most ambiguous of all the compromise methods, with a wide variety of tools and techniques used. There are a few general categories of decoding: key analysis, invasive/manipulative, disassembly, visual/optical, thermal, and radiological. Key analysis, manipulative, and visual decoding are the most common, with visual decoding probably being the one most exploited in actual use.

Decoding does not necessarily create a key for the lock, like impressioning would, nor does it always open the lock, as is the case with lockpicking. The power of decoding lies in the ability to gather information that allows the production of working keys for the lock. Decoding is also powerful because many forms are surreptitious, thus leave no discernible forensic evidence. See the Anti-Forensics page for more information.

Keys can be directly examined and decoded. Key decoding focuses on identifying the pattern of bitting cuts on the key. These can be determined by looking at the code numbers stamped on the key, or through direct measurement of each cut with a ruler, micrometer, or caliper. These measurements are used to determine the manufacturer's bitting code so that a key may be easily made. Sophisticated locksmithing tools are available that will automatically identify the bitting code based on the cuts and keyway profile of the key. This is the most basic of decoding methods, and may be problematic with high-security keys that have advanced features like sidebars, angled bitting cuts, moving parts, or magnetic/electronic components.

Components inside the lock can also be decoded through invasive, manipulative tools. These tools have radically different designs, and are generally specific to particular brand or model of lock. Most manipulative tools focus on measuring each component to determine: weight, range of movement, shape, spacing, and alignment. Many manipulative decoding tools resemble traditional lockpicking tools with the addition of a measurement device. Opening the lock via lockpicking is sometimes a pre-requisite to decoding the components. Many tools also decode the lock as they pick it. The standard tubular lockpick and the Sputnik tool are the most popular examples. Manipulation of combination locks requires no invasive tools and is discussed more thoroughly on the Anti-Forensics page.

Disassembly of the lock can also be done to directly measure all internal components. This can be a complicated procedure depending on what type of lock it is and how it is installed. This process usually requires the lock be compromised first so that the door can be opened. Facilities with lax security measures may leave doors unlocked and unguarded, allowing someone to quickly remove, disassemble, and decode a lock. Reassembly and reinstallation of the lock is equally important, and if done incorrectly can cause the lock or proper key to no longer function.

Visual/optical decoding focuses on observation or surveillance of the key or internal components without needing to invasively manipulate them. A photograph of a standard key's bitting is enough to decode the bitting code. Surveillance may be used against combination locks to observe the correct combination being entered by an authorized user. Optical decoding uses tools like borescopes or otoscopes to look inside the lock at the internal components. Optics can be used to look at the size, shape, color, alignment, and spacing of internal components.

Radiological imaging is a form of surreptitious decoding that uses penetrating radiation (X, beta, and gamma rays) to "see" inside the lock or safe, revealing the proper positions of components. This is most often used against rotary combination locks to determine the position of each gate in the wheel pack. While very effective against many combination locks, it is expensive and only used by medium-high skill attackers.

Thermal imaging is another form of surreptitious decoding that uses special devices to look at thermal residue left on keypad or pushbutton combination locks. This reveals buttons recently pushed, but may not directly reveal the combination sequence. Like radiological imaging, this is generally not used by low skill attackers.

As you can see, decoding is a vast array of techniques with forensic evidence equally varied. Manipulation-based decoding tools provide forensic evidence that is similar to lockpicking, but may vary depending on the specific techniques. Examination of keys may leave forensic evidence depending on the type of tools used. Visual, optical, radiological, and thermal decoding are all considered surreptitious and leave no lock related forensic evidence. Again, see the Anti-Forensics page for more information on surreptitious entry.

Colored components are a red flag that optical decoding may be possible. The colors signify the size of components, and can be viewed with a borescope or otoscope to decode the lock. Colored pins are rare in factory-original locks, but are popular in many do-it-yourself lock repinning kits.

Low security wafer locks can be visually or optically decoded simply by looking at the size of the wafers. Unlike pin-tumbler locks, wafers block at the same position outside above the plug. Keying is made possible by varying the amount of material in the middle of the wafer, causing it to be raised high or lower by a key.

Keypad-based combination locks can often be visually decoded based on wear. In the photo, the worn down numbers help to reduce the search space to only a few combinations of numbers. It is possible that the combination is meaningful to the owner, such as their birthday year or lucky number.

More to come, stay tuned!

BYPASS

Bypass is a form of covert entry that attempts to circumvent the security of the lock by attacking the cam, bolt, or locking knobs directly. While lockpicking focuses on defeating the security of the lock through manipulation of components, bypass goes directly to retracting the bolt without affecting the integrity of the components. Certain bypass techniques are also forms of destructive entry, but bypass generally refers to non-destructive methods.

Attacks against the cam or actuator are a class of bypass that is surprisingly effective. In this attack, a poorly designed cam or actuator may be manipulated without affecting components. This vulnerability is somewhat uncommon, but extremely effective and easy to do when present. Because tools must generate a mild amount of torque as well as travel through the plug, they leave distinct tool marks.

Spring loaded bolts or latches are subject to an attack known as shimming. In shimming, a wedge is used to separate the bolt from the spring, or the bolt from the recess (such as in a door). The classic credit card trick to open doors is a popular example of this technique. Low-security padlocks are also commonly susceptible to shimming of the shackle. Shimming against doors is also known as loiding.

Locks that use a thumb-turn or lever handle on the inside of the door may be vulnerable to bypass. In this attack a tool is slipped under the door and attempts to swing and catch onto the thumb-turn or lever. The tool is used to turn or pull until the door is opened. This may or may not have forensic evidence, depending on the material of the tool, handle, and how many attempts are necessary to gain entry.

In automobiles, the door frame may be attacked with what is known as a air wedge. First, a wedge (usually plastic) is used to lightly separate the door from the frame of the automobile, then a deflated air wedge is placed in the opening. The air wedge is filled with air, causing it to expand, and the door is held open to allow a tool to be inserted to manipulate the inner unlocking mechanisms inside the vehicle. This technique is commonly used by locksmiths during automobile lock-outs.

The American 700 (old models) have a vulnerability that allows bypass via manipulation of the cam. Essentially, the cylinder is not required to move in order to actuate the cam. Tool marks left on the cam and back plate indicate that bypass was used as the method of entry.

In response to the above attack American Lock (now owned by Master Lock) issued a hardware patch to prevent the bypass method. It is just a small metal disc, and in the photo we can see tool marks from where bypass was attempted. The 700 has since been redesigned because another attack against this component makes bypass again possible.

The Code Lock (4000 series) electromechanical lock is subject to a bypass attack that manipulates the bolt actuator. In the photo, material has been removed from both the actuator and the tool (a thin piece of metal) and scattered around the inside of the lock.

In most forms of bypass that target the actuator, tool marks on the actuator are distinct. In this photo, we see tool marks on the actuator of a Code Lock (4000 series). Notice tool marks are at a variety of angles and depths, all of which are inconsistent with normal use or wear.

IMPRESSIONING

Impressioning is a covert entry technique that creates a working key for a target lock. Impressioning has two variants: copying, which focuses on making a mold of a working key; manipulation, which focuses on using a blank key to manipulate lock components to determine their proper positions. This page will focus on manipulation-based impressioning.

For information on copying-based impressioning, please visit the "Tool Mark Identification" and "Material Transfer" sections of the Key Analysis page.

Manipulation-based impressioning works by taking a blank key that fits a target lock, applying extreme torque to the key (thus binding components), and manipulating the key blank in order to produce marks on the key. This is correct for pin-tumbler locks, but the actual process varies for different lock designs. The theory behind impressioning is that components at the wrong position will bind and become immobile. When the soft brass key contacts the immoble components, a mark should be produced. When a component is properly positioned it should no longer bind and thus no longer leave marks. The blank is used to gather marks, then filed in those positions. This is repeated until all components are in their proper position and the lock opens.

Because this type of manipulation is stressful on the key and cylinder we expect to find various types of forensic evidence. Namely, it is expected that the forceful binding of bottom pins, all of which are raised at or above shear line, to cause marks. We may also find material transfer from filing the key if the attacker is not careful to properly clean the key after each filing.

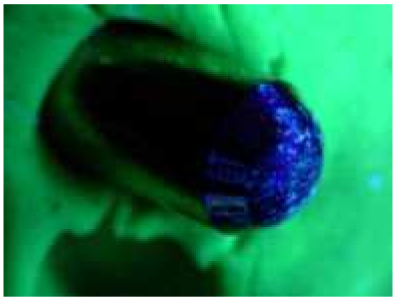
There are variations on the manipulation process that use pressure responsive materials, such as lead, tape, or plastic to facilitate the process of impressioning. In these cases we may also find material transfer as the soft materials rub against the keyway and inside of the plug.

