THE EFFICACY OF ACIDIFIED HYDROGEN PEROXIDE ON CARTRIDGE CASES AS A LATENT PRINT DEVELOPMENT TECHNIQUE

by

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List of Definitions/Abbreviations

AHP	Acidified hydrogen peroxide
ALS	Alternate light source
CA	Cyanoacrylate ester, also known as superglue
Clarity	How well the ridges reproduced
dH_2O	Distilled water
DSLR	Digital single lens reflex camera
Fingerprint residue	A mixture of water, inorganic and organic compounds excreted from glands
FSIS	Full Spectrum Imaging System
GB	Gun blue
H_2O_2	Hydrogen peroxide
Percent Yield	The percent ratio of the actual yield to the expected yield
R.A.Y.	A combination of Basic Red, Ardrox, and Basic Yellow dye stains
S&W	Smith & Wesson, a firearm manufacturer
Substrate	Surface the friction ridge impression is on

Abstract

Friction ridge impressions, commonly known as fingerprints, are a type of evidence investigators search for when examining crime scenes and evidence. They are left behind by friction ridge skin after physical contact with a surface. These impressions not readily visible by the naked eye are latent prints. Latent prints are composed of oils, perspiration, and other constituents (Dutelle, 2014). In order to visualize these impressions, agencies follow protocols proven to develop prints on various surfaces of substrates. A cartridge case is a nonporous surface, which means the fingerprint residue will not be absorbed by the substrate. Due to the small surface area and the influence of the firing process on any impression left behind, recovering latent prints on cartridge cases is a challenge. This study aims to analyze the effectiveness of various formulations of Acidified Hydrogen Peroxide (AHP) as a fingerprint processing technique on various metal-types of unfired and fired cartridge cases. A subsequent study analyzes how the processing technique can be implemented in conjunction with three commonly used chemical processing techniques for cartridge cases. The techniques are cyanoacrylate ester fuming, fluorescent dye staining, and gun bluing. This study revealed that a manufactured formula of AHP developed the greatest number of samples compared to other formulae. This study also showed that the sequence of AHP, cyanoacrylate ester fuming, and then R.A.Y. developed the greatest number of samples with measurable ridges by the end of the sequence.

Keywords: *latent prints, acidified hydrogen peroxide, unfired cartridge cases, fired cartridge cases, ridge development*

Introduction

Overview

In the fingerprint community, recovering latent prints from cartridge cases is a challenge. A cartridge case is a nonporous surface, but latent prints cannot be easily retrieved due to the small surface area and the influence of the firing process, such as friction, heat, propellant byproducts, and pressure (Girelli et al., 2015). Agencies use chemical and physical techniques to enhance the visibility of these impressions, such as cyanoacrylate ester fuming, dye stains, and powders for nonporous surfaces, and gun bluing specifically for cartridge cases (Chesapeake Bay Division - International Association for Identification [CBD-IAI], n.d.). They follow an established sequential protocol that has been proven to work across various surfaces of the same substrate type. Acidified Hydrogen Peroxide (AHP) is a post-gun blue treatment step in a cartridge case latent development kit (Tritech Forensics, n.d.). A study examining the use of AHP to remove excess Gun Bluing (GB) on treated cartridge cases noted observations of AHP oxidizing ("etching" or "cleaning") around oxidation-resistant substances, revealing ridge impressions on cartridge cases (Cantu et al., 1998). This solution is available through a manufacturer, but it can also be made by distilled white vinegar with over-the-counter hydrogen peroxide.

Questions asked throughout this research are:

- Will this method develop latent prints on different types of metal cartridge cases or is it limited to certain metals?
- Is this method destructive to the latent print? If so, how destructive?
- What formulation of AHP will recover any ridge detail?

- Can this processing technique be incorporated into a widely accepted sequential processing protocol for nonporous surfaces or will this method perform better on its own?

Based on previous research, the hypotheses of this study are that AHP would develop latent prints on unfired brass and nickel cartridge cases, while fired cartridge cases will result in unrecoverable ridges. The commonly used sequence method that would develop the most latent prints would be cyanoacrylate ester fuming, R.A.Y., and then AHP.

