What Micro Serialized Firing Pins Can Add to Firearm Identification in Forensic Science: How Viable are Micro-Marked Firing Pin Impressions as Evidence?

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Todd Lizotte of ID Dynamics in Londonderry, New Hampshire.

EXECUTIVE SUMMARY

Every time a semiautomatic firearm is discharged, a bullet will leave the barrel and the cartridge case, which initially contained the bullet and powder charge will be ejected from the firearm. During the discharging process, working surfaces inside the firearm impart microscopic markings onto various areas of each bullet and cartridge case. One of these working surfaces is the *firing pin*, an object that strikes the primer surface in the base or back of the cartridge case, thereby causing the powder charge to deflagrate and fire the bullet. These ejected cartridge cases are one of the key pieces of evidence used in solving firearm-related crimes. More precisely, it is the microscopic markings, such as those impressed onto the back of the cartridge case by the firing pin, that forensic firearms examiners scrutinize in order to determine whether an identification with the crime gun can be made. This examination and comparison process is highly meticulous, time consuming and requires a forensic scientist with specialized equipment, training and experience.

The transfer of intentional microscopic impressions of intentional microscopic marking from the working surfaces of a firearm to each fired cartridge case was the goal behind the recent development of a micro-machining technology designed to machine an array of microscopic characters onto the face of a firing pin. The surface area of a firing pin is sufficiently large enough for a wide variety of alphanumeric characters, symbols, barcode lines, or other encoding structures to be machined on it. Todd Lizotte of ID Dynamics, located in Londonderry, New Hampshire, developed a micro-machining method that utilizes an ultraviolet laser to engrave micro-encoding structures onto firing pins. The method is similar to that used to engrave codes on computer chips.

When the trigger is pulled, the firing pin strikes the softer primer portion of the cartridge case in a center fire firearm cartridge or the rim of a rimfire caliber cartridge depending on the type of firearm in question. This process stamps the laser-machined code into the primer or rim of the cartridge case. In principle, the code impressed on the spent cartridge case could be looked up in a database and matched to a specific firearm, considerably facilitating the work of forensic science or police investigators. Through continuous testing and development, this technology has progressed from a basic alphanumeric code laser-machined on the face of the firing pin (known as first-generation firing pins) utilizing a masking method, to the current direct-writing process that can place three different encoding formats on a given firing pin: an alphanumeric code, a gear code and a radial bar code. (The latter are known as second-generation firing pins).

The viability of this emerging technology will impact the recent California Assembly Bill No. 1471 (AB 1471), the Crime Gun Identification Act of 2007, which was chaptered into to law and amended California Penal Code section 12126 on October 13, 2007. This law requires that all new models of semi-automatic pistols have the capability of placing an microscopic array of characters that identify the make, model, and serial number of the pistol, etched in 2 or more places on the interior surface or internal working parts of the pistol, and that are transferred by imprinting on each cartridge case when the firearm is fired.

The goal of this study, which was funded in 2005 by the California Policy Research Center (CPRC) as part of its annual competitive grant cycle offering to UC faculty, was to evaluate the efficacy of this new technology so that policymakers could make informed decisions in support of facilitating the identification of forensic science evidence in firearm-related crimes.

Research Objectives, Methods and Materials

A series of tests were conducted using a sample of readily available firearms to determine (1) the durability and longevity of an array of micro-characters laser-machined onto various firing pins, (2) the effect of repeated firings on the legibility of impression of the micro-characters on the ejected cartridge cases, and (3) the ease with which laser-machined micro-characters could be intentionally defaced or obliterated, and (4) to evaluate the cost of the proposed technology.

A primary question regarding the technology of laser-machined micro-characters laser-machined onto firing pins has to do with their ability to withstand repeated firing. To assess their durability, six firing pins for a .40 caliber Smith and Wesson Model 4006 semi-automatic pistol were equipped with second-generation encoding structures (containing the dot code). These six firing pins were placed in six different Smith and Wesson pistols at the California Highway Patrol Academy and issued to six different cadets for testing during their firearms training. Each cadet fired approximately 2500 rounds of ammunition. Photomicrographs were taken of the firing pins before and after test firing with a Philips FEI XL-30 Scanning Electron Microscope (SEM) so that direct comparison of any changes could be assessed. The range of firearms used for this study included pistols; a rifle and a shotgun because these are all used in crimes of violence and may leave cartridge case evidence. They consist of various handgun models (including new pistols at the CHP Academy) and firearms that will be in use for the foreseeable future. This allowed us to observe the effects of different firing pin impressions made by firearms that have different discharge pressures. These firearms and their future model derivations are expected to provide similar results.

The vendor was supplied with 14 firing pins which were subsequently engraved at a cost of $3,500 or ~ **$250.00** per firing pin. These firing pins were obtained after their initial laser machining without any additional processing steps such as deburring, etching and diamond coating or initial test firing. The study showed that these additional steps are not needed because the failure mechanism is primarily influenced by the firearm design and these secondary processes including diamond coating would not resolve that issue.

In order to determine the legibility of the impressed characters made by second-generation firing pins, five different semi-automatic pistols (of varying make, model and caliber), two different caliber semi-automatic rifles and one pump action shotgun where chosen. The firearms tested were:

- Ruger Mark I, .22 Long Rifle (rimfire semi-automatic pistol)
- SeeCamp, .25 ACP-LWS (semi-automatic pistol)
- AMT " Backup", .380 auto (semi-automatic pistol)
- Sig Sauer P229, .40 Caliber (semi-automatic pistol)
- Colt 1911 Government Model, .45 ACP (semi-automatic pistol)
- Colt AR-15, .223 Caliber (semi-automatic rifle)
- Norinco AK-Series, 7.62x39mm (semi-automatic rifle)
- Mossberg 500, 12 gauge (pump action shotgun)

These firearms were chosen based not only upon their availability but also for the sake of diversifying the caliber and quality of firearm tested. For each of the above firearms, a single second-generation (containing gear code) micro-serial numbered firing pin (i.e., bearing a gear code) was obtained[1] and documented using an SEM.

In addition to testing this technology with the above firearms, a variety of different ammunition brands were also tested with each firearm. The point of introducing such variance in ammunition brand was to observe how the transfer and legibility of the impressed micro-characters were affected by varying primer cup composition and primer cup hardness. (The brands of ammunition tested with each firearm can be seen in Table 3.)

[1] The firing pin for the Ruger, 22LR only contains the alphanumeric encoding structures. This is due to the design of the firing pin and the nature of rim fire firearms. Due to the firing pin geometry for the Norinco, radial bar coding was not possible.

The type of ammunition one uses, can affect the impressions made by a firing pin. This has been well documented. We used ammunition that was available in the local community. This ammunition can be commercial, import or military surplus. The subjects who commit crimes of violence are not selective about the type of ammunition they use. The Norinco type AK rifle is one of the popular rifles used by street gangs as are some of the 9 mm and .45 ACP type pistols. The Colt 1911 .45 ACP pistol continues to be one of the most popular pistols with a substantial after-market parts support. A detailed study of the California database could provide a frequency breakdown for new handguns sales but it is difficult because this database is not structured for easy sorting. Furthermore, the California new handgun sales profile may not be reflective of what is routinely used in gang shootings.

Every cartridge case was collected in order of firing and analyzed with a variable magnification stereo-microscope equipped with a ring light and polarizing filter. From these analyses a data table was created for each firearm documenting the number of characters from each encoding format that were legible on each and every cartridge case. This data was translated into a transfer percentage for each encoding format for each cartridge case. An average transfer percentage was then calculated for each brand of ammunition tested. During the course of the experiment, the serial numbers where extensively documented with photomicrographs. Finally, the averages for each brand of ammunition were plotted for each firearm. These charts can be found in the appendix associated with each firearm.

Two different methods were designed to evaluate the ease with which laser-machined micro-characters could be intentionally defaced or obliterated. In the first method, the firing pin for an AMT "Backup" 380 Auto semi-automatic pistol was held perpendicular to a household sharpening stone and rubbed back and forth for 30 seconds. The second method involved placing the firing pin for a Sig Sauer P229 semi-automatic pistol on its side on an anvil and rolling it back and forth while lightly peening it with a ball peen hammer for 15 seconds. The firing pin was then stood on its base and the tip was peened for an additional 15 seconds.

Key Findings

The legibility and quality of the micro-stamped characters for all three encoding formats varied among the set of firearms tested. The function and design of each firearm affected the manner in which the firing pin struck the primer or rim of the cartridge case, thereby controlling the depth of the firing pin impression and the presence or absence of firing pin drag, multiple strikes of the firing pin and flow back. Three of the firearms tested demonstrated an overall decline in transfer rate, while the transfer rate for all firing pins tested demonstrated a direct relationship between the brand of ammunition tested and the transfer rate. Each brand of ammunition produced a different transfer rate. This ammunition-specific transfer rate was reproducible upon repeated testing. (These results are illustrated in the “Encoding Structures Transfer Trend” graphs located in the appendix for each firearm.)

Overall, the alphanumeric characters and the gear code structures proved more durable under repeated firings (i.e., these characters were still legible on the firing pins upon completion); however, some degree of degradation—i.e., flattening—was seen on the alphanumeric structures of the firing pins tested. The dot code structures on the Smith and Wesson firing pins suffered severe degradation and deposition of foreign material, making them illegible on the firing pins (arguably a function of their small dimensions).

The radial bar code structures on eight out of the fourteen firing pins tested exhibited severe degradation, including all six of the Smith and Wesson firing pins and those for the SeeCamp .25 ACP and AMT .380 Auto. The degradation observed involved the flattening/peening of the radial bar code structure by continual contact with the walls of the firing pin aperture during repeated firing. With the exception of the radial bar code structures on the Sig Sauer firing pin, which showed moderate degradation, the radial bar codes on the remainder of the firing pins showed minimal signs of degradation, consisting only of the deposition of foreign material.

Because of patent issues we could not obtain the coding sequence of the radial, dot and gear codes. For order to remain usable there will be a minimum size for these alternate coding technologies and decoding information must be provided.

Finally, both defacement/obliteration methods demonstrated that the micro-characters could easily be intentionally destroyed with the firing pin removed from the firearm. The destruction of these characters while the firing pin was installed in the firearm would be difficult.