Of course, the key used in manipulation-based impressioning will provide a good deal of forensic evidence, but that is covered in the "Hand-made Keys" and "Tool Mark Identification" sections on the Key Analysis page.

Because we are forcibly binding bottom pins at or above the shear line we expect to see marks on the pins where this occurred. In the photo we can see several marks where the pin was bound against the plug in the form of straight lines sheared into the pin. (Note: the scratches to the left are pick marks)

Sometimes, impressioning marks are so clear that we can count the rounds of impressioning. If marks are far apart the forensic locksmith can also measure the distance between them. This may indicate a more skilled attacker if they are using factory depth increments to speed up the impressioning process.

The key blank may be specially prepared for impressioning via manipulation in a variety of ways. One of the possibilities is the use of Ultraviolet ink and an ultraviolet light source. This is an interesting technique, but as you can see in the photo it leaves ultraviolet ink residue on the face and insides of the lock.



When using UV impressioning, UV ink is reapplied each time the blank is filed. In turn, the pins will have a large amount of UV reside on them. Notice the obvious key pattern of UV ink across the sides of the pin. In addition, the UV pen fibers may have been stuck to the key and left behind on the pins or the plug walls.

LOCKPICKING

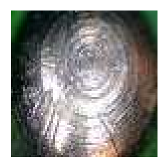
Lockpicking is a general term for a wide variety of covert entry techniques, all of which attack the locking components directly. Unlike impressioning or decoding, lockpicking attempts to open the lock without producing a working key or decoding the correct position of components. There are many different lockpicking tools for various lock types.

Pick Guns and Key Bumping are technically forms of pin-tumbler lockpicking, but are given their own pages because of their unique forensic evidence.

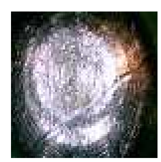
In almost all cases of lockpicking two tools are used. A tension tool is used to gently apply tension to the lock, and a pick is used to position components. As tension is applied to the plug, bolt, or other component, locking components will bind in some way. The pick can be used to determine which component is binding and then used to position it properly. The correct position of a component is known by the attacker through feedback in the form of touch, sound, or sight. The tension tool holds properly positioned components in place, and the attacker repeats the process. Once all components are properly positioned the lock can be unlocked or locked.

The nature of lockpicking necessitates that strong materials be used for tension and picking tools. Tools are commonly made out of steel, iron, and aluminum. Tools are thin (on average 0.025 with pin-tumbler picks) and require a medium amount of force to move locking components. When contacting the softer brass or nickel-silver of locking components, pick and tension tools leave marks in the form of gouges and scratches. The best source of forensic evidence of lockpicking are on the components themselves, but the lock housing, bolt, and cam may also be examined, depending on the type of lock.

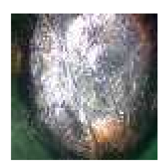
The act of using a pick tool is invasive, and we expect the stronger material of the pick tool to cause marks on the softer brass or nickel-silver of the lock components. In this photo, we see scratches where the pick tool was used to lift the pin. These appear to be single-pin picking marks due to their shape and consistency.



This photo is similar to the last, but instead there are many varied, elongated scratches at different angles and depths on the pin. This type of marking is indicative of a pick that is designed to be gently rubbed against the pins at varying height and tension. Of course, this is the technique known as raking or rake picking.



In this photo, marks left appear to be a combination of both picking techniques. Many attackers will attempt to lightly rake as many pins as possible and then proceed to use single-pin picking against the rest. This may be necessary in the case of security pins that are triggered while raking, also.



The marks left by an attacker are in many ways indicative of their skill level. In this photo, extremely deep and plentiful pick marks are shown. The attacker, an amateur, used extreme force on both tension and pick tools. The extreme tension causes pins to bind against plug and require more force to be lifted.

This is a very skilled attacker who uses extremely light tension and picking force to reduce forensic evidence. Despite skill, we still find similar forensic evidence. In this photo, pick marks are extremely light but still visible in the center of the pin. We can also see some marks on the side of the pin which are more defined.

There are many other designs of pin-tumbler besides the standard round or pointed tips. This is a photo of a Mul-T-Lock telescoping pin tumbler that uses an inner and outer pin stack. Both show signs of picking tools. If we separate the pins, we would also probably find picking marks on the inside chamber of the outer pin.

Some pin tumbler designs are rather strange, designed to deter manipulation. This photo shows a Vachette VIP "nippled" pin. The design of this pin is rather complex, with not only a nippled tip but also a very spool like appearance. In any event, picking marks are visible along the nipple and base of the pin.

Forensic evidence is also left behind by various lock-specific tools, which are growing more common with high-security locks. In this photo, the pick marks from a Medecoder type tool are visible in the sidebar channel where the tool was used to rotate the bottom pin.

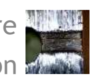
For the attacker, it is difficult to not touch the sides of pins. This can happen during raking as well as single-pin picking. Marks left on the sides of pins are quite noticeable and not as prone to wear and those in the center of the pin. In the photo, light scratches at varied angles are visible.

In the case of low-high pinning combinations it is even harder to lift pins without touching the sides of other pins. In this photo, a series of long scratches travel up the side of the pin. Interestingly, we may be able to measure the length of scratches to determine if the attacker raised the adjacent pin high enough.

Like the bottoms of the pins, the sides can tell a great deal about the skill level of the attacker. In this photo, gouges on the sides of the keys are rather deep, caused by extreme force being used on both the tension and picking tools. With this much material removed, it may be possible to identify pin material on a suspect's possessions.

The movement of the pick through the keyway also leaves forensic evidence in several places. The most common is on the walls of the plug itself. In this photo, scratches left by the pick tool are found below the pin chambers on the walls of the plug. The scratches are at various angles inconsistent with the use of a key.

One of the best places to look in the plug is at the top of the keyway. The key will never touch this area, so it is one of the few "virgin" areas in the lock. In this photo, we can see that there are light scratches along the area before the first chamber, probably from the use of a tension tool at the top of the keyway.



Marks on the warding inside of the plug are also common. Normal use of keys does not usually cause these marks, but if they are indeed the cause marks should be present on several other wards, as well. In this photo, a deep gouge has been made by the pick tool on one of the wards deep inside the plug.

Marks may also be left in the pin chambers themselves. In this photo, we see a mark on the left side of the pin chamber. This area of the plug cannot be touched by the key and pins would not make a mark like this unless they were severely deformed. Compare with the chamber wall on

the right.

We might find pick marks higher in the pin chambers, too. These areas are subject to wear as pin stacks are moved by the normal action of the key. In this photo, an up-down-up patterned scratch is seen. This is probably caused by the attacker lifting and lowering the pin stack, trying to find the shear-line.

Forensic evidence of the tension tool can also be identified rather easily, especially if the attacker is a beginner or amateur lockpicker. The act of putting tension on the plug causes the tool to lightly shear the plug walls. In this photo, we can see the gouges left by the tension tool being placed at the bottom of the keyway.

Destructive disassembly of the plug lets us get a better picture of tension tool marks. In this photo, we can see that there is a deep gouge where the tension tool was actually used, as well as several scratches below it. The scratches are likely from positioning of the tool or tapping it with the picking tool while picking.

In the case of a skilled attacker, very light torque is applied to the tension tool. It may be more complicated to identify marks without proper lighting, but even in this example, where low tension was used, the tension tool marks can be identified when they are properly illuminated.

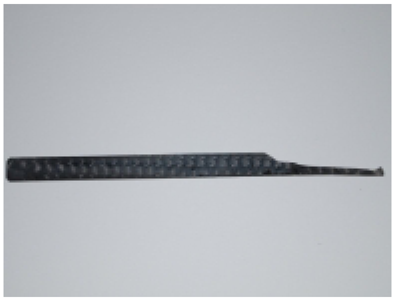
The cam may also have marks because many attackers, when navigating the back of the plug, will hit the cam. This is especially true of less controlled techniques like raking. In the photo, a light scratch is present in the center of the cam, a place the key normally does not touch.

One of the problems as an amateur is knowing where the pick is. It is common to see many amateurs with the tip of the pick poking out of the cylinder. When the cam is on, this may translate into extreme scratching on the back of the cam, as seen in this photo. Similar marks may be left by some forms of bypass.