Importance of Research

While there is existing research on the effectiveness of different formulations, most of the results are classified by whether or not the latent print is "of value" or "not of value." The comparison is confirmed by a latent print examiner. A study conducted by Swofford et al. (2013) concluded that AHP negatively interferes with the microscopic details evaluated in firearm examinations (p. 359). Though it interferes with firearm examinations, they recommend that if AHP is used, it should be on cartridge cases only after cyanoacrylate ester fuming and a fluorescent dye stain. The cartridge case should not be in the solution for more than 75 seconds. The goal for this research is to observe and analyze the latent print after each development step, including the firing process, through qualitative and quantitative measurements.

Background Information

Skin is a three-dimensional surface. There are two different kinds of skin on the body: smooth and friction ridge skin. Smooth skin is generally smooth, contains hair, and has sebaceous and eccrine glands. Friction ridge skin is corrugated, hairless skin and only contains eccrine glands (Maceo, 2016; Yamashita & French, 2016). Sebaceous glands secrete primarily lipids while eccrine glands excrete water and organic compounds.

Friction ridge skin is only found on the palms of hands and the soles of feet of humans, as it exists in order to help to grasp surfaces. When a finger comes in contact with a surface, there is fingerprint residue that transfers onto the surface of the substrate, creating a friction ridge impression. These impressions are usually latent, meaning they are invisible to the naked eye. They need to be visibly enhanced through photography or lifted directly from the surface with powder and tape, and to be included in the documentation of the crime scene. Latent print examiners analyze the clarity of these latent prints, or how well the ridges are reproduced as a print (Ashbaugh, 1999). They evaluate each print based on levels of details established by Ashbaugh (1999). Level 1 detail refers to the overall pattern of the friction ridge impression, as shown in Figure 1. This level of detail can only classify impressions into pattern types. Level 2 detail evaluates the specific ridge path. Depending on how the ridge path behaves, it creates characteristics called Galton details (Dutelle, 2014). Level 3 detail refers to the ridge shape and the relative location of pores on the ridge. Figure 2 shows some of the different types of Galton details and shows pores along the ridges. The presence of Levels 2 and 3 can make the print potentially be identifiable.

Figure 1

Types of Level 1 Fingerprint Patterns (Felinczak, 2016)

Figure 2

Types of Level 2 and presence of Level 3 Details (Borah et al., 2015)

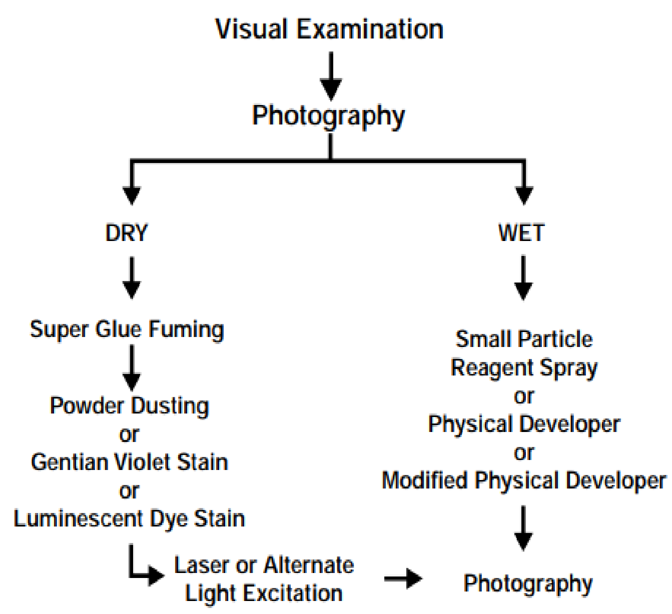
Two factors that can influence the clarity of a print are deposition and distortion. Deposition refers to the differences that affect the number of ridges recorded and the thickness of them (Ashbaugh, 1999). Light deposition shows the impression of the top of each ridge. Medium deposition flattens the ridges slightly and reveals the most Level 3 details. Heavy deposition flattens the ridges even more, which can fill in the Level 3 details. Extremely heavy deposition is when the furrows of the fingerprint also come in contact with the surface, potentially obliterating Level 2 and 3 details. Clarity tends to increase towards the outer edges of a print despite the heavy deposition. Distortion can also affect the clarity due to the movement of the friction ridge skin while it is in contact with the surface, resulting in smearing the fingerprint residue. All impressions, smudged or clear, go through the same scientific approach, regardless of how long the analysis may take.