Due to the varying amounts of degradation seen on all of the firing pins, a determination of what constitutes a suitable lifespan of these characters needs to be developed. At the current time only the alphanumeric encoding format has the potential to reliably transfer information from the firing pin to the cartridge case, thereby facilitating the identification of crime guns outfitted with micro-stamping technology. If any numbering system has the future potential to handle a large database and have some survivability, it is the alpha–numeric system. Future research effort should begin focus on alpha-numeric coding and it’s applicability to the various firearms that are used in gang related shooting. The other area that needs more research is to evaluate the effectiveness of firing pin serial number impressions (or the equivalent breech face engraved serial numbers) on brass cartridge cases (excluding the primer area). Our study so far shows that this is a significant problem area based on our limited evaluation of impressions made by the firing pin in the .22 caliber pistol.

Our expectation is that the results of the firing pins used in this study will be relevant to the current models we tested and their future derivation. In this study we also used the Scanning Electron Microscope (SEM) to image the firing pins. However in a typical laboratory, such imaging will have to done by trained laboratory staff using a properly configured stereomicroscope. The SEM will be off-limits to the cartridge case because most crime labs use the SEM for the detection of Gunshot residue on shooters hands and the presence of a cartridge case would severely contaminate the SEM.

The basis for this report, in the form of a thesis was also reviewed by Professor Michael Hill in the Mechanical Engineering Department and the report, as submitted to the CPRC, was externally reviewed by Lucian Haag, an independent Firearms expert and Professors Simon Cole and George Tita of the UC Irvine Department of Criminology. The report fulfilled and exceeded the purpose of the original grant and the reviewers' comments are provided in Appendix O: External Review of the Micro-Serialized Report.

Policy Implications and Recommendations for Further Research

The findings of this study will have a direct impact on any legislation involving micro-serialized firing pins including the recently enacted revisions to California Penal Code section 12126 application which proposed the application of second-generation micro-serialized firing pins manufactured by ID Dynamics to *all* semiautomatic handguns sold in the state of California. As shown, while the technology works with some firearms, it does not perform equally well for every encoding structure or for every semiautomatic handgun tested. As only a limited number of firing pins, encoding sequences, and firearms were tested in this study, it is not known how this emerging technology would perform across the board in relation to the over 2000 different makes and models of semiautomatic handguns sold in California each year. *At the present time, therefore, because its forensic potential has yet to be fully assessed, a mandate for the implementation of this technology in all new semiautomatic handguns sold in the state of California is counter-indicated. We specifically propose further research on alpha-numeric* *serial numbers on firearms mostly in gang related shootings, suitability of such alpha-numeric imprint on fired cartridge case areas other than the soft primer area, realistic and accurate production cost estimates for such micro-engraving and a evaluation as to what percent of gang related shooting could realistically be solved by such technology given current gang firearms usage.*

The recent release of the National Research Council of the National Academies report on Ballistics Imaging, March 5, 2008 supports the concept of our research and they (NRC) recommend further research on "microstamping," a technique that imprints unique marks on guns or ammunition-"

Several areas for further research recommend themselves, including:

1. Criteria to determine the transfer rate required for identification

The data collected for each cartridge case in this study only provides the transfer rate of each encoding format. In order for this information to be useful, criteria need to be set stipulating exactly what transfer rates (for each encoding format) constitute a sufficient quantity of characters to allow for the potential identification of the firing pin that produced them. These criteria should be created in conjunction with practicing firearms examiners, the state of California and the personnel responsible for the creation of the database for this technology.

2. Decoding protocols for properly interpreting radial bar and gear codes

At the current time no protocols have been provided regarding the interpretation of the radial bar codes and gear codes. Without such protocols the impressions of these encoding structures are nothing more than that: impressions. This could affect the current California Penal Code 12126 section if the intent of this law requires the implementation of this unproven secondary technology. Decoding conventions need to be obtained from ID Dynamics for these two encoding formats to be interpretable. Once this information is obtained, testing will need to be conducted to determine what factors affect their interpretation, such as changes in width and spacing. Without these instructions the radial bar codes and gear codes are rendered mute, unable to provide any identifying information.

3. Firearm-related crime statistics to be compiled

A survey of crimes committed with semiautomatic handguns needs to be compiled and sorted into two specific categories: crimes committed by the registered owner of the firearm and firearm crimes committed by someone with a firearm not registered to the end user, such as gang related shootings. This is especially important in the area of gang related shootings since firearms are frequently recovered, linked to past homicides but the holder of the firearms cannot be charged for prior homicides. This information will aid considerably in determining the forensic potential this technology holds for the law enforcement community in the identification of possible suspects in firearm-related crimes.

4. Implementation strategies to be developed collaboratively

The development of a viable commercial implementation strategy for this technology is a necessity. This must be completed in collaboration with officials from the state of California, firearms manufacturers and ID Dynamics. Many different implementation strategies for this technology may be possible. The laser micro-machining could be conducted by each individual firearm manufacturer, a consortium, an independent company, or by the state although the latter possibility is unlikely. These and other scenarios should be prototyped and evaluated prior to any implementation of this technology. The role of the State could be one of developing specific technical detail as to the form and sequence of the micro-serial numbers that would complement the State's firearms databases. The State would also have to ensure that this technology is not proprietary and can be competitively bid by interested parties at a reasonable cost. Ideally these scenarios should be prototyped and evaluated prior to any legislative or commercial implementation of this technology.

5. Technology implementation prototype to be piloted

Prior to implementing this technology statewide, a smaller-scale prototype should be piloted. The ideal scenario for testing such a prototype would involve a group of selected law enforcement agencies equipped with a variety of handguns so that about 3,000 firing pins from assorted handgun models can be evaluated. This number of firearms equipped with micro-machined firing pins should be sufficient to allow for a more accurate evaluation of this technology and allow for interested parties to provide a realistic bid on firing pin manufacturing costs. This study would provide beneficial information as to the time required and cost incurred for the laser machining of micro-characters onto firing pins. It would also address the suitability of such micro-numbers in handguns other than the CHP Smith and Wesson firearms. As an example, Glock firing pins are substantially different and have different dynamics. Furthermore if radial and gear code technology is to be contemplated, we need to test the coding structure with realistic serial numbers.

Along with this we would recommend that a survey be conducted as to the utility of this technology in gang and non-gang related shooting incidents and compare this to the current NIBIN technology which images the cartridge cases found at crime scenes and conduct a preliminary automated comparison.

INTRODUCTION

When a firearm is discharged, microscopic toolmarks are imparted from the firearms' internal surfaces onto the bearing surface of each bullet and cartridge case. It is these individual toolmarks that forensic firearms examiners scrutinize, through a comparison microscope, to classify and identify the firearm from which these items were fired. More specifically, a microscopic comparison is conducted to determine if a match can be made between the evidence bullet or cartridge case and test-fired specimens obtained from the firearm in question. This identification process is highly time consuming, as the number of microscopic toolmarks that must be compared can vary in position, illumination and orientation, and requires specialized equipment, training and extensive experience.

Basic Firearm Function and Firearms Evidence

Every time a firearm is discharged, a specific series of events occur that in turn leave unique toolmarks on the bullet and cartridge case. When the trigger is depressed the firing pin travels forward, striking either the primer (with center fire cartridge cases) or the rim of the cartridge case (with rimfire cartridge cases). Upon impact, the shape of the firing pin as well as any imperfections and/or residual manufacturing tool marks on the firing pin are transferred into the firing pin impression. This impact initiates the deflagration of the friction-sensitive priming compound. In turn this ignites the gunpowder, causing an instantaneous expansion of hot gases.

The deflagration creates pressure that forces the bullet through and out of the barrel. As the bullet travels down the barrel, and engages the rifling, microscopic imperfections from the barrel's manufacturing processes are transferred to the bullet, creating a series of striations (*striae*).

The increase in pressure also has an effect on the cartridge case, causing it to expand outwards against the chamber walls as well as rearward against the breach face. This expansion causes the transfer of chamber markings onto the sides of the case and as well as breach face markings onto the head or rim of the case and the primer. Additional toolmarks are impressed on the cartridge case as it is extracted and ejected from the action of the firearm. An extractor pulls the cartridge case out of the chamber. This motion will result in extractor markings being produced on the rim of the cartridge case. As it is being extracted, the cartridge case will come into contact with the ejector which will cause it to rotate towards the ejection port. The ejector also produces markings that are left of the head of the cartridge case. During ejection, the cartridge case can also sustain toolmarks from contacting the ejection port.

Each ammunition component (bullet and cartridge case) and the markings imparted on these two items during the discharge of a firearm are the key items of firearms evidence. All of the markings created on the ammunition components will contain both class and individual characteristics. *Class characteristics*—generally, manufacturing and design features that are transferred to the bullet or cartridge case—constitute a family of firearms or specific firearms manufacturers. *Individual characteristics* are the markings, imperfections and striae transferred to the cartridge case or bullet that serve as crucial evidence in the identification of a specific firearm.

Micro-machining Technology

Todd Lizotte of ID Dynamics, LLC developed a micro-machining technology that utilized a solid-state ultraviolet laser to machine an array of microscopic characters onto the tip of a firearm's firing pin. By normal standards, the tip of a firing pin is small (typically about 0.075 inches in diameter), however in the micro-machining world this diameter is sufficiently large enough that a wide variety of letters, numbers, symbols and or barcodes can be machined on its surface. These characters are not readily visible to the naked eye, but can be easily viewed under an optical microscope at approximately 20 times magnification or with a scanning electron microscope (SEM). The principle behind this technology is that every time a firearm is discharged, the characters machined on the firing pin will be impressed into the primer or cartridge case rim, thereby allowing for the identification of the gun from which the cartridge case was fired by merely reading off the impressed characters and looking them up in a database of all engraved firing pins and their associated firearms.

Since the advent of this technology, ID Dynamics has continuously made changes to the morphology and arrangement of the micro-characters. The first-generation engraved firing pins contained only an array of alphanumeric characters on the face of the firing pin. Proof of concept testing on this generation of firing pins was conducted by ID Dynamics as well as by George G. Krivosta of the Suffolk County Crime Laboratory in Hauppauge, New York[2] and Lucien C. Haag of Forensic Science Services.[3]

[2] "NanoTag™ Markings From Another Perspective," Krivosta, George G., Suffolk County Crime Laboratory, Hauppauge, NY. *AFTE Journal*, Vol. 38, No. 1, Winter 2006.
[3]. Ballistic ID Tagging' A Further Look", Haag, Lucien C., Forensic Science Services, Carefree, AZ. PowerPoint Presentation.