The question always arises as to how we can determine when pick marks were made or how long it takes normal wear to remove them. In this photo is the first pin from a lock that has been picked once. We will use this as a reference to see the effects of wear after 250 uses.

After 250 uses (roughly 2-4 months use) the tip of the pin has been worn by the key, leaving fewer distinct picking marks. At the same time, the sides of the pin still show very clear and distinct picking marks. This is because the key does not touch these areas as frequently and may never, depending on the key bitting.

While taking the last photo I noticed a strange shape in the top right of the photo. When I refocused in that area I found this. It appears to be a small piece of brass that has transferred to the tip of the pin, probably a very small fragment of the key. Quick, call the crime lab!



Carbon fiber lockpicks were considered for use in Anti-Forensics, but my research shows that they leave marks similar to traditional metal lockpicking tools. The photo shows a finished carbon fiber lockpick in the half-diamond design. This pick is roughly 0.025" thick.

Carbon fiber picks did not work as well as I had hoped. Most importantly they fell short of surreptitious by leaving marks on pin-tumblers similar to traditional tools. In this photo, light scratching along the tip and side of the pin can be seen, caused by a carbon fiber lockpicking tool.

Carbon fiber lockpicks also seem to grab and hold pin materials much better than their metal counterparts. In the photo, a carbon fiber pick is shown with brass residue from the pins of a lock it has picked. This can be used in court as evidence to link a suspect to a crime.

Also considered for Anti-Forensics were fiberglass based lockpicking tools. My research shows that these are also unsuitable because they leave distinct forensic evidence on the pins and inside the plug. In this photo, a half-diamond fiber glass pick is shown. This pick is roughly 0.028" thick.

Fiberglass also left various traces similar to traditional metal lockpicking tools. In this photo, parallel scratches at various angles and positions can be seen on the bottom and side of the pin-tumbler. All marks were cause by the fiberglass picking tool.

Fiberglass is also less surreptitious than carbon fiber because the act of picking and raking the lock leaves behind a sizeable amount of fiberglass on the pin-tumblers and walls of the plug. In this photo, fiberglass residue can be seen on the tip of the pin-tumbler.

Like carbon fiber picks, fiberglass does a very good job of trapping trace evidence from the pin-tumbler inside the lock onto the pick. In this photo, the tip of the fiberglass pick is shown with light brass residue and lubricant (black) clearly visible.

KEY BUMPING

Key bumping is a covert entry technique against pin-tumbler locks that uses a specially prepared key to "bump" top pins above the shear-line to allow the plug to rotate. There are two types of key bumping, pull-out and minimal movement, but both produce similar forensic evidence on the bump key and the lock.

Key bumping is similar in function to pick guns.

To bump a lock, a key is acquired that fits the keyway of the lock. The key is modified so that all cuts are at their lowest depths or lower. This is commonly referred to as a "999 key," because 9 is usually the designated lowest cut depth. If done by hand, a key gauge or micrometer can be used to measure the key and ensure cuts are deep enough. If done with a key machine, the key may be duplicated from a working bump key, or cut by code to the lowest depths.

In the pull-out method, the key is inserted into the lock fully then withdrawn one pin space. In the minimal movement method, the key is further modified by removing material from the tip and shoulder of the key. The minimal-movement key is inserted completely into the lock. In both cases, light tension is applied to the key and a tool (known as a bump hammer) is used to impact the bow of the key, causing the key to be forced into the lock. The impact on the key causes kinetic energy to travel from the key to the top pins, causing the top pins to momentarily jump. If all top pins jump above the shear-line while tension is applied the plug is free to rotate.

As with pick guns, the main source of forensic evidence of bumping is on the pins themselves. The action of striking the bump key into the lock causes distinct dents and scratches on the bottom pins. Bumping also affects the face of the plug, the keyway profile, pin chambers, top pins, and the bump key itself. For forensic examination of bump keys, see the Key Analysis page.

The act of key bumping basically slams the key against the bottom pins to allow for kinetic energy to be transferred from the key to the top pins. Because they are immobile and absorb the kinetic energy, this causes considerable damage to the bottom pins in the form of large dents and scratches.

A bump key that is cut by hand, with a low speed key cutter, or made of a considerably stronger material (steel, iron, nickel-silver) than the pins may act as a file as it impacts bottom pins. In this photo, light scratches can be seen traveling through the bumping dent.

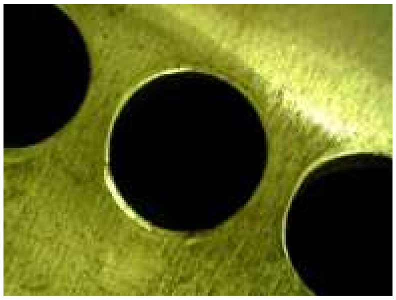
Alternate lighting may be used to illuminate bumping scratches and dents more efficiently. In this photo, there are dents on the left, center, and top of the pin, as well as scratches. In many cases it is posisble to count the number of times the bump key was used by counting the dents.

Bumping is rarely 100% successful, either because bottom pins are bumped above shear line, or top pins are not bumped high enough. When this happens the tension applied will misfire, causing one or more top pins to bind. This causes light shearing against the bottom of the top pins.

Some top pin designs will be more affected by bumping than others. In this photo, a spool pin with serrated edges is shown. Repeated bumping of this pin has caused the serration to close up (compare with previous photo). In general, situations like this slightly decrease pick resistance.

In some pin designs the bottoms of the top pins will be considerably damaged by bumping. In this case, the bottom pins are lightly rounded on both sides, allowing them to be inserted either way. When bumped repeatedly, the bottoms of the top pin become considerably dented.

The pin chambers within the plug may also be damaged by bumping. When kinetic energy does not properly transfer to the top pin, the pin stack may instead press against the chamber walls (caused by the movement of the bump key). Repeated bumping may cause these areas to distort, stretching in various directions.



One of the most noticeable pieces of evidence from key bumping is damage to the face of the lock. This is caused by the shoulder of the key impacting the area above and below the keyway. The use of modified shoulders may prevent this from happening, see the Anti-Forensics page.

In the minimal-movement method, material is removed from the tip and shoulder. This makes the method work but also inserts the key far enough that in some cases affects the keyway. This is due to the key material getting thicker as it reaches the bow. In the photo, this can be seen around the edge of the keyway.

Many unskilled attackers may attempt to bump unbumpable locks. This will probably damage the lock and borders on breaking the lock completely. In the photo, an EVVA 3KS wafer is shown after an bumping attempt. The wafer arm has broken off and a large dent is present, this lock was non-functional after this.

In this photo we see the cylinder from the failed bumping of an EVVA 3KS. The serious damage to the walls of the cylinder is due to the wafers slamming against the cylinder when bumping was attempted.

COMING SOON: Effects of Wear

OOLS & WORKSPACES

What does it take to identify different types of forensic evidence in locks? In truth, a surprisingly small amount of tools. Care is taken to select the proper tools and workspace for a laboratory investigation so that evidence is preserved and false evidence is not created. Remember, proper handling and disassembly of the lock is equally important to the choice of tools.

For more information on the investigative process and how these tools are used, please visit the Forensic Investigation page.

In most of the world the pin-tumbler cylinder is king. Proper disassembly of the pin-tumbler requires a plug follower be used. This tool pushes the plug out of the cylinder while holding top pins and spring in the upper cylinder chambers. When used for forensics, plug followers must be wood or plastic to prevent creating false evidence.

Shims are a tool used to open pin-tumbler cylinders for investigation. Shims are small, thin strips of metal that are inserted into the back of the lock. A blank key is used to raise all pin stacks, then is slowly withdrawn to allow the shim to split pin stacks at the shear line. The use of a shim is somewhat invasive, but may be preferred to destruction of the cylinder in some cases.

Tweezers are an absolute necessity when dealing with the small pieces of a lock. Trying to work with components by hand is almost sure to result in problems. The key to using tweezers in an investigation is that, like plug followers, they must be plastic. When working with the small components of the lock a pair of metal tweezers, no matter how polished and smooth, will create false evidence. Plastic tweezers are inexpensive and I would recommend a variety of shapes so that you can determine what you prefer.

Microscopes are essential in tool mark identification and other laboratory work. You have the choice between a manual and digital microscope, with most modern manual microscopes having a camera port that can be used to connection a digital output device. Digital microscopes are cool because they connect directly to a computer and function a bit like a high power webcam. Some things to note:

- You need a "top lit" microscope, commonly called a metallurgy or jeweler's microscope. Do not buy a biology microscope (bottom lit).