Apart from latent prints, there are two other types of friction ridge impressions: patent and plastic. Patent prints are easily seen in ambient light due to the fingerprint residue mixed with another substance, such as dirt, blood, or ink. Plastic prints are when a three-dimensional impression is created on a moldable surface, such as gum or wax. Unlike patent and plastic prints, latent prints need chemical and physical processing techniques to make them visible. The processing techniques are based on the substrate type the impression is on and what the chemicals react with. Two main substrate types are porous and nonporous. The fingerprint residue would be absorbed by a porous substrate. On a nonporous surface, the residue remains on the surface. Chemicals react with the specific constituents on the fingerprint residue to develop latent prints. For example, 1,2-indandione would react with the amino acids, and under an alternate light source (ALS), the latent print would become visible. A combination of chemical and physical processing techniques is used to increase the possibility of developing a latent print clear enough for comparison.

For porous and nonporous surfaces, there is a sequential processing followed in which reagents are used in order from least likely to be destructive to most likely to be destructive to the latent print. The sequential processing for nonporous surfaces can be seen in a flow chart created by Lee & Gaensslen in Figure 3. At any point, if there is a visible latent print, it needs to be photographed in the event that it is no longer visible after subsequent processing.

Figure 3

Flow Chart of The Systematic Approach for Developing Latent Prints on Nonporous Surfaces (Lee & Gaensslen, 2001)



The evidence would go through a visual examination with ambient lighting and an ALS. Though it is not common to come across a latent print that naturally fluoresces under an ALS, it is not impossible. Once the evidence has been examined under lighting conditions, it goes through a cyanoacrylate ester fuming. This is a non-abrasive technique and is semi-permanent (Lee & Gaensslen, 2001). In a humidity-controlled chamber, CA monomers are heated to vapors. The monomer vapors are circulated in the chamber. Once the vapors encounter the fingerprint residue, polymerization of the CA monomers begins (Bleay et al., 2017; Swofford et al., 2013; Yamashita & French, 2016). The residue turns translucent, off-white under ambient light. The chamber is purged of the toxic fumes before retrieving the evidence for another visual examination.

For some nonporous items, it may be difficult to visualize the cyanoacrylate-treated latent prints due to a lack of contrast against the substrate. The evidence is treated with a fluorescent dye stain to provide better contrast than just cyanoacrylate esters alone, which are not highly luminescent under an ALS (Lee & Gaensslen, 2001). An alternate light source is "a light-emitting device viewed with light of a narrow wavelength range, rather than the usual full spectrum ('white light') viewing range" (Dutelle, 2014, p. 182). When the ALS shines on the dye-stained latent print, molecules of the dye stain would be excited into a higher energy level and then lowered back to its original energy level. The energy released to return to its original state is in the form of light called photoluminescence (Yamashita & French, 2016). Items that fluoresce would cease to fluoresce when the ALS is no longer shining on them. There is a wide variety of dye stains which each fluoresce under different wavelengths, such as Ardrox, Basic Yellow 40, R.A.M., and Rhodamine 6G. Choosing a dye stain is based on the examiner's preference or whichever dye stain would give the best contrast against the background. The evidence is sprayed or immersed into the dye stain, which is absorbed by the CA polymers (Yamashita & French, 2016). The stained polymers would fluoresce under an ALS light and can be seen with the appropriate barrier filter. The barrier filter “blocks the reflected wavelengths of light from the light source while allowing the fluorescent wavelengths to pass through” (Yamashita & French, 2016, p. 7-29). These can also be photographed with the respective barrier filter attached at the lens of the camera.

Some nonporous surfaces have other processing technique options that can be used with the current or a modified version of the processing sequence. Gun bluing (GB) is a technique used specifically for brass cartridges. This chemical is traditionally used to refinish clean guns. If there is any grease or dirt on the surface, the chemical will not adhere to those parts. For latent print processing, the GB solution is prepared by diluting it with water. When the evidence is immersed in the solution, a reaction between the selenious acid and the metal surface occurs, creating a black-blue copper-selenium coating (Yamashita & French, 2016). It is advised that a cyanoacrylate ester fuming treatment is used prior to gun bluing to improve the detection of the latent print (Yamashita & French, 2016). The GB would not react with the CA polymers and gives a dark contrast against the white latent. Overdevelopment can occur if the evidence is submerged for too long, which can potentially damage the print. Some manufacturers produce a cartridge case development kit, which includes an additional solution to remove excess GB. Cantu et al. (1998) studied the excess GB on GB-treated cartridge cases and used Acidified Hydrogen Peroxide (AHP) to remove the overdevelopment. AHP is a solution of a weak acid and hydrogen peroxide that oxidizes (“etches” or “cleans”