Subsequently two formats of second-generation firing pins have been produced—see Figures 1 and 2 below—each containing three different types of encoding structures. The first of the two formats (*Figure 2*) contained alphanumeric characters on the tip of the firing pin surrounded by a dot code a radial barcode. The second layout (*Figure 1*) was based on the same design as the first; however the dot code was replaced by a gear code.

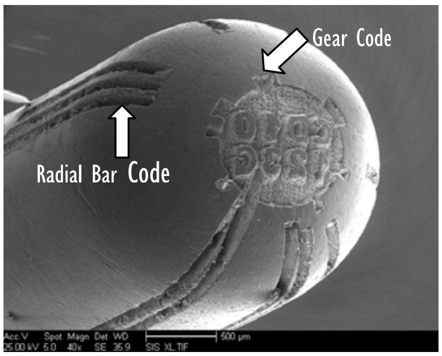

Figure 1

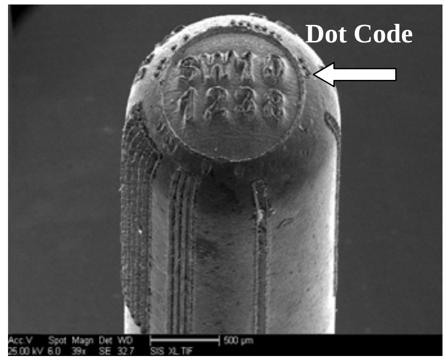

Figure 2

The alphanumeric coding on the tip of the firing was provided in two different formats: uncorrected and corrected. The uncorrected format was such that the characters were directly legible on the face of the firing pin thereby the impressions they left were backwards. The corrected format provided the alphanumeric characters written backwards on the firing pin so that their impression would be directly legible.

According to proposed Assembly Bill 1471 (formerly AB 352),[4] (missing footnote #4 and need to update) the "make, model and serial number" of every semiautomatic handgun sold in California must be machined on its firing pin. However, due to geometry and size constraints, the manufacturer placing an eight-digit alphanumeric tracking/reference code (i.e., two lines of 4 characters) on the face of the firing pins. By reducing the number of characters machined on the face of the firing pin, the size of each character can be increased which will enhance the legibility of their impressions on the primer. This eight-digit alphanumeric code provides enough possible combinations to allow for an individual tracking code to be assigned to all semiautomatic handguns sold in the State of California. The concept is that a database will be created that will pair the alphanumeric tracking code placed on each firing pin with the make, model and serial number of the firearm in which it is placed. As long as the tracking code in the firing pin impression is legible, a basic database search can be conducted to identify the registered owner of the firearm in question.

[4]. Subsequently chaptered into law in October of 2007.

Issues with Laser Machining

The firing pin in a particular firearm is typically unique to that specific make and model of firearm. It is not generally interchangeable with other makes and models of firearms. For this reason, every different geometry of a firing pin will have a unique a fixture that must be manufactured so that it will hold the firing pin perfectly in line with the laser. If this alignment is not obtained, the encoding structure will be improperly placed on the firing pin and/or the encoding structures may be deformed or damaged. This will cause an unsatisfactory or illegible transfer of the encoding structures into the firing pin impression. As this micro-character laser machining process is still in the developmental stage, the above issues were encountered in five out of the fourteen firing pins that were machined for this study. The manufacturer was notified of these issues and the fixtures were corrected; replacement micro-serialized firing pins were obtained and subsequently used in this research. See appendix B for images and details of specific the issues encountered.

Issues with Firing Pin Machining

For the purpose of this study, we wanted firing pins that came directly from the laser machining without any subsequent process such as deburring, etching, diamond coating and preliminary test firing. Some of the subsequent firing pins provided by the vendor had this deburring/etching process completed. In particular; the process of diamond coating is a common industrial technique to increase the abrasion resistant of a particular tool that is subject to lateral abrasion. The technique consists of placing a very thin coating/layer of diamond like material on the surface of the tool. The mechanism of wear of a firing pin micro-serial number is impact abrasion and this result is not in surface wear but in structural deformation. Impact deformation results in structural change of the micro engraved numbers and a diamond coating that reduces surface wear would have no effect this structural change. The subsequent result of the CHP pistol tests and their alpha-numeric data shows that these additional machining steps appear to be unnecessary.

The issue is not with the micro-engraved alphanumeric number reproducibility but with the fact that certain combinations of firearms and ammunition will not allow legible reproduction of the micro-engraved numbers, alphanumeric numbers and the radial codes. In this test, only the alphanumeric encoding performed well on the new CHP Smith & Smith & Wesson pistols, the radial bar codes and the dot codes being illegible.

Research Objectives, Methods and Materials

A series of tests were conducted using a sample of readily available firearms to determine (1) the durability and longevity of an array of micro-characters laser-machined onto various firing pins, (2) the effect of repeated firings on the legibility of the imprint of the micro-characters on the spent ammunition, and (3) the ease with which laser-machined micro-characters could be intentionally defaced or obliterated.

Durability and Longevity of Micro-Characters

The initial question regarding the laser-machined micro-characters is their durability to withstand repeated firing. To answer this question, six firing pins for a .40 caliber Smith and Wesson Model 4006 semi-automatic pistol were equipped with second-generation encoding structures (containing the dot code). These six firing pins were documented prior to firing by imaging with a Philips FEI XL-30 Scanning Electron Microscope (SEM). The California Highway Patrol (CHP) Academy provided assistance for the durability study, in that they allowed these firing pins to be installed in six of the Smith and Wesson Model 4006 firearms issued to their cadets. Their assistance was requested because of the number of rounds of ammunition fired by each cadet in a relatively short period of time. During the course of the academy, each recruit fired approximately 2500

Table 1
Encoding Data for Smith & Wesson Firing Pins

Pin	Alphanumeric	Dot Code	Bar Code
A	SW10, 1234	20	22
B	SW10, 1235	19	22
C	SW10, 1236	21	23
D	SW10, 1237	21	23
E	SW10, 1238	21	20
F	SW10, 1239	19	21

rounds of ammunition (Winchester Ranger SXT). The alphanumeric encoding structures for all six firing pins were identical except for one character so as to allow for the inter-comparison of the wear patterns on the characters of all six firing pins. The encoding characters for the six Smith and Wesson firing pin are listed in Table 1 above.

The first ten cartridge cases fired from each of the six Smith and Wesson pistols were collected to determine if the character impressions undergo an initial break in period.[5] Six more cartridge cases from each firearm were collected during the remainder of the cadets' firearms training. Upon completion of the CHP cadets' firearms training, the serialized firing pins were removed and imaged once again utilizing the SEM. A comparison of the firing pins was then conducted utilizing analysis ™ imaging software.

Legibility of Impressed Characters

In order to analyze the legibility of the impressed characters in the firing pin impressions, five different semi-automatic pistols (of varying make, model and caliber), two different caliber semi-automatic rifles and one pump action shotgun where chosen. These firearms were:

- Ruger Mark I, .22 Long Rifle (rimfire semi-automatic pistol)
- SeeCamp, .25 ACP-LWS (semi-automatic pistol)
- AMT " Backup", .380 auto (semi-automatic pistol)
- Sig Sauer P229, .40 Caliber (semi-automatic pistol)
- Colt 1911 Government Model, .45 ACP (semi-automatic pistol)
- Colt AR-15, .223 Caliber (semi-automatic rifle)
- Norinco AK-Series, 7.62x39mm (semi-automatic rifle)
- Mossberg 500, 12 gauge (pump action shotgun)

These firearms were chosen based upon their availability as well as to diversify the calibers and quality of firearm tested. For each of the above firearms, a single second-generation (containing gear code) micro-serial numbered firing pin was obtained[6] and documented using an SEM. Images of all the unfired firing pins are illustrated in Appendix A.)

[5] A ten round break in period was suggested by Todd Lizotte, ID Dynamics.
[6] The firing pin for the Ruger, 22LR only contains the alphanumeric encoding structures. This is due to the design of the firing pin and the nature of rim fire firearms. Due to the firing pin geometry for the Norinco, radial bar coding was not possible.

Table 2 Encoding Structures for Each Second-generation Firing Pin Tested			
Firearm	Alphanumeric Code	# of Teeth in Gear Code	# of Lines in Radial Bar Code
Ruger	SR10123K (Single Line of Text)	N/A	N/A
SeeCamp	SC10, 123C (Uncorrected Format)	7	11
AMT	AM10, 123E (Corrected Format)	9	12
Sig Sauer P229	SS10, 1232 (Corrected Format)	7	13
Colt 1911	CD10, 123G (Corrected Format)	7	11
Colt AR-15	CD10, 123H (Corrected Format)	8	12
Norinco AK	NC10, 123D (Uncorrected Format)	9	N/A
Mossberg	MS10, 123B (Corrected Format)	8	12

In addition to the testing of this technology with multiple calibers of firearms, there was also a need to conduct testing with different brands of ammunition because of the differences in primer cup composition and primer cup hardness. A study conducted by Fred Tulleners[7] illustrates the hardness of a primer can vary depending on the manufacturer of the cartridge case. The brands of ammunition chosen for this study were based upon public abundance and availability (see Table 3). For each of the five semi-automatic pistols tested, fifty rounds of each brand of ammunition were fired. Upon completion of the first series of test firing, further test firing was conducted keeping the order of ammunition brand constant. This second test firing sequence allowed cartridge cases of the same brand of ammunition to be compared when fired several hundred rounds apart from one another, allowing for more complete documentation of any possible changes in transfer of the characters to the firing pin impressions. For the two rifles the brands of ammunition were changed every 60 rounds for the first series of test firing, and every 40 rounds for the second test firing. (It should be noted that the order of ammunition brand was kept constant between the two test firing series.)
The number of rounds per brand of ammunition was altered in the case of the rifles due to the number of rounds of ammunition per box.

[7] "Vickers Hardness Values of Selected 40 S&W Primers," Tulleners, Fred, California Department of Justice, Sacramento, CA; Randich, Erik, Lawrence, Livermore National Laboratories, Livermore, CA; Giusto, Michael, California Criminalistics Institute, Sacramento, CA. *AFTE Journa*l, Spring 2003, Vol. 35, No 2, pp. 204-8.