- Magnification should go to *at least* 20x, but preferrably 100x or higher. The extreme close up pictures on this site are in the 200-220x range.

- Digital microscopes are considerably cheaper, but manual microscopes are generally better quality. Most pictures on this site are from digital microscopes.

If you are doing high profile investigative work you might also consider a comparison microscope. Comparison microscopes have two sets of optics that combine in the viewer so you can do instant side by side comparisons. This is great for tool mark comparison, but not altogether necessary in most investigations. Note: This is only useful to the investigator; in your investigative report you place images together for comparison purposes.

A scanning electron microscope (SEM) is recommended if you have access to or own (!) one. The SEM can produce extremely high quality images of material residue, tool marks, and various other forensic evidence. Unfortunately, due to the expense of owning or renting one, not all forensic locksmiths can take advantage of them. Manfred Göth has a number of great SEM photos on his site.

Without getting into a holy war, all medium to high quality cameras are suitable for forensic locksmithing. The brand and model chosen is a matter of personal preference, and the quality of pictures will largely depend on the skill level of the photographer. A ring strobe, filter kit, and tripod are recommended for use with locks and crime scene photography.

Depending on where you live, courts may prefer that you use a non-digital camera. This is due to a somewhat archaic idea that non-digital photographs are harder to manipulate, thus more secure. Personally, I find this a bit silly considering we are in an age where technology to manipulate *any* type of photography is abundant, if not downright overwhelming.

If your camera will be mounted to your microscope directly (I prefer the digital connection, personally), you'll need to ensure that a mounting piece is available or can be manufactured. There are a few companies that specialize in making custom mounting pieces, and it is generally not too expensive.

Proper lighting is essential to identifying forensic evidence on components. I would recommend trying a variety of light sources until you find a set that meets your needs. As you can see from the pictures on this site, I use varying intesity and color light sources. I also recommend buying an inexpensive Ultraviolet A (UVA) light source. Even the $20 handheld UVA devices are suitable for the purposes of forensic locksmithing.

Hand tools, besides those listed above, are usually in the form of saws to cut pieces of the lock apart for further investigation. A thin, fine-tooth hacksaw is used to cut the plug into thirds. This can also be used to disassemble padlocks, but the process is rather time consuming.

In general, power tools are only used when destructive disassembly is an absolute necessity. In this case, you must be careful to understand where anti-destructive features of the lock are located, as hitting these points with a power tool may be dangerous to the disassembly process as well as to you. Power tools may include dremels, drills, saws (including a jeweler's saw), and milling machines.

Here are some other tools that are invaluable in laboratory work:

- Pinning trays
- Reference materials (keyway, pinning, factory-original data)
- Micrometer, caliper, ruler (wood/plastic)
- Vise (with plastic/rubber inserts) and lock cylinder holder (plastic)
- Notebooks, pens, pencils, colored markers
- Allen wrench (hex key) set
- Screwdriver (Flat and Phillips) set
- Rubber mallet
- Scotch, masking, and electrical tape
- Modelling clay (used to hold components under microscope)
- Selection of common key blanks in your area/country.

The place you choose to do your laboratory work should be separate from your normal workspace. Using anything but a clean, prepared workspace will cause problems down the road. How many times have you been working with locks and dropped a pin, a spring, or even the whole lock? Combining the dust, dirt, and spare parts of your normal workspace with a forensic investigation is a terribly bad idea. My recommendation, if you are doing this professionally, is to own or rent a workspace that you use only for investigative work. Many companies specialize in this sort of thing, they are usually called "clean rooms."

Things to remember:

- Always wash your hands prior to doing laboratory work.
- Always clean tools prior to doing laboratory work.
- Never use tools that may contaminate evidence (see above).
- Photograph your progress through the laboratory investigation.
- Document all actions performed during laboratory investigation.
- Always examine components before cleaning them in any way.
- If components are washed, save the wash in case it contains foreign objects.

ANTI-FORENSICS

Forensics is a neverending cat and mouse game. Investigators look for better methods to determine what happened while attackers are look for better ways to cover their tracks. This page discusses so called 'anti-forensics,' various techniques and methods to conceal evidence of entry.

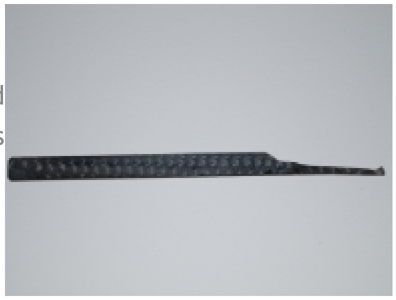
Entry techniques that leave no forensic evidence are known as surreptitous entry. While technically surreptitious and leave no forensic evidence, the act of using them may leave non-lock evidence. When we talk about "no forensic evidence" on this page we mean as it relates to the examination of the lock, safe, or related components, other forensic evidence may still be available. For example, forensic evidence may be found in the form of fingerprints on a safe dial, hair, fiber, footprints, surveillance, et cetera.

In many cases the forensic locksmith is asked to provide an assessment of how plausible certain surreptitious entry techniques are against a given lock. This can be done through a series of laboratory tests, an analysis of the required skills, tools, or money required, and examination of the installation and configuration details of the lock. Cases of completely surreptitious entry are viewed by the investigators on the basis of what facts and logical conclusions present themselves.

Note: I am just one person and I certainly do not know every trick in the book from both the perspective of the investigator or attacker. If you can disprove any of the information on this page (from either perspective), please contact me.

You can read more about various anti-forensics techniques on the articles page.

The idea of anti-forensics materials in tools is a popular but not well researched (publicly) area. Lockpicks made of soft materials such as wood or plastic would, in theory, not leave any marks on the considerably stronger brass, nickel-silver, or steel components. While they sound great in theory, they are considerably harder to use in practice. Tools made of these materials are considerably weaker, less maneuverable, and more prone to fracture or breakage than the steel normally used in tools. These types of tools also exhibit drastically reduced feedback capabilities, important in many covert entry techniques, when compared to metal. Coating standard tools with other materials has also been attempted, with limited success. The best example is teflon coated lock picks, which do not leave traditional marks, but still leave marks.



I have been doing my own research into anti-forensics materials and find that most of them are lacking in all areas. To date, no materials that I have tried have been successful at both picking a cylinder once and not leaving any forensic evidence. So far I have tried:

- Carbon Fiber
- Fiberglass
- Brass
- Teflon coated steel pick

These materials have left various forensic evidence that is detailed on the Lockpicking page under the heading "Non-Metal Lockpicks".

One area that anti-forensic materials may be used in is the production of non-metal keys. Plastic keys are considerably easier to use than plastic picks because their size is much bigger than the common lock pick. Research into this area is rather sparse, as well, with the use of a plastic pen casing to surreptitiously open low-security tubular locks being the most notable example.

Another area is "glue gun" shoulders for bump keys. As we saw on the key bumping page, bumping can cause pronounced, noticeable damage to the face of the lock. This damage can be reduced or eliminated by removing the shoulder of the key and replacing it with a glue gun stick, an inexpensive piece of soft plastic. (Note: This technique does not remove the forensic evidence found inside the plug or on the pins.)

Tryout keys are a surreptitious entry technique against pin-tumbler and wafer locks. They use a series of keys with varied cut and spacing configurations to exploit poor tolerances in low-security, master keyed, or extremely worn locks. A tryout key works by being inserted into lock and jiggled back and forth in order to attempt to align components at the shear line. To assess the effectiveness of tryout keys against a particular lock, 25 random keys for the lock are produced. The forensic investigator attempts to use these keys, inserting and jiggling them, to open the cylinder. The investigator can provide a reasonable assumption on their effectiveness based on how many were able to open the cylinder.

Visual and optical decoding of the combination, key, or internal components is another form of surreptitious entry. In this case, observation, surveillance, photography, or optical devices are used in various ways. In all cases, a key can be produced with the information gathered from decoding:

- Observation of a key's bitting depths or direct code.
- Photograph of a key's bitting depths or direct code.
- Observation/surveillance of a combination lock sequence being entered.
- Visual decoding of a key impression.
- Visual decoding of a master key system through the analysis of system key(s).
- Optical viewing of component positions.

- Optical viewing of component shapes (Medeco Biaxial, for example).
- Optical viewing of component coloring (indicates depth).
- Thermal viewing of electronic keypads.
- Radiological imaging (see below).

When we speak of optical viewing of components we're usually referring to invasive tools such as a borescope or otoscope.