Table 3 List of Firearms and Ammunition Brands Tested	
Firearm	Ammunition Manufacturers
Ruger, 22 LR	Winchester, Remington, Federal (American Eagle), PMC, CCI Blazer
SeeCamp, 25 ACP	Winchester, Remington, Federal (American Eagle), CCI Blazer
AMT, 380 Auto	Winchester, Remington, Federal (American Eagle), PMC, Armscor, Cor-Bon
Sig P229, 40 S&W	Winchester, Remington, Federal, Speer, PMC, Corbon, CCI
Colt 1911, 45 ACP	Winchester, Remington, Federal (American Eagle), PMC, Wolf, Armscor, Cor-Bon
Colt AR-15, .223	Winchester (USA, Military), Remington, Federal, PMC, Golden Bear, Squires Bingham, Corbon[8]
Norinco AK, 7.62 x 39 mm	Winchester, Remington (UMC), Federal, PMC, Wolf, Foreign Steel Case
Mossberg 500A 12 gauge	Winchester, Remington, Federal, PMC, Wolf, miscellaneous

The test firing series was conducted in a slightly different manner for the shotgun. The first series consisted of 50 rounds of each brand of ammunition and for the second series mixed brand bulk ammunition was used: the brand of ammunition for each shot was random. Prior to the beginning of the test firing process, all ammunition, except for the mixed bulk 12 gauge, was engraved numerically identifying the location in the order of which it would be fired.

Throughout the test firing process, the firing pins were removed and imaged with the SEM. The intervals at which firing pins were imaged are as follows: after one shot, after 10 shots, after 100 shots and upon completion of test firing.

Every cartridge case was analyzed visually utilizing a 7.5-64-power variable magnification Olympus stereo zoom microscope. To reduce the amount of glare and reflection from the metallic surface of the primers, a Schott ring light equipped with a polarizer/analyzer was used. On the majority of the cartridge cases, the impressed encoding characters were best visualized under crossed

[8] The Cor-Bon ammunition utilized for this research was packaged and distributed by Corbon, but assembled with Remington cartridge cases (headstamp R-P) and unknown primer manufacturer

polarized light. This method of examination was chosen, as the stereo zoom microscope is one of the key pieces of instrumentation present in forensic firearms laboratories. The use of alternative methods such as Scanning Electron Microscopy (SEM) or confocal microscopy to identify the illegible characters was not investigated since these instruments are not readily available for the analysis of firearms evidence within forensic laboratories. The purpose of most SEM's in forensic laboratories is for Gun Shot Residue (GSR) and trace evidence analysis, thus the placement of firearms evidence into the sample chamber of the SEM would be prohibited due to GSR contamination issues. A data table was created for each of the firing pins based upon the visual the observation of the cartridge cases and documenting the number of characters from each type of encoding that were readily legible within the firing pin impressions. For any individual alphanumeric character to be counted as a positive transfer, it had to be fully legible; partial character transfers were not counted. For the bar code characters to be counted, both edges of each individual line had to be visible. For the gear code characters to be counted, all three edges of each individual structure had to be visible.

Although the above listed firearms were intended to test the legibility of the impressed characters, micro-character durability and longevity data was also obtained and analyzed as the firing pins were documented throughout the test firing process.

Micro-Character Defacement/Obliteration

The ease in which these micro-characters can be removed or obliterated was questioned. In order to answer this question, two different methods for character obliteration were chosen. The methods were chosen based upon common household tools and objects readily available to the general public. The firing pins that were selected were the AMT .380 Auto and the Sig Sauer P229 semi-automatic pistols.

The first obliteration method tested entailed rubbing the face of the AMT firing pin on the fine-grain side of a household sharpening stone. This method attempted to obliterate the alphanumeric and gear code structures from the firing pin while leaving the radial bar code undamaged. The firing pin was held perpendicular to the fine grain side of the sharpening stone and rubbed back and forth with moderate pressure for 30 seconds. No further action was taken. The firing pin was then installed in the firearm and ten rounds of Winchester ammunition were test fired.

In the second obliteration method a 16-oz. ball peen hammer was used to lightly peen the Sig Sauer P229 firing pin containing all three encoding structures. To do so, the firing pin was laid on its side on the anvil portion of a steel bench vice and rolled back and forth while lightly peening the radial bar code. This process was conducted for 15 seconds. The firing pin was then placed with its base on the anvil and the face of the firing pin containing the alphanumeric and gear code structures was lightly peened for 15 seconds. No further action was taken to obliterate the encoding structures. The firing pin was then installed in the firearm and ten rounds of Winchester ammunition were test fired.

KEY FINDINGS AND DISCUSSION

Durability and Longevity of Micro-Characters

The SEM images of all micro-serialized firing pins were analyzed using analySIS^{TM} imaging software. For each firing pin, measurements were obtained (in microns) of the width and height of every alphanumeric character. These measurements were taken prior to test firing, at set intervals throughout test firing, and then once again after test firing: measurements were only taken before and after test firing for the six Smith and Wesson Model 4006 firing pins.

Smith and Wesson Model 4006, 40 S&W Semi-Automatic Pistol

Comparing the measurements of the height and width of the alphanumeric characters before and after firing 2500 rounds of ammunition, only minor changes were seen on all of the firing pins except for Pin F. All of the firing pins showed a softening[9] of the alphanumeric characters' visual appearance. Two of the alphanumeric characters on firing pin F, "W1", in the top row of text showed a large amount of deformation. Both of the characters where flattened and shifted slightly to the right. The number "6" in the second row of text on firing pin C also showed a slight deformation in character. One other issue noticed amongst the alphanumeric characters was the deposition of foreign material in and around the characters. This deposited material is from byproducts of the discharge of the ammunition as well as from the softer primer material.

The dot code structures surrounding the face of the firing pin showed extreme wear and degradation. On all six of the firing pins, the multiple dot code structures were obliterated from repeated firing, or were filled completely with foreign material: The filling of these structures with foreign material was common to all six firing pins. The majority of the dot code structures did not survive through the full test firing cycle.

The radial barcode structures also showed extreme wear and degradation. First noted was obliteration of the bar code structures near the tip of the firing pin by the firing pin aperture. Enough size difference between the diameter of the firing pin and the diameter of the firing pin aperture (*Figure 3*) was present to allow the firing pin to move from side to side while at full extension during firing. The

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[9] "Softening" describes the smoothing out of the characters' surfaces, rounding of the characters edges, and disappearance of rough/jagged fragments on the characters' surfaces left from the laser machining process.

impact of the firing pin against the walls of the firing pin aperture caused a peening affect, thus pounding a portion of the bar code structures flat (*Figure* 4). This effect was noticed on all six of the firing pins. The remaining portion of the bar code structures between the obliterated section and the tip of the firing pin were filled with deposited foreign material.

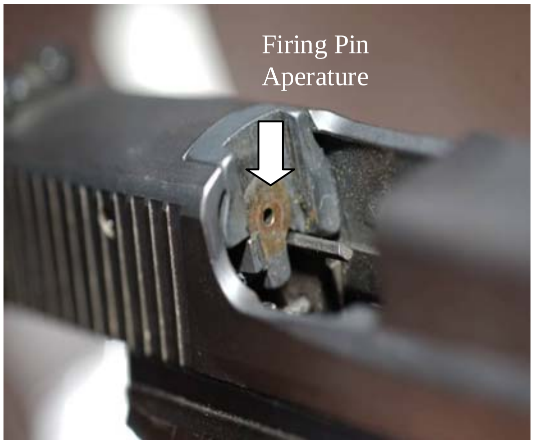

Figure 3

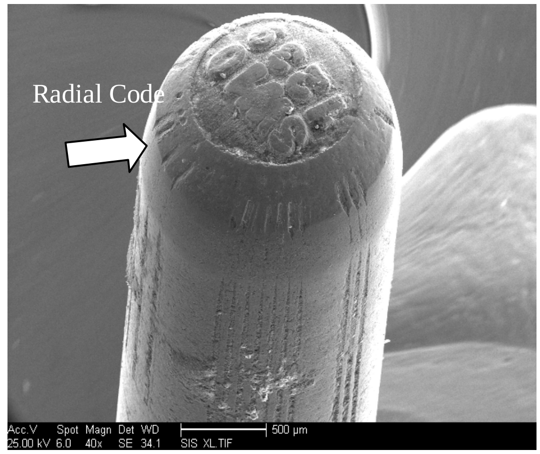

Figure 4

Of the three forms of encoding structures present on the six Smith & Wesson firing pins tested, the bar code structures and dot code structures were the most susceptible to degradation from repeated firing. The alphanumeric encoding structures on the face of the firing pins demonstrated moderate-to-good durability and retention of overall shape, except for the few above-mentioned characters on firing pins C and F. The testing of the durability and longevity of the micro-characters over a period of firing 2500 rounds of ammunition was felt to be adequate in comparison to the average number of rounds of ammunition fired over the lifetime of most semi-automatic pistols. The measurements for the alphanumeric characters and supporting images are illustrated in Appendix C.

Ruger MK I, .22 LR Semi-Automatic Pistol

The evaluation of the micro-machined characters for the Ruger .22 LR firing pin was based upon alphanumeric encoding only, as most of the firing pins for .22 caliber rimfire firearms are not amenable for gear and radial bar code labeling. The first issue to address regarding this firing pin is the quality of its original manufacture. The quality of the alphanumeric characters on this firing pin was inferior to those found on the rest of the firing pins tested. The edges of the characters lacked crispness and their alignment was poor. The largest issue was that the first character in the encoding sequence, "S," was machined off the face of the firing pin. The manufacturer informed the investigators that the geometries to be utilized for this technology on rimfire firing pins had not yet been perfected.

The second issue has to do with the fact that this is a rimfire firearm in which case the firing pin strikes the rim of the brass cartridge case rather than an exposed primer. Thus every time the firearm is discharged; the firing pin is contacting a much harder material. The last issue with the firing pin for a rimfire firearm is that only a portion of the end of a rectangular firing pin strikes the cartridge case, thus allowing for only part of the encoding structures to come into contact with the rim of the case.

This firing pin was test fired for a total of 250 rounds of ammunition. Over this test firing period, the alphanumeric characters showed extreme signs of degradation, so much so that no character dimensions were obtainable. The degradation and deformation of the alphanumeric characters were documented through SEM images only. These images can be seen in Appendix D.

SeeCamp .25 ACP LWS Semi-Automatic Pistol

The alphanumeric characters on the SeeCamp firing pin showed negligible degradation over the course of test firing 394 rounds of ammunition.[10] The only change in the alphanumeric characters that was noted was the softening of the characters' appearance in comparison to their original state. By the completion of the test firing, some build up of foreign debris was noticed in and around the alphanumeric characters.

The gear code structures did not appear to incur any major changes during testing. The only noticeable event was the slight narrowing of the structures; however, this narrowing was not significant.

The radial bar code structures suffered the same degradation as the radial bar codes on the Smith & Wesson Model 4006 firing pins. After ten cartridges were fired, the effects of the firing pin contacting the firing pin aperture were observed. By the completion of the test firing, a section of the radial bar code structures was showing severe peening from this lateral pin movement. The remaining portion of the radial bar code structures, between the damaged section and the tip of the

[10] Test firing of the SeeCamp firing pin was ceased at 394 rounds of ammunition due to firearm malfunction. An integral component within the firearm broke disallowing continued use of the firearm. This malfunction was in no way related to the testing of the laser-machined firing pin.

firing pin, contained deposits of foreign material. All measurements and images for the above results are illustrated in Appendix E.

AMT "Backup" .380 Auto Semi-Automatic Pistol

The appearance of the alphanumeric characters was softened after firing ten rounds. Both the "A" and the "3" showed slight deformation after the completion of test firing 600 rounds of ammunition. The left side of the "A" began to collapse toward the center of the character and the number "3" was slightly flattened and gained in height by approximately 28 microns. Both of these characters were still legible.

The gear code structures showed no major signs of degradation. The deposition of foreign material in the gear code structures was noticed throughout the test firing; however, the location and severity of these deposits were not constant.

The radial bar code structures suffered the same degradation as those on the Smith & Wesson firing pins. After ten rounds had been fired, the effects of the firing pin striking the aperture of the firing pin port were noticed. By the completion of the test firing, a section of the radial bar code structures showed severe peening to complete obliteration from this lateral firing pin movement. All of the radial bar code structures, except one, were damaged all the way to the tip of the firing pin. The data and images for the above results can be seen in Appendix F.

Sig Sauer P229, .40 S&W Semi-Automatic Pistol

The alphanumeric characters on the Sig Sauer firing pin showed signs of softening after ten rounds of ammunition had been fired. Throughout the remainder of 1000 rounds test fired, no major signs of character degradation or deformation were noticed. The number "3" in the bottom row of text showed the most signs of degradation. Large amounts of foreign material deposits were noticed in and around the alphanumeric characters. In some areas these deposits were level with the top of the characters. However, the location and size of the deposits did not remain constant throughout the test firing.

The gear code structures showed minimal to no signs of degradation. Throughout the test firing process, deposits of foreign material were noticed accumulating within the gear code structures. None of the deposits remained constant except for one; the gear code structure directly above the second "S" in the top row of text was almost completely filled with foreign material at 100 rounds of ammunition fired and remained this way through 1000 rounds fired.

The firing pin material that separates one radial bar code structure from the next suffered the most degradation within the radial bar code structures. These separating structures began to fail near the tip of the firing pin, creating the appearance of one wide bar code structure as opposed to the intended two structures. However, these separating structures were exceptionally narrow on this firing pin prior to testing. Large quantities of foreign material deposits were visible in the entire length of most radial bar code structures. These deposits were also not constant throughout the test firings. See Appendix G for the data and images for the above results.

Colt 1911, .45 ACP Semi-Automatic Pistol

In the laser machining of this firing pin, the fixture issues were apparently not resolved. The ends of the radial bar code structures are uneven and one set of radial bar code structures continue through the gear code almost reaching the alphanumeric structures. The continuation of these two radial bar code structures causes them to join together at the tip of the firing pin and looked like one wide structure.

The softening of the appearance of the alphanumeric characters on the Colt 1911 firing pin was not noticed until 100 rounds of ammunition were fired. At this point in the test firing sequence a large quantity of foreign debris had been deposited around the alphanumeric characters. By completion of test firing, at 750 rounds fired, no major degradation of the alphanumeric characters was noticed; however, a large quantity of foreign debris was present around the characters making the “3” difficult to visualize.

The gear code structures showed no sign of degradation. Throughout the test firing process, varying quantities of foreign debris deposits were noticed within each gear code structure. The most sever deposits were noticed upon completion of the test firing.

The separating structure between two radial bar code structures, located below the “12” in the second line of text, was the only portion of the radial bar code that showed any degradation. A portion of this separating structure was destroyed within the first 100 rounds fired (This degradation is indicated in the images on page 4 of Appendix H with the white arrows). Throughout test firing, varying quantities of foreign debris were noticed within the radial bar code structures. See Appendix H for data and images associated with the above results.

Colt AR-15, .223 Semi-Automatic Rifle

The alphanumeric characters on the Colt AR-15 firing pin were not as rough before firing as those on some of the other firing pins. This was due to a secondary process performed by ID Dynamics to remove unwanted debris left behind by the laser machining process. Even with the removal of the machining debris from the face of the firing pin, a softening of the alphanumeric characters was noticed after 10 rounds were fired; after 100 rounds, there was noticeable degradation. The top of the number "1" in the bottom row of text was beginning to disintegrate and the rest of the characters, except for the "C", were beginning to flatten out. Upon completion of test firing, through 760 rounds of ammunition, all of the alphanumeric characters had begun to flatten and lose surface material.

The only sign of degradation exhibited by the gear code structures was a softening in their edges. Deposits of foreign material were minimal throughout test firing except for one of the gear code structures after 760 cartridges were fired, the one directly to the right of the number "1" in the bottom line of text, had been filled with a foreign substance.

Throughout the test firing, the quantity of foreign material deposition present in the radial bar code structures increased to a maximum upon completion of the test firing. See appendix I for the data and images for the above results.

Norinco AK, 7.62x39mm Semi-Automatic Rifle

All of the encoding characters on the Norinco AK firing pin were extremely crisp prior to firing. After ten cartridges had been fired, a softening of the alphanumeric characters was noticeable. Also, at ten rounds fired, the right side of the letter "N" was beginning to slant to the left and the letter "D" was beginning to rotate clockwise on the base. Imaging at 100 and 600 rounds of ammunition fired revealed the continued deformation of the letters "N" and "D" as well as the elongation of the letter "C" and the number "3." Various quantities of foreign deposits were seen throughout test firing, however at 600 rounds, severe deposition of foreign material had accrued, covering over half of the letter "N" and the number "1" (in the bottom row). All alphanumeric characters were readily legible upon completion of test firing except for the "N" and "1". The "D" could potentially be mistaken for a deformed "0" or "O".

The gear code structures showed discernable signs of degradation. Throughout test firing, varying quantities of foreign material deposits were observed. The most severe deposits were seen after 600 rounds by which point three of the structures were completely filled and not readily visible and a fourth partially filled but still visible. The images and data for the above results are illustrated in Appendix J.

Mossberg 500A, 12 Gauge Pump Action Shotgun

Post machining, secondary processes were conducted on the Mossberg firing pin by the manufacturer to remove unwanted debris left behind by the laser machining process. No noticeable changes occurred to the alphanumeric characters after 10 rounds of ammunition were fired. After 100 rounds, a softening of the characters was noticeable. At this point, minor degradation to the number “1” in the top row was observed as a loss of material in the center of the character. Also at this point minor deposition of foreign material around the characters was noticed. In the images taken upon the completion of the test firing, after approximately 850 rounds fired, significant flattening of the characters was noticed. The spacing between the top and bottom rows of text had collapsed, as had some of the spacing between the characters in each row. At this point a larger quantity of deposited foreign material had accrued around the alphanumeric characters.

Throughout test firing, varying quantities of foreign material were deposited in the gear code structures. After 100 rounds, damage to the face of the firing pin was noticed, consisting of a small depression that caused the narrowing of the gear code structure located above the number “1” in the top row. Through the remainder of the test firing the edges of the gear code structures were rounded causing a slight change in their dimensions.

The radial bar code structures showed no visible sign of degradation; however, throughout test firing varying quantities of foreign material deposits were visible. The quantity of foreign material present in the radial bar code structures was not constant. See Appendix K for images and data for the above results.

Legibility of Impressed Characters

Each firearm tested produced a unique shape and depth of firing pin impression. Due to this variation in the firing pin impressions the results for the legibility of the impressed characters will be presented separately for each firearm.

There were three main factors that contributed to the quality of the impressed characters as well as the quantity of the characters that were transferred: depth of firing pin impression, firing pin drag and multiple strikes of the firing pin in the same impression. Firing pin drag is caused by the cartridge case beginning its ejection prior to the firing pin being fully retracted from the firing pin impression. This causes the firing pin to be drug out of the firing pin impression and across part of the surface of the primer. In some instances this action obliterated some of the transferred characters. Firing pin drag did not occur on all of the firearms tested.

Firing pins striking more than once in the same firing pin impression can cause several different issues. Each time the firing pin strikes the primer it does not strike in the exact same location as the original impression. The method by which the firing pin is secured in the firearm as well as the design of the firearms bolt assembly will dictate the impending results, the character orientation and location of each subsequent strike. The analysis of cartridge cases that were struck more than once by the firing pin was conducted in a specific manner. Many of the cartridge cases containing multiple firing pin strikes showed more legible characters than are present on the firing pin. In these cases, whichever strike produced the greatest number of impressed legible characters was counted. Any legible characters produced by one of the other firing pin strikes were not counted.

Smith and Wesson Model 4006, .40 S&W Semi-Automatic Pistol

Seventeen cartridge cases were collected, throughout the micro-character longevity study from each of the six Smith & Wesson firing pins tested. All six Smith & Wesson firearms produced, on average, firing pin impression of sufficient depth to allow for the engagement of all three types of encoding structures with the primer. Instances of multiple firing pin strikes in the same impression were observed in at least two of the cartridge cases collected from each firing pin. Firing pin drag was also observed from each of the six firing pins tested. In the majority of instances, where firing pin drag was observed, it was responsible for the obliteration of some of the transferred characters.

The alphanumeric characters, for the cartridge cases from all six firing pins, showed an average overall transfer rate of 90%. The percent transfer for any one cartridge case ranged from a complete transfer (100%) to as low as a 38% transfer. The crispness of the alphanumeric characters impressions was diminished through continued firing. This was especially noticed in the evaluation of the first 10 cartridge cases. No discernable overall pattern was identifiable for their transfer rate. The deformation of the “W1” seen on the firing pin had a direct affect on the transferred characters. The flattened “W1” caused these two characters as well as the “S” and the tops of the “2”and “3” not to be legible in the impression.

The dot code structures were the most difficult of the encoding structures to visually identify in the firing pin impressions. An average overall transfer rate of 62% was observed. The percent transfer of dot code structures for any one cartridge case ranged from a complete transfer (100%) to no transfer (0%). A general decreasing trend throughout test firing was noticed in the transfer rate of the dot code structures for all of the firing pins except for firing pin F. The transfer rate of the dot code structures for pin F was sporadic. This decreasing transfer rate can be attributed to the accumulation of foreign debris within the dot code structures.