There are several high-profile anecdotes which illustrate the power that visual decoding has. The Diebold company once published a picture of a key used for voting machines across the country on their website. This key (wafer) was visually decoded and it was found that it could be used to gain access to every single voting machine in the country. In the great story of the Antwerp Diamond Heist, thieves obtained the combination sequence by installing surviellance above the combination lock on the overhead alarm used above the safe door.

Almost all low-security combination padlocks and Group 2 safe combination locks are subject to compromise by manipulation. Manipulation may be seen as a method of decoding where diagnostic information is taken through the use of the combination dial in order to determine the proper combination sequence. Manipulation is commonly (though erroneously) portrayed in many films, and is indeed an effective method against many combination locks. Group 1 or Group 1R safe locks are considered "manipulation resistant" because of various design changes the limit the effectiveness or drastically increase the time required to successfully perform manipulation.

Auto-dialers (or computer dialers, robot dialers) are machines that automate the process of manipulation either through sophisticated manipulation software or brute-force cracking of the combination. Auto-dialers may leave forensic evidence depending on how they are mounted to the combination lock and how long it takes to work. The process of auto-dialing accelerates wear on the lock components, and this may be detectable. The use of rotary combination locks with an electronic audit log may also be able to spot and prevent this sort of activity.

Radiological imaging is a form of surreptitious decoding that uses penetrating radiation (X, beta, and gamma rays) to "see" inside the lock or safe, revealing the proper positions of components. This is most often used against Group 2 rotary combination safe locks to determine the position of each gate in the wheel pack. This is a surreptitious entry technique unless the use of such a device can be detected. In many cases, even if the ability to detect this form of entry is available it may be considerably expensive.

The use of low-density wheel materials (such as Delrin) combats this attack. Group 1R safe locks are specifically designed to defeat various radiological attacks as well as provide manipulation protection.

There are some forms of bypass that may be surreptitious if used properly. Most padlock bolt shims are made of metal, but some low-security padlocks are of a poor enough quality that they can be shimmed with paper. This, of course, does not leave marks on the padlock bolt. (see Deviant Ollam demonstrating paper shims)

In the case of a thumbturn or lever (handle) lock, there are tools that will reach under the door and attempt to grab the thumbturn or handle and unlock or open the door. Depending on the design and material of the tool and the number of attempts it takes to open the door there may not be any forensic evidence. In this case, the forensic locksmith will note that the potential for this attack exists. If no other evidence is found it may be decided that this was one of the most probable methods of entry.

FORENSIC INVESTIGATIONS

This page focuses on methodology and proper procedures of a forensic locksmithing investigation. Investigations are broken down into several steps: crime scene investigation, laboratory examinations, investigative reports, and expert testimony. Some investigations may not require all steps; evidence may be mailed to you, testimony may not be required, and so on.

The goal of the investigation should be clearly defined from the start. Many investigations will not require that you exhaust all possibilities, but instead give you a clear, direct goal. For example, identifying if a key could have been used to open a lock, if the lock has any pick marks, or if a key machine was used to make a specific key. All of this depends on who the forensic locksmith is working for; insurance companies only need facts relating to their liability, but criminal investigations will be looking for as much information as possible.

Everyone has their own way of doing things in an investigation; an order, preferred tools, personal beliefs. The following are my personal beliefs on how proper crime scene investigations are conducted. They should not be taken as final, and you should experiment to find what works best in your investigations.

The following is a list of initial questions that should considered during the investigation. They are very helpful in narrowing down possible methods of entry, suspects, and providing other information.

- What are the obvious signs of entry?
- Was entry successful? Why?
- Which locks, if any, were opened or manipulated to affect entry?
- What is the relative security of the locking system?
- Are there any known vulnerabilities with the locking system?

- Was the locking system properly installed?
- Does the lock function properly?
- Could any windows or doors have been left open or unlocked?
- Are all known keys accounted for?
- Were working keys left in easy to access areas? (Desks, cabinets, etc.)
- Are there any tool marks or trace evidence?
- Were any tools left at the crime scene?
- Were any parts of the crime scene cleaned or repaired?
- Were any dangerous substances left or created at the crime scene?
- Does the value of the stolen goods correlate with the apparent method of entry?
- Could any employees have been responsible, intentionally or unintentionally?
- How often is the lock operated per day?
- Was the lock found unlocked or locked?
- Have any keys been used on the lock since entry was accomplished?

In any investigation, the first thing to do is determine what the method of entry was. This information will allow the forensic locksmith to determine the average time required for entry, the tools used, the noise made during entry, and the skill level of attackers. All of this is passed on to insurance or law enforcement personnel in order to properly identify and link suspects to a crime, provide proof that the insurance claim is valid or not, and other things, depending on who is employing the forensic locksmith.

A thorough examination at the scene of the crime yields valuable insight and provides leads for the forensic locksmith and investigators to follow. Experienced forensic locksmiths can quickly rule out many possibilites and focus on what is relevant to the current case. The key to examination of the crime scene is documentation and photography. You will only have one chance to investigate the crime scene, in most cases, so make it count. Write down, sketch, and photograph as much information as possible. Be thorough, detailed, and (most importantly) organized. It may be many months before you are asked to provide expert testimony on the crime scene, so make sure to organize your notes in a logical way so that the crime scene details can be recalled without difficulty.

When first arriving at the crime scene, the forensic locksmith makes a sketch of the crime scene and surroundings. Use a compass to properly document the orientation of objects at the crime scene. Of course, you do not need to be Van Gogh, just simple sketching of shapes is enough. Remember, the purpose of sketching is to quickly recall of the layout of the crime scene at a later date. This is a personal preference, but I found that Don Shiles' method, described in an interview from Locks, Safes, and Security, is very effective. He recommends using colored markers to help remember different types of objects. His coloring scheme is:

- Black: Notes
- Red: Evidence (tools, locks, safes, doors)
- Green: Shrubbery, plants, trees
- Blue: Everything else

After making the sketch, the forensic locksmith will evaluate the condition of all locking systems, any tools left at the scene, and any trace evidence found. Many notes and photographs will be taken here, and some basic information may be added to the sketch where needed. The number and type of locks may be noted, as well as their current states, the direction they must be turned to unlock (while mounted), and whether or not the lock has been used in any way after the crime was allegedly committed.

Once the forensic locksmith has completed his investigation of the crime scene, locks will be removed for further analysis. All locks must be photographed prior to being disassembled and removed from the scene. Once photographed they must be carefully removed from their mountings and properly labelled with their location, their current state, and other information. Obviously, the disassembly process should only be done by a qualified locksmith. All parts of the locking system (including strikes, bolts, mounting screws) are stored as evidence. Once removed, the walls, doors, and other areas where lock components were mounted are examined for any additional tool marks or trace evidence, including indications that the lock was repaired or replaced.

If working with law enforcement, they may provide the facilities to "bag and tag" the evidence. Otherwise, the forensic locksmith uses evidence bags (or the budget option, household freezer bags) to store and document evidence. All evidence should be labeled properly and sealed. A popular method of sealing evidence is through the use of so-called "evidence" tape, which provides indications whenever it is tampered with. A good method of ensuring that evidence has not been tampered with is to seal the evidence bag with the proper tape and then put your signature over the tape. While not 100% effective, it does provide a reasonable amount of protection when transporting or storing evidence yourself.

Things to remember:

- Place tape over both ends of the lock to prevent anything from falling out or going in. If necessary, place tape on the bottom and top of the lock, too.
- Document which way the lock normally turns to unlock (while mounted).
- Document the state the lock was found in (locked, unlocked, plug partially turned).
- Color code your sketches so that they may be easily deciphered at a later date.
- Take lots of pictures, you only have one chance!
- Properly collect, catalog, and store evidence. Evidence bags and tape are recommended.
- If working with law enforcement:
    - Always ask permission to do anything.
    - Always ask personnel to do or move things for you, such as opening doors and moving objects (a plant, for example) at the crime scene.
    - If working with a crime scene photographer, specify exactly what objects or marks need to be visible in photographs.

Toolkit for crime scene investigations:

1. Notebook
2. Pens/markers (different colors)
3. Camera & tripod
4. Evidence bags (if not provided)

5. Masking tape, "evidence" tape
6. Disposable plastic/latex gloves
7. Compass
8. Disassembly tools (screwdrivers, wrenches, etc)
9. Optional: Handheld microscope

Once the crime scene investigation is complete the forensic locksmith can continue with the laboratory examinations. In this phase we address six major areas:

1. Purchase, installation, and maintenance details
2. Lock specifications
3. Lock operation and functionality
4. Lock security
5. Tool mark and material transfer identification
6. Key analysis

Knowing where the lock came from, who installed it, and who maintains it is absolutely essential to an investigation. This information might not only reveal the method of entry, but it may have legal or insurance consequences if the lock was not installed or maintained properly.