The transfer of the radial bar code structures to the firing pin impression was directly dependent upon the depth of the firing pin impression. All instances where zero impressed bar code structures were identifiable, the firing pin impression lacked sufficient depth to allow the radial bar code to engage the primer. The average overall transfer rate of 66% for the radial bar code structures was observed. The percent transfer for the number of radial bar code structures transferred to any one cartridge case ranged from a complete transfer (100%) to no transfer (0%). The transfer rate for each of the six firing pins was sporadic, except for firing pin E that showed a general decreasing transfer rate. The quality of transfer of the radial barcode structures was diminished by the degradation of a section of the encoding structures. The peening of a section of radial barcodes by the firing pin aperture caused the transferable length of each bar code structure to be greatly shortened. All tables, graphs and images for the above results are illustrated in Appendix C.

Ruger MK I, .22LR Semi-Automatic Pistol

Given the nature of this rimfire firing pin and firearm design, it was determined that a maximum of five out of the eight alphanumeric characters can contact the rim of the cartridge case, thus providing a maximum possible transfer rate of 63%. Over the 250 rounds of ammunition test fired, the average transfer rate of legible alphanumeric characters was 16%. The percent transfer rate for any one cartridge case ranged from no transferred characters (0%) to a maximum observed transfer rate of 38%. The transfer rate of these alphanumeric characters demonstrated an overall decreasing trend over the course of test firing. This decrease in character transfer rate can be directly correlated to the continual degradation of the alphanumeric characters seen on the firing pin throughout test firing. None of the impressions contained a readily legible “S”. The lack of this character’s presence in the firing pin impression is due to the character being improperly machined off of the face of the firing pin.

Seventy-eight out of the 250 cartridge cases analyzed showed instances where the firing pin struck more than one time in the same impression. These multiple strikes of the firing pin made the characters, already difficult to decipher, more difficult to interpret. This same situation of multiple strikes of the firing pin along with insufficient and poor quality character transfer, by a .22 caliber rimfire, was observed in a study conducted by Krivosta.[1] All data and images for the above results are illustrated in Appendix D.

SeeCamp, .25 ACP LWS Semi-Automatic Pistol

The major issues facing the rate and quality of character transfer for this firearm were the shallow firing pin impressions, multiple strikes of the firing pin within the same impression and flowback. Flowback is the bulging of the primer into and around the firing pin port. This is caused by a combination of the firearm design, weak primer cup material and the high pressure in the cartridge case upon discharge. Flowback was noticed with all brands of ammunition tested; Remington produced the most severe. On cartridge cases with nickel plated primers, the flowback caused this plating to crack, thus increasing the difficulty of impressed character identification.

Of the 394 rounds of ammunition fired, 356 of the cartridge cases showed multiple strikes of the firing pin within the same firing pin impression. In the majority of the multiple strike impressions, the subsequent firing pin strikes displayed a lateral movement. This lateral movement, in some instances, created impressions that appeared to contain more characters in each row of alphanumeric text than were actually on the firing pin. Multiple instances of impressions appearing to contain two rows of five or six characters were observed. This firearm also failed to discharge multiple rounds of ammunition in all brands of ammunition except for Winchester. The ammunition showing the worst failure to discharge rate was CCI Blazer: thirty out of fifty rounds of CCI Blazer ammunition tested failed to discharge.

The alphanumeric characters on this firing pin displayed an average overall transfer rate of 78%. The percent transfer rate for any one cartridge case ranged from a complete transfer (100%) to a minimum transfer of 13%. No overall pattern was identifiable for the transfer percentage of the alphanumeric characters. Each brand of ammunition tested demonstrated a different transfer rate.

The quantity and quality of gear code structures that were identifiable in the firing pin impressions were directly related to the depth of the firing pin impression and the extent of flowback. With increased flowback, the legibility of the gear code structures decreased. An average overall transfer rate of 58% was documented for the transfer of gear code structures. For any one cartridge case a range from complete transfer (100%) to no transfer (0%) was observed for the gear code structures. No discernable overall pattern was noticed for the transfer rate of the gear code structures throughout test firing: the transfer rate was ammunition brand specific.

The radial bar code structures on the SeeCamp firing pin did not transfer to a single cartridge case. This total lack of transfer for this encoding structure was due to the shallow depth of the firing pin impression. The depth of all of the firing pin impression for this firearm was insufficient to allow the radial bar code structures to engage the primer. All data and images for the above results can are illustrated in appendix E.

AMT "Backup" .380 Auto Semi-Automatic Pistol

The only major issue facing the transfer of the encoding structures on the AMT firing pin was shallow firing pin impressions. Throughout the test firing, 224 out of the 700 rounds of ammunition fired showed signs of multiple firing pin strikes in the same firing pin impression.

The alphanumeric characters transferred with an average overall transfer rate of 95%. The transfer rate for any one cartridge case varied from a maximum of 100% to a minimum of 25%. The transfer rate remained relatively constant throughout test firing, except for test fires conducted with Armscor and Corbon ammunition. These two brands of ammunition showed a 10% decrease in the transfer rate.

The gear code structures transferred at almost the exact same pattern as the alphanumeric characters, demonstrating a fairly constant transfer rate except when test fires were conducted with Armscor and Corbon ammunition. The average overall transfer rate for the gear code structures was 94%. The transfer rate for any one cartridge case ranged from a maximum of 100% to a minimum of 22%.

The transfer of the radial bar code structures showed a completely different transfer pattern. The first fifty rounds of ammunition fired demonstrated an average barcode transfer rate of 43%, with a range from 0% to 92% for any one cartridge case. The remaining 650 rounds of ammunition test fired showed a significant drop in the transfer rate of the alphanumeric characters. The average transfer rate for test fires 51-700 was just over 1%. The depths of the firing pin impressions were too shallow to allow for the radial bar code structures to engage the primer. The data and images related to the above results are illustrated in Appendix F.

Sig Sauer P229, .40 S&W Semi-Automatic Pistol

The major issue that affected the legibility of the impressed characters for the Sig Sauer P229 firing pin was firing pin drag. Every brand of ammunition tested, showed signs of firing pin drag, indicating that this is a result of the firearm's function rather than being ammunition brand specific. The gear code and radial bar code structures suffered the most damage from the firing pin drag, however in some cases the alphanumeric characters were affected as well.

Some ammunition manufacturers stamp an identifying character into the surface of the primers placed in their ammunition. Of the ammunition brands tested in this study, CCI Blazer and Speer contained primer stamps. These primer stamps interfered with the transfer and subsequent legibility of the impressed encoding structures. Multiple strike situations were also noticed, but only in 113 cartridge cases out of the 1000 rounds of ammunition test fired. The transfer rates for all three encoding structures followed almost the exact same ammunition brand based trends. CCI Blazer and Remington ammunition produced the worst transfer rates.

The alphanumeric characters showed an overall average transfer rate of 94%. The transfer rate for any one cartridge case ranged from a complete transfer (100%) to a minimum of no legible transfer (0%). The transfer rate of these characters was directly dependent upon the brand of ammunition being tested as well as the severity of the firing pin drag.

The gear code structures provided an overall average transfer rate of 88%, with a range from complete transfer (100%) to as low as 14%. The legibility of the transferred gear code structures was also dependent upon the presence and severity of firing pin drag as well as the brand of ammunition being tested. No correlation was present between the transfer rate of these characters and the number of rounds of ammunition fired.

The radial bar code structures transferred at a much lower percentage when compared with the other two encoding structures. However, the same patter of transfer rate based upon ammunition brand was observed. The overall transfer rate for the radial bar code structures was 29%, ranging from 0-69% for any one cartridge case. All data and images for the Sig Sauer P229 results are illustrated in Appendix G.

Colt 1911, .45 ACP Semi-Automatic Pistol

As previously documented by Krivosta[1], the micro-character impression for the Colt 1911 collected in this study demonstrated a high rate of multiple firing pin strikes in each firing pin impression. Out of the 750 rounds of ammunition test fired 459 of the tests revealed multiple strikes within the same firing pin impression. This was the major issue facing the legibility of impressed characters for this firing pin.

The alphanumeric characters transferred with an overall average rate of 76%, ranging from no transfer (0%) to complete transfer (100%) for any one cartridge case. Around 100-150 rounds of ammunition fired the number “3” began to loose legibility. This decrease in legibility can be associated with the deposition of foreign material seen on the firing pin beginning at 100 rounds of ammunition fired. The transfer rate for the alphanumeric characters was dependent upon the brand of ammunition being tested.

The gear code structures transferred with an average overall rate of 90%. The transfer rate of these structures for any one cartridge case ranged from 57% to 100%. The transfer rates for the gear code structures closely followed the ammunition brand specific pattern.

The radial bar code structures once again showed the lowest transfer rates of the three encoding structures, but still followed the same pattern as that seen with the other two types of encoding structures. The radial bar code produced an overall average transfer rate of 59%, ranging from 0% to 91%. The initial micro-machining errors on this firing pin precluded a complete transfer of the radial bar code structures. The two adjacent bar code structures that did not remain separated at the tip of the firing pin transferred into the firing pin impression as a single bar code structure that was twice as wide as the rest. Since only one large structure was legible, instead of two narrower structures, it was counted as one line. The data and images for the Colt 1911 45 ACP results are illustrated in Appendix H.

Colt AR-15, .223 Semi-Automatic Rifle

Out of the 760 rounds of ammunitions test fired with the AR-15 firing pin only 77 of them had multiple strikes within the same firing pin impression. Golden Bear and Remington ammunitions caused shallow firing pin impressions. This reduction in firing pin impression depth was observed both times each ammunition was tested. Trends for the transfer rates of all three types of encoding structures were noticed following similar patterns specific to the brand of ammunition being tested.

The alphanumeric characters had an observed overall average transfer rate of 88%. The transfer rate for any one cartridge case ranged from no transfer (0%) to complete transfer (100%). A decreasing trend in the transfer rate of the alphanumeric characters was seen over the course of test firing.

The gear code structures on this firing pin transferred with great success. This can be attributed to the lack of firing pin drag and few instances of multiple strikes within the same impression. The overall average transfer rate for the gear code structures was 100%, ranging for any one cartridge case from 75% to 100%.