- Where and when were locks purchased?
- Are all keys factory-original?
- Who installed the locks?
- Who maintains the locks?
- Have the locks been serviced recently?
- Do keying records exist, if so, could they have been compromised?
- For keying records, has there been any recent inquiries or key requests?

The installation, design, and model specifics of the lock will determine what the relative security of the lock is. Locks that have been poorly installed, poorly maintained, or modified prior to entry may have little ability to resist compromise. This part of laboratory examinations identifies the lock and components, the lock characterstics, and expected resistance to compromise.

- What is the brand and model of the lock?
- What is the lock design? (i.e. pin-tumbler, lever, warded, etc.)
- What is the lock type? (i.e. mortoise, rim, key-in-knob, european profile, padlock)
- Has the lock been properly assembled?
- Was the lock been properly installed?
- Are all components factory-original? (including springs, screws, strikes, etc)
- Are any components missing?
- Does the lock have any ball bearings?
- Does the lock have any anti-drilling or anti-cutting features?

- Does the lock have a security rating?
- For components (factory data):
    - Number of components
    - Shape (for pins, flat, rounded, pointed, angled, nippled, etc)
    - Size
    - Design (any non-standard or security features)
    - Position
    - Alignment (if applicable)
    - Color (if applicable)

Analysis of the size of components means that they are measured to determine their actual size as well as their bitting code. In pin-tumbler locks, the full length of the pin pairs and springs is measured to determine if a comb pick could be used. The position of components is especially important in dimple locks that do not use all of their pin chambers.

This phase of the investigation determines the current state of the lock in terms of age, wear, and how well it operates. This must be done with great caution, because if done wrong it has a large effect on tool mark and material transfer examination. Care is taken not to destroy evidence or create false evidence that may be incorrectly interpreted or confusing. This is especially true if a key will be used to test if the lock can be operated. What happens in this phase depends on the preferences of the forensic locksmith and the sensitivity of the case.

- Does anything block keys from being inserted into the lock?
- Is there a broken key in the lock?
- Does the working key(s) fit into and open the lock? If no, why not?
- Does the key need to be jiggled or lifted to work?
- Is the lock heavily worn, or excessively dirty?
- Are the chamber casing or individual chamber screws loose?
- Are the cam screws loose?
- Are all retaining clips fastened properly?
- Has the lock been moved to a "picked" position?
- Could normal operation of the lock move it to a picked position?
- Are the correct size components being used?
- Are the correct number of components being used?
- Do all components exhibit the same amount of wear?
- Are the correct number, type, and position of security components being used?
- Is the lock master keyed?
- Are master components too small, too large, or improperly placed?
- Are springs present? If so, are they the proper size and tension?
- Are springs broken or compressed?
- For components (lock-specific data):
    - Number of components
    - Shape (for pins, flat, rounded, pointed, angled, nippled, etc)
    - Size
    - Design (any non-standard or security features)
    - Position
    - Alignment (if applicable)
    - Color (if applicable)

Testing if the key(s) work for the lock is a delicate procedure. This must be done while the lock is intact; before it is disassembled. Unfortunately, you cannot disassemble then check because the lock would be in an altered state. The components are checked for looseness because loose components, especially the cam screws and retaining clips, leave erratic markings in the lock. Checking if the lock is in a picked position is helpful, but not altogether damning. Locks with a staircase style bitting may allow a key to be removed prematurely from the lock, and most tubular keys can be modified to remove the key prematurely (sometimes used as a poor-man's key control measure).

Once the lock has been operationally tested it can be disassembled and components examined. If disassembly is destructive, you must first get permission to do so. Once disassembled, components are cross-checked with our lock specifications to determine which components are factory original. We also check to make sure that all components are proper for a given lock; proper security components, proper number of components, and so on. All of these steps are photographed and documented for later reference. Beyond that, we check the relative wear of all components on a graded scale:

1. New; no wear
2. Minimal wear; high tolerance
3. Average wear
4. Heavy wear; low tolerance
5. Extreme wear; unreliable tolerance

Components may conflict with the expected level of wear, either by being too worn or too new. In the former, we might be wondering why components are more worn than expected. Were they not new when purchased, installed, or rekeyed? Could an attack against them accelerate wear? In the latter case, we might consider if components have been replaced, rekeyed, or recently serviced.

Lock specifications provide the security baseline offered by the lock, but may not accurately describe the security of the lock that is being examined. In many cases the lock has been assembled incorrectly, is missing components, or has substitute components. All of these factors can dramatically affect the lock's ability to resist compromise. This stage of laboratory investigation evaluates the actual security of the lock to identify possible avenues of attack.

- What is the security rating of the lock?
- Has the lock been assembled correctly?
- Are all components factory original?
- Are all components present?
- Does the lock use security features on components? (i.e. security pins, serrated levers/wafers, false notch discs)
- Are all security components present? (i.e. security pins, sidebars, profile bars/pins)
- Have lock components been added, removed, modified, or replaced to affect resistance to compromise?
- Are there any known attacks for this brand/model of lock? (i.e. decoding, bypass)
- Are there any known attacks against specific components in this lock?
- Can the lock be picked easily?
- Are component positions conductive to picking?

- Are there any anti-picking features?
- Can the lock be impressioned easily?
- Can the lock be decoded easily?
- Can the lock be bumped open?
- Can the lock be opened with a comb pick or other overlifting attack?
- Are there ball bearings, rods, or discs to prevent forced entry?
- Is the lock master keyed? How many levels of master keying exist?
- Does the lock use a restricted or patented keyway?
- Does the lock have a paracentric keyway?
- Does the keyway frustrate attempts at manipulation?
- Does the lock provide any measure of key control besides warding?
- How difficult is it to manufacture a key blank for the lock?
- Is the lock considered high tolerance?
- Does the lock have a round or flat plug to cylinder mating surface?
- Has the top of the plug been filed flat?
- Have components been manually shaped to proper size?
- Does the lock appear to have been worked on by an amateur locksmith?
- Does the lock show any signs of being repaired or replaced?
- Is the lock removable, rekeyable, or reprogrammable without disassembly?
- What is the assessed security against manipulation for this lock?
    1. No security
    2. Low security; minimal skill required.
    3. Medium security; moderate skill and time required.
    4. High security; high skill, time, and money are required. Specialized tools may also be a prerequisite.
    5. Extra-high security; very difficult to open. Extreme time, money, skill, and complex tools are required to open this lock.
- What is the assessed security against force for this lock?
    1. No security; can be opened by manual force. (i.e. pulling, kicking, punching)
    2. Low security; can be opened with simple hand tools.
    3. Medium security; can be opened with simple power tools.
    4. High security; can be opened with power tools, but requires time and skill.
    5. Extra-high security; can be opened with extreme time, skill, and expensive tools.

Analyzing the security of the lock is fairly straightforward. We look at all the characterstics of the lock in question and identify any deviations from factory standards. In many cases components are missing or substituted, leaving the lock with a reduced ability to resist compromise. The depth of the forensic locksmith's knowledge of compromise techniques will be essential in order to identify any model or design specific attacks against a given lock.

The preceding sections have all served to better understand the lock as it is and should be. They help the forensic locksmith to identify specific security problems with the lock so that laboratory tests can be selected to best identify evidence that helps determine method of entry, skill level of suspects, and (most importantly) identify suspects. This stage will identify specific tool marks left behind by various compromise techniques. Microscopy and macrophotography are used to provide detailed pictures of the components and any tool marks they contain.

It is important to remember that all tools have unique characterstics developed by the manufacturing process and wear. These characteristics can be identified from tool marks found on components and linked to the suspect's tools. Examination of tool marks identifies both the class of the tool mark (i.e. screwdriver, wrench, drill, etc) as well as any characteristics specific to the tool. The class of tool may indicate the method of entry and the skill level of the attacker.

- What class does the tool mark belong to?
- What are the unique characteristics of the tool mark?
- Could tool marks be the result of normal wear?
- Could tool marks have been made during installation?
- Could tool marks have been made during maintenance or rekeying?
- What type and size of tools were used?
- Do tool marks indicate any common compromise methods?
- Does the direction of tool marks correspond with a compromise method?
- Does the angle of attack correspond with a compromise method?
- Does the position of tool marks correspond with a compromise method?
- What do the tool marks indicate about the skill level of the attacker?
- Do tool marks indicate conflicting tools/techniques?
- Do tool marks indicate an attempt to hide the real method of entry?
- Do tool marks indicate an attempt to simulate forced or covert entry?
- Do tool marks fit into any of the following compromise categories?
    - Destructive Entry
    - Lockpicking
    - Impressioning
    - Pick Guns
    - Key Bumping
    - Decoding
    - Bypass

Tool mark identification is a huge topic, and specific examples of covert and destructive entry techniques and their tool marks are available with the links above or on the left hand navigation bar. If tools are found with a suspect that match the class of marks found by investigators a tool mark comparison may be conducted to determine if suspect tools were in fact used in the crime.

In the previous stage we identified tools used to affect entry and the forensic evidence they leave behind. In a similar fashion, this stage identifies any materials transferred between locks, tools, and their surroundings. It is not uncommon to find wood, metal, paint, blood, hair, fiber, and other materials, all of which may be found inside the lock itself, on keys, on tools, or in the surrounding area.. All materials transferred may help to determine the method of entry and identify suspects. All materials found in the lock are evaluated to determine their origin and relevance to the investigation.

- Could material transfer be a result of:
    - Manufacturing processes
    - Installation or maintenance
    - Normal use
    - Keys, new or poorly cut (consider key material, too)

    - Vandalism or sabotage
    - Compromise technique(s), including previous attempts
    - Planting of evidence
    - Corrosion or oxidation
    - Environmental conditions
- What materials are present in the lock components?
- Do the lock or components use any proprietary alloys?
- Are different materials used for various components?
- Are materials found different from the lock components, including keys?
- Are materials normally used in installation or maintenance? (i.e. lubricant, cleaning solutions)
- Is material transfer present on or around tool marks?
- Can materials on locks or keys be matched to a specific origin?
- Can materials on tools be matched to a specific locks or components?
- Does the amount, position, and method of transfer for materials appear natural?
- Does the placement of material(s) conflict with the method of entry?
- Could material transfer be the result of planting evidence?

Equally important to examination of locks and tools is the examination of keys. Because keys are handled by users they provide an excellent source of forensic evidence. To the forensic locksmith, keys may provide insight as to the method of entry, skill level of attackers, and identification suspects. If keys lead investigators to locks outside of the crime scene they can also help to locate victims, evidence, contraband, and stolen items.

See the key analysis page for more information about forensic evidence available from keys.

MATERIAL, CUTS, KEYWAY, CODES

- What material(s) is the key made of?
- Is the key plated? Does plating include bitting surface(s)?
- Is the key "synthetic"; made out of a nonstandard object or material? (i.e. flat piece of metal or plastic)
- Is it the proper key blank for locks under investigation?
- Has the key profile/warding been modified to fit locks under investigation?
- Does the key, in fact, fit the keyway of locks under investigation?
- Is the key profile or type common to the area?
- Is the key profile patented, restricted, or possession considered illegal?
- Does the key bow help identify manufacturer?
- Does the key have any identifying codes or logos?
- If present, are key bitting codes direct or indirect?
- If indirect bitting codes are used, can the manufacturer identify the owner?
- What type of components does the key interact with?
- How many components does the key interact with?
- How many bitting surfaces does the key have? How many are actually used?
- What are the cut depths of the key? Do they correspond to factory standards?
- Are ramp angles for the key cuts proper?
- Do the cut depths follow maximum adjacent cut specifications (MACS)?
- Does the key follow shoulder-to-first cut and cut-to-cut specfications?
- Are any cuts jagged, cracked, or otherwise mis-shapen?

KEY HISTORY & DUPLICATION

- Who manufactured the key blank?
- What is the availability of the key blank?
- Is the key hand-made, machine cut, or stamped cut?
- Is the key a factory original, licensed blank, knock-off, or duplicate?
- If the key is a duplicate, can generation be ascertained?
- Has the key been recently cut?
- Has the key been recently duplicated?
- How much wear does the key show?
- If machine cut, was the key accidentally tilted at an angle?
- If machine cut, do cuts travel along the bitting surface or drop straight down?
- Does the key require a special cutting machine to be made?
- Has the key been modified to obfuscate its purpose?

KEY SYSTEMS & SECURITY

- Is the key part of a master keying system?
- What type of master keying system is used?
- What rank or level is the key in the system?
- Is the master key system properly designed and implemented?
- Can the master keying system be easily decoded?
- Is the master keying system too complex, leading to high rates of cross-keying?
- Does the key have any high security features?
- Is the key brand or type primarily used in high-security areas?
- Is the key used in niche areas? (i.e. vending machines, lockers, luggage)

INVESTIGATIVE QUESTIONS

- Has the key been modified in any way?
- Does the key have any tool marks?
- Do tool marks indicate method of creating or using the key?
- Does the key have any foreign materials?
- If hand-made, what tools were used to do so and can they be identified?
- If machine cut, can the key be tied to a specific cutting machine?
- Is the key a depth key? (uniform cut depths)
- Is the key a bump key? (uniform *low* cut depths)
- Is the key a tryout key? (deviated cut depth and/or spacing)
- Does the key appear to have been used for copy-based impressioning?
- Does the key appear to have been used for manipulation-based impressioning?
- Were any keys ever lost or stolen?

Once laboratory examinations are complete the investigative report is compiled. This report summarizes the facts of the case, the apparent method of entry, and any other information that may be useful to investigators, such as material transfer or trace evidence found. In high profile cases it may be prudent to include supporting examples in your report. For example, taking three duplicate locks, with the same type of keys and bitting codes, and performing picking, bumping, and impressioning on them. These test locks can be examined and included in the report to support your findings, either by being similar to the evidence from the actual case, or completely different. Of course, this is somewhat costly and requires more time to complete, so it will probably not be done for every case.

See the Forms & Reports page for more information on writing investigative reports.

The forensic locksmith may be asked to provide expert testimony in court for the prosecution, defense, or as an independent witness. The role of the forensic locksmith, as an expert witness, is to provide the judge or jury with the facts so that they have a complete picture of the situation. As an expert witness he/she is entitled to compensation for their time and insight into the case.

As an expert in a field that most people know little about, it is helpful to prepare diagrams and animations for the judge or jury to understand what you are talking about. Locks are inherently simple mechanical devices, and only security through obscurity prevents most people from understanding them. This assumes that the side that will benefit from the facts wants these details brought to light. In many cases the expert witness can answer only the questions posed rather than speak freely. This, of course, depends on your level of expertise and your jurisdiction's laws concerning expert witnesses.

PICK GUNS

Pick guns are a covert entry tool used to pick pin-tumbler based locks. Pick guns have manual and electric variants, each with their own type of forensic evidence. Both work to rapidly separate pin pairs at the shear-line to allow the plug to rotate.

Pick guns are similar in function to bump keys.

Manual pick guns are spring-loaded tools that resemble a toy gun with a lockpick attached to the front. The lockpick is interchangeable, and referred to as the "needle." To open the lock, the needle is inserted in the lock and placed under all pin stacks. As with lockpicking, a separate tension tool is used to apply tension and rotate the plug. Light tension is applied to the tension tool and the trigger of the pick gun is fired. According to physics, the kinetic energy transfers from bottom pin to top pin, causing the top pins to "jump" in their chambers. If all top pins jump above the shear-line at the same time, the plug can be rotated to unlock the lock.

Electric and vibrational pick guns work on a similar principle, but instead oscillate the needle back and forth, causing it to vibrate. The tool is controlled to get the resonating frequency of the needle at the right point so that top pins jump above the shear-line.

The main source of forensic evidence with pick guns is on the bottom of the pins, where the needle strikes. We may also see marks in the plug if the needle is not properly positioned and makes contact with the plug walls when triggered. The cam on the back of the lock may also have marks if the needle is inserted too far into the lock. As is the case with lockpicking, we can also identify tool marks left by the tension tool.

In the case of vibrational or electric pick guns, we will see considerably more evidence on the plug walls because the device is constantly moving.

The striking of the pick gun needle against the bottom pins causes very clear forensic evidence. Unlike picking, which causes scratches, the pick gun causes impact marks that, when done many times, begin to resemble the spokes of a bicycle along the circumference of the pin.