The transfer rates for the radial bar code structures varied greatly between each brand of ammunition tested. Upon repeated testing, the transfer rate observed for each brand of ammunition was seen to be the same. The overall average transfer rate for the radial bar code structures was 45%. The transfer rate for any one cartridge case ranged from 0% to 92%. The two brands of ammunition that caused shallow firing pin impression showed the lowest transfer rates for the radial bar code structures. The data and images for the Colt AR-15 results are illustrated in Appendix I.

Norinco AK-Series, 7.62x39mm Semi-Automatic Rifle

Without the incorporation of radial bar code structures, the Norinco AK firing pin was evaluated based on the transfer rates of the alphanumeric and gear code structures. This firearm demonstrated the most severe instances of multiple firing pin strikes in the same firing pin impression. Every cartridge case collected had been stuck multiple times by the firing pin. The severity of these multiple strike situations were enhanced due to the change in direction of each impression. Each time the firing pin struck the primer, during one cycle of the firearm, the orientation of the encoding structures was different. This made the identification of the encoding structures impression extremely difficult.

The alphanumeric characters had an overall average transfer rate of 41%. The transfer rate for any one cartridge case ranged from 0% to 100%. These characters showed a decreasing trend in transfer rate through continued test firing. Each brand of ammunition provided a different transfer rate between the first and second test firing, except for the foreign steel case ammunition. The foreign steel case ammunition showed very similar transfer rates between the first and second test firing. The degradation that was noticed on the firing pin was transferred to the quality of its impression. In many of the impressions, the deformed “D” looked like a “0” or “O” in the impression. The other degraded alphanumeric characters increased the difficulty of interpreting the impression. It was not apparent if the deposition of foreign material on the firing pin affected the transfer of the characters into the firing pin impression, due to the severity of the multiple strikes of the firing pin.

The gear code structures followed the same decreasing transfer rate trend and ammunition dependent transfer rates as that of the alphanumeric characters. The overall average transfer rate was 52%, ranging from 0% to 100%. The effects of the foreign material deposits that were seen in the gear code structures could not be identified, once again due to the affects of the multiple strikes of the firing pin. Each additional strike of the firing pin made the identification of the gear code structures very difficult, and in many cases their orientation unknown. The data and images for the Norinco AK results are illustrated in Appendix J.

Mossberg 500A, 12 gauge Pump Action Shotgun

The impressions created from the Mossberg firing pin showed a decreasing trend in the transfer rate in two of the encoding structures: the alphanumeric and gear code structures. These two encoding structures followed similar decreasing patterns. No correlations between transfer rate and the brand of ammunition can be drawn, as each brand of ammunition was only fired once: the first 300 rounds of ammunition fired. The remaining 552 rounds of ammunition fired can only provide individual and overall transfer rates, as the ammunition utilized was of mixed brands and the order of firing was random. One further issue facing the legible transfer of the encoding structures was the presence of oxidation on the surface of some of the primers. The oxidation filled many of the impressions preventing the impressed characters from being identified: the oxidation also hindered the viewing of the impression with cross-polarized light. Throughout test firing 172 of the 852 rounds of ammunition fired showed signs of multiple firing pin strikes. Shallow firing pin impressions were also seen in roughly 100 of the shot shells collected.

The alphanumeric characters transferred at an overall average rate of 50%, ranging from 0% to 100% for any one shot shell. The degradation and flattening of the characters seen on the firing pin was also observed in the impressions. Beginning at around 150-200 rounds of ammunition fired the quality of the impressed characters began to rapidly decrease. The transfer rate for the alphanumeric characters in the first fifty rounds of ammunition fired was 98%, decreasing to a transfer rate of 16% for the last 50 rounds of ammunition fired.

The overall average transfer rate for the gear code structures was 67%. The transfer rate for any one shot shell ranged from 0% to 100%. The transfer rate of the gear code structures decreased with increased test firing; this can be correlated to the identified degradation of these structures and deposition of foreign material with in them.

The transfer of the radial bar code structures to the primer provided no increasing or decreasing trend. The average overall transfer rate for these structures was 63%, ranging from 0% to 100% for any one shot shell. Instances of shallow firing pin impression depth directly affected the percent transfer of the radial bar code structures. See Appendix K for data and images supporting the Mossberg 500A results.

Micro-Character Defacement/Obliteration

Due to the location of the firing pins within the firearms, defacement of the micro-characters while the firing pin is in the firearm will be extremely difficult. The two micro-machined firing pins that were defaced in this study were removed from the firearm.

The time and tools required for the removal of a firing pin varies between firearms. Table 4 lists the time and tools required to remove and immediately replace the firing pin in all of the firearms utilized in this study.

Table 4
Time and Tools Required to Remove and Replace Firing Pins

Firearm	Tool Required to Change Firing Pin	Time
Ruger, .22 LR	3/32" punch	4 min., 30 sec.
SeeCamp, .25 ACP	1/16" punch, needle nose plies	3 min.
AMT, .380 Auto	1/8" roll pin punch, hammer, bench block	1 min
Sig P229, .40 S&W	3/32" punch, hammer, bench block	3 min.
Colt 1911, .45 ACP	1/8" punch	30 sec.
Colt AR-15, .223 caliber	No tools required	1 min.
Norinco AK, 7.62x39mm	1/16" punch, hammer, bench block	1 min., 15 sec.
Mossberg 500A, 12 gauge	1/16" punch, 1/8" punch, hammer, bench block	3 min.

AMT "Backup", .380 Auto Semi-Automatic Pistol

The AMT firing pin was chosen for the defacement test due to the overall shallow firing pin impressions precluding the transfer of the radial bar code structures. One of the intentions of ID Dynamics for machining the radial bar code onto the firing pins was to allow for the transfer of potentially identifying characters in the event that the characters on the face of the firing pin were damaged or intentionally removed. The method of defacement for this firing pin was chosen to test when the alphanumeric characters and gear code structures were removed, whether or not the radial bar code structures would be transferred into the firing pin impression.

The rubbing of the firing pin for 30 seconds on the sharpening stone completely removed the alphanumeric and gear code structures while leaving the radial bar code structures intact. Of the ten rounds of ammunition test fired none of the impressions contained any of the encoding structures, except for one. Cartridge case number seven had two out of the nine radial bar code structures transfer, however they were very faint.

The defacement method was successful and it was documented that even with the removal of the encoding structures from the face of the firing pin the firing pin impressions were too shallow to allow for the transfer of the radial bar code structures. The transfer data and images of the defaced AMT 380 Auto firing pin and cartridge cases are illustrated in Appendix L.

Sig Sauer P229, .40 S&W Semi-Automatic Pistol

The Sig firing pin was chosen for defacement because the majority of the cartridge cases in the legibility study contained impressions of all three encoding structures. The method chosen for the obliteration of the encoding structures on this firing pin was intended to observe the transfer rate upon defacement of all three encoding formats.

The light peening of the encoding structures, for an overall time of 30 seconds, was a successful method of defacement. Through ten rounds of ammunition test fired, no alphanumeric characters were legible in the firing pin impressions. The gear code structures transferred with an average rate of 21%. At least one gear code structure was visible in each impression. Five out of the ten firing pin impressions contained 1 out of the eight radial bar code structures. The transfer data and images of the defaced Sig Sauer firing pin and cartridge cases are illustrated in Appendix L.

Blind Test of Impressed Character Legibility

All character legibility and character transfer data for this study was collected by this author. The author having knowledge of exactly what characters and number of encoding structures were present on each firing pin prior to the observation of their subsequent impressions, analyses of a select number of cartridge cases by impartial parties were conducted to remove any biased conclusions. To conduct this blind test, two cartridge cases were chosen from each of the firearms tested in this study (except for the Smith and Wesson Model 4006 firearms tested at the CHP Academy) for a total of 16 cartridge cases. Table 5 seen below lists the cartridge case number selected for each of the firearms.

Table 5
List of Cartridge Case Numbers Chosen for Blind Test

Firearm	Cartridge Case Number
Ruger	53, 93
SeeCamp	76, 177
AMT	4, 104
Sig Sauer	9, 70
Colt 1911	29, 215
Norinco	126, 130
Colt AR	24, 183
Mossberg	51, 680

The cartridge cases selected for this test were chosen to demonstrate different quality and quantity of micro-character legibility.

Prior to analysis, each of the test participants were provided with a general description of the geometry of the different types of micro-characters that were machined on the second-generation firing pins. A variable magnification stereomicroscope equipped with a ring light and polarizing filter was used for the analyses. The participants were instructed to view each cartridge case and record the number of characters from each encoding format that were legible. This data was then directly compared to the transfer data obtained by this author for each of the sixteen cartridge cases used in this test.

The results obtained from this test varied by participant. The results obtained by this author and those obtained by the two participants in this test were placed into bar graphs so as a direct comparison of transfer results for each encoding format from each cartridge case analyzed could made. The analysis of these comparisons shows variability in the interpretation of the impressed characters. For the sixteen cartridge cases forty-eight comparisons were made. In only nine of the forty-eight comparisons did the results obtained by the two test participants, match those obtained by this author. In the remainder of the comparisons at least one of the sets of results differed, with fourteen comparisons in which all three sets of transfer data differed. The comparisons of these results are illustrated in appendix M.

This blind test demonstrates the occurrence of variability in the transfer data results obtained through visual analysis of the micro-characters' impressions. Each individual that analyzes these cartridge cases will potentially obtain different results. This is due to each individual's interpretation of the "legibility" of the encoding structures and alphanumeric characters.

The concept of laser-machined micro-characters on firing pins explored by ID Dynamics can be a feasible technology. Overall, the alphanumeric characters and the gear code structures proved to be capable of withstanding repeated firing, however, some degradation of the structures was seen with specific firearms. Since varying amounts of degradation of the micro characters was observed between all of the firearms tested, a determination of what constitutes an acceptable lifespan for these characters needs to be developed. Further research and development are required for the use of this technology on rimfire firing pins.

The dot code structures tested on the Smith and Wesson firing pins were determined to be an unsuitable form of encoding structure for this technology. Due to their relatively small dimensions (in comparison to the other encoding structures) they suffered severe degradation as well as severe deposition of foreign material making them illegible on the firing pin. These same issues were realized by the manufacture and were the reasons for the change to the gear code structures on the second-generation firing pins.