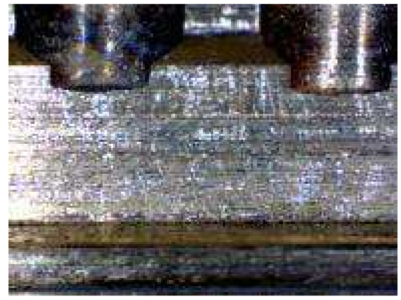
The marks left by a pick gun are so distinct, compared to the rest of the pin, that is is often possible to count them to determine how many times the pick gun was triggered. Each time the needle strikes, the bottom pins may rotate slightly, allowing marks to be separate and distinct.

As with many other techniques, the cam of the lock is a good source of forensic evidence. This is sometimes the best evidence, because the needle of pick gun often shears very clear marks into the cam. In this case, the pick gun appears to have been used at least eight times.

Up close we can see the very distinct markings left on the cam by the pick gun needle. These marks are well defined and would make for a very good tool mark comparison. Because they are so deep, the pick gun needle may also have material residue that can be linked back to this cam.

Electric and vibrational pick guns leave different marks because they are constantly moving in the lock. When using this type of pick gun, material removal from the components and plug is so extreme that you can see brass particles exiting the keyway. In this photo, repeated use of a vibration pick gives the bottom pins a rough, uneven texture.

Constant movement of the vibrational pick gun needle causes numerous tool marks on the plug walls, as well. In this photo, various vertical scratches are present throughout the length of the plug. Some vibration picks also leave a stuttered or angled type of tool mark on the plug walls.



COMING SOON: Effects of Wear

NORMAL WEAR

In order to identify compromise of a lock it is important to know what the lock components and keys look like when they are used normally.

The amount and nature of the wear on components varies and is highly dependent on the lock, key, and component materials. The most common material for pin-tumbler locking cylinders, keys, and components is brass. Cylinders and components (pins, levers, wafers, etc) also commonly use nickel-silver, steel, and other materials. Keys are made from a wide variety of materials besides brass, such as nickel-silver, aluminum, iron, steel, zamak, and various proprietary alloys.

The nature of wear also depends on the design of the key and the components. Unfortunately, I cannot display all possible combinations of designs and materials. Regardless, it is the duty of the forensic locksmith to conduct laboratory tests if an unknown combination is found during an investigation.

The following is a microscopic examination of different stages of wear on a standard pin-tumbler cylinder (Falcon FA3, 6 chambers, pinned for 5) that is made of brass. Bottom pins in this cylinder have rounded tips. Prior to disassembly, the key to this cylinder was used no more than ten times. For the sake of space, I will only show 1-2 pins of each stage, rather than all 5.

New pins are clean, with no dust, grease, or dirt. Light abrasions and corrosion may exist depending on how the pins were stored prior to being used in the lock. Factory original pins usually do not exhibit these characteristics. A clear indication that pin has not been used is the fresh milling marks around the tip of the pin.

Up close, we notice many small imperfections in the tip of the pin. Very light scratches, dents, and bumps are visible. The dents and bumps are natural imperfections in the manufacturing process, while the light scratches are likely from the use of a key.

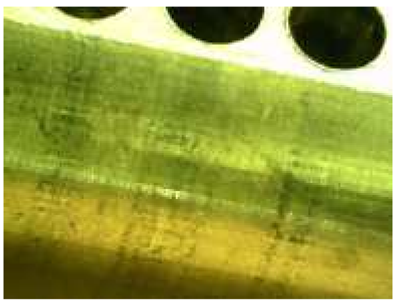
The key for this lock is also new. It is factory original, made of brass, and has been cut with a high speed key machine. As stated above, it has been used a few times, and because of this we can see a light track in the center of the key where it has picked up lubricant from the pins.

The face of the plug is also clean on a new lock. There should be few scratches or dents and little dirt or corrosion. The keyway material is not damaged, and the material just inside the keyway should not have any markings.

After 250 uses (roughly 3-6 months of use) a ring develops around the pin. This is the key gliding under the pins, spread around the tip because insertion and removal lightly rotates them back and forth. The key is also lightly polishing the pins, too.

Up close we can see that the ring is actually due to the milling marks starting to be removed and lightly polished. The pin has also been slightly distorted in the very center, also due to the key making contact with it.

The key has also started to show signs of wear, mostly in the center where the pins have been touching it. In this particular case, wear resembles a staircase pattern. In addition, the key has picked up more lubricant, making the line on the key considerably darker.

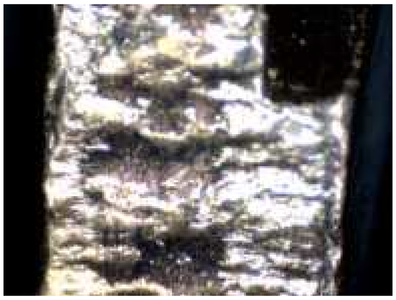


The plug is also showing signs of wear, caused by the top pins gently rubbing against it when the cylinder is turned. (Note: The top pins also show signs of wear because of this, but I have left them out to keep our examination simple.)

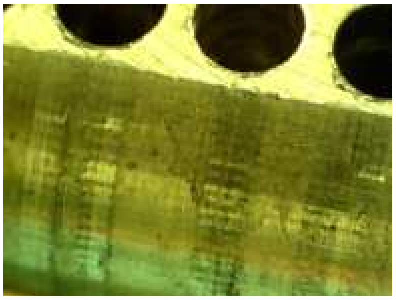
At 1,500 uses (roughly 1.5-2 years of use) a distinct change in the appears of the pins. The key has been used so many times that the milling marks have almost completely been removed. Again, slight scratches on the pin are being caused by the key becoming more jagged as it too wears down.

What is most interesting is that pin 5 (the furthest back) has considerably less wear, and more visible scratches. This all makes sense; it is only touched by the tip of the key, and the tip of the key is the most worn down because it makes contact with all of the pins.

The key continues to wear and collect lubricant. Image shown at high zoom to show the literal pits that are being created. At this point, certain ramps on the key may be acting like a file when going in and out of the lock. As seen above, this translates to more light scratches on the tips of the pins.

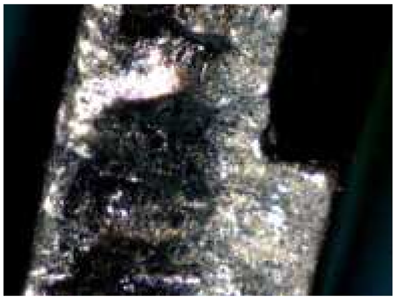


Of course, the plug and the top pins have continued to wear, with more brass being polished off and more pronounced staggering of the lubricant along the sides of the plug.

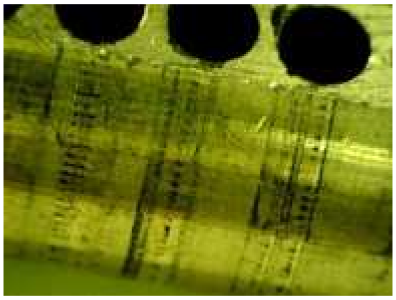


At 5,000 uses (roughly 5-6 years of use) the front pin has no milling marks, and almost all scratches have been polished away. From this point on wear looks similar to this, with light markings sometimes being created by wear of the key.

Compared to other pins, pin 5 (the farthest back) continues to show reduced signs of wear and retain its milling marks. We can also now see that wear is not evenly distributed on this pin, as it resembles an oval shape. Compare with above picture and 1,500 use pictures.



They key continues to wear down, with small craters from the previous example now very large and uneven. Slight imperfections like this in the key will cause light, seemingly random scratching on the soft brass on the pins. Stronger key materials may even act as a file against pins.



At 5,000 uses the plug continues to show increased wear, though not much has changed. More pronounced staggering of wear and lubricant can be seen along the circumfrence of the plug. Compare with example at 1,500 uses.

The face of a lock that has seen moderate to heavy use will have many dents and imperfections caused by normal use. How many times have you went to unlock a door and slightly missed the keyway? In the photo, many small dents and scratches from normal use are visible.

In shoulder stopped locks (almost all modern locks qualify), continued use will cause light impact marks along the face of the plug. This is normal, and should not be confused with the extreme material displacement that occurs during key bumping.

In cylinder based locks, the use of different materials for the plug and cylinder reduces wear. This also applies to wear on the pins, but most changes to pin material are to increase resistance to destructive entry, not longevity.

The speed at which a key was cut will translate into smooth or jagged ramps on the key. In some cases, a sufficiently strong key material, such as steel, with jagged ramps acts as a file on the pins, causing wear at an accelerated rate. See the key analysis page for more information.

http://deviating.net/lockpicking/resources.html