The radial bar code structures withstood repeated test firing overall, however issues with specific firearms were noted. The flattening/obliteration of a portion of the radial bar code structures by the continual contact with the firing pin aperture was observed on eight out of the fourteen firing pins tested: the SeeCamp 25 ACP, AMT 380 Auto and all six of the Smith & Wesson Model 4006. Since a limited number of firearms were tested in this study, it is unknown how many different firearms will produce this same result. A second issue facing the radial bar codes arose with the observed degradation of the separating structures between groups of bar code structures on the Sig Sauer firing pin. It was unknown if this degradation was a result of these separating structures being machined too narrow, or if it was due to the material from which the firing pin was manufactured. This degradation will directly affect the width of the radial bar code structures as well as their impressions, thereby directly affecting the legibility and potential decoding.

The quality and legibility of the impressions of the three encoding formats were firearm and ammunition brand specific. Each firearm demonstrated a different transfer pattern. The function and design of each firearm affected the manner in which the firing pin struck the primer or rim of the cartridge case, thereby controlling the depth of the firing pin impression and the presence or absence of firing pin drag, multiple strikes of the firing pin and flowback.

Three of the firearms tested showed signs of decreasing overall transfer rates throughout test firing, however the transfer rates for each of the encoding formats was seen to be directly dependent upon the brand of ammunition tested. Each brand of ammunition provided a different transfer rate that can be seen in the "Encoding Structures Transfer Trend" graphs locate in the appendix for each firearm. In most all instances the transfer rate for each brand of ammunition was constant upon repeated test firing. The testing of such a wide array of ammunition brands demonstrated that the brand of ammunition utilized plays a direct role in the percent transfer and legibility of the micro-characters. Unfortunately, the brands of ammunition available to the public are most likely uncontrollable.

It was demonstrated that the encoding structures on the firing pin can be damaged or obliterated with relative ease once the firing pin is removed from the firearm.

The alphanumeric encoding format is currently the only one of the three encoding structures utilized on the second-generation firing pins that will allow for the potential identification of a firearm. ID Dynamics could provide no information regarding the reading and decoding the impressed radial bar code and gear code structures. This lack of information precludes the analysis, assessment and viability of these two encoding formats.. Without decoding protocols, it is unknown what factors and quantity of degradation will negate a positive identification of a firearm from these two encoding formats. The results provided in the text above and in the appendices only provide the quantity of the radial bar code and gear code structures that were transferred into each firing pin impression. No data was collected regarding changes in the dimensions and or spacing of the structures for these two encoding formats. In order for the radial bar code and gear code formats to be utilized as a method of individual firearm identification from micro-serialized firing pins, the methods for reading and decoding these two encoding formats must be obtained from the manufacturer and tested.

Estimated Costs for Firing Pin Fabrication

We developed cost estimations based upon two scenarios. The cost estimates assume a large production effort and serialization of numerous firing pins. The details of the cost estimate and the source of the data is listed in Appendix N Estimated Cost for Equipment Setup and the Machining of Micro-Serialized Firing Pins. These costs assume full-scale production of serial firing pin for all new handgun sold in California. If micro-serial requirement applies only to a few selected new models, one can logically expect a dramatic increase in manufacturer production costs which would invalidate the cost efficiencies we used in our estimate.

Scenario 1:
Stand alone processing station capable of engraving 100-200 firing pins per day.
First year cost per engraved firing pin - **$7.87**

Scenario 2:
Fully automated processing station, capable of engraving 1000 plus firing pins per day.
First year cost per engraved firing pin **-$6.72**

These costs are very conservative costs and can be much higher. In fact, if additional processing steps are added such as deburring, etching, and diamond coating, then the end cost can be much more than what has been calculated in Appendix N

External Review of the Micro-Serial Number Report.

The initial report submitted to the CPRC was reviewed by three external reviewers; Lucian Haag, a well known independent firearms expert, and former president of the Association of Firearms and Toolmark Examiners (AFTE) and Simon A. Cole and George Tita from the UC Irvine Department of Criminology, Law & Society, School of Social Ecology. These unedited reviews and the responses to some of the suggestions appear in Appendix O. External Review of the Micro-Serialized Report.

In summary Mr. Haag said: ***"The research presented not only fulfills the general objectives stated in the Report but goes beyond in that it also addresses the second generation micro-serialization---"*** *"The authors clearly understand forensic science and forensic firearms evidence. Their appendices also demonstrate skilled use of stereo microscopes and scanning electron microscopes. Other forensic scientists should have no difficulty in reaching similar conclusions from a detailed inspection of the data and illustrations in this Report"*.
Professor Cole said: "***This is a comprehensive and informative report. The research was performed appropriately and competently, and the report clearly and coherently reports the results of the research". "The investigators have appropriately performed the research they set out to do. They have also addressed some important issues that I do not recall from the original proposal (e.g., Recommendation #3, which is excellent and insightful***".

Professor Tita said: ***"I have found the research report to be written in a clear and concise manner ----. The authors have also done a solid job in fulfilling the stated purpose of the originally funded research proposal. It is my opinion that the report provides extremely valuable information with regards to the pending legislation regarding the implementation of a micro-imagine process for firing pins on all guns sold in California (Assembly Bill 1471). The research findings and recommendations, all of which are supported by the careful and compelling analyses conducted by the authors, clearly demonstrate that funding such a program would be wasteful without further research".***

POLICY IMPLICATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The finding of this study have direct implications for the *Crime Gun Identification Act of 2007*'s (AB 1471's) proposed application of second-generation micro-serialized firing to *all* semiautomatic handguns sold in the state of California. As shown, while micro-stamping technology works with some firearms, it does not perform equally well for every encoding format or in every semiautomatic handgun. As only a limited number of firing pins, encoding sequences, and firearms were tested in this study, it is unknown how this emerging technology would function across the board in relation to all the different makes and models of semiautomatic handguns sold in California each year. Given this uncertainty this research suggests that is this technologies current stage of development it is likely inadequate to provide the satisfactory transfer of the micro-character from all firearms currently on the California Safe Handgun List. To determine if any other firearms equipped with this technology will inadequately provide a satisfactory transfer of the micro-characters, one of every make and model of semi-automatic handgun sold in the state of California would have to be tested. This would implicate that over 2000 different firearms would have to be equipped with micro-serialized firing pins and thoroughly tested.

Furthermore, it must be determined if the current placement of an eight-digit alphanumeric code (consisting of two lines of four characters) on the face of the firing pin will accurately allow for the inclusion of sufficient information to create a searchable database associating this encoding format with the "make, model and serial number of the pistol" as required by AB 1471 (and by AB 352. *At the present time, therefore, because its forensic potential has yet been fully assessed, a mandate for the implementation of this technology in all semiautomatic handguns sold in the state of California is counter-indicated. Further testing, analysis, and evaluation are required.*

Several areas calling for further research recommend themselves, including:

1. Criteria to determine the transfer rate required for identification

The data collected for each cartridge case in this study only provides the transfer rate of each encoding format. In order for this information to be useful, criteria need to be set stipulating exactly what transfer rates (for each encoding format) constitute a sufficient quantity of characters to allow for the potential identification of the firing pin that produced them. These criteria should be created in conjunction with practicing firearms examiners, the state of California and the personnel responsible for the creation of the database for this technology.

2. Decoding protocols for properly interpreting radial bar and gear codes

At the current time no protocols have been provided regarding the proper interpretation of the radial bar codes and gear codes. Without such protocols the impressions of these encoding structures are nothing more than that: impressions. Decoding conventions need to be obtained from ID Dynamics for these two encoding formats to be interpretable. Once this information is obtained, testing will need to be conducted to determine what factors affect their interpretation, such as changes in width and spacing. Without these instructions the radial bar codes and gear codes are rendered mute, unable to provide any identifying information.

3. Firearm-related crime statistics to be compiled

A survey of crimes committed with semiautomatic handguns needs to be compiled and sorted into two specific categories: crimes committed by the registered owner of the firearm and firearm crimes committed by someone with a firearm not registered to the end user, such as gang related shootings. In the crime laboratory, it is the firearms used in gang related shootings that are of most concern. It is not unusual to link several homicides based on fired cartridge case identifications from the IBIS system. When the responsible handgun is later recovered from a suspect, they are unable to charge the suspects with the prior homicides because the gang participants pass the handguns between their fellow members. By looking at the source/history of these recovered handguns we can estimate whether or not the issue of firing pin serialization would have a significant effect on linked the suspect to the actual homicide. This information will aid considerably in determining the potential benefit this technology will provide to the law enforcement community for the identification of possible suspects and potential leads to the identification of individuals responsible in firearm-related crimes.

4. Implementation strategies to be developed collaboratively

The development of a viable commercial implementation strategy for this technology is a necessity. This must be completed in collaboration with officials from the state of California, firearms manufacturers and ID Dynamics. Many different implementation strategies for this technology may be possible. The laser micro-machining could be conducted by the state, each individual firearm manufacture, a combined effort of the two, or by another private entity. These and other scenarios should be prototyped and evaluated prior to the legislative and commercial implementation of this technology.

5. Technology implementation prototype to be piloted

Prior to implementing this technology statewide, a smaller-scale prototype should be piloted. The ideal scenario for testing such a prototype would be a group of selected law enforcement agencies equipped with about 3,000 semiautomatic handguns. This number provides an incentive for vendors with firing pin engraving technology to come up with competitive bids to manufacture such serialized firing pins, which would have unique serial numbers. It would also expand the study by providing for a mix of different handgun and calibers for those that we have not tested. This number of firearms equipped with micro-machined firing pins should be sufficient to allow for a more accurate evaluation of this technology. This study would provide beneficial information as to the time required and cost incurred for the laser machining of micro-characters onto firing pins. It would also address the suitability of such micro-numbers in handguns other than the CHP Smith and Wesson firearms. As an example, Glock firing pins are substantially different and have different dynamics. Furthermore if radial and gear code technology is to be contemplated, we need to test the coding structure with realistic serial numbers.

6. Relevance to Current Firearms

The firearms and firing pins used in this study are relevant to current firearms and most of their future model changes. The manufacture of firearms is a traditional and incremental process and any changes happen over a long period of time. Many model variations of firearms involve only incremental change to that particular firearm. The CHP Smith and Wesson pistols used in this study were new pistols purchased by the CHP. The Colt 1911 design pistol is still produced both in the traditional design and new model variation with interchangeable parts. Thus our expectation is that the results of the firing pins used in this study will be relevant to the current models we tested and the future derivatives.

What Micro Serialized Firing Pins Can Add to Firearm Identification in Forensic Science: How Viable are Micro-Marked Firing Pin Impressions as Evidence?

APPENDICES

Appendix A thru Appendix O are listed in a separate PDF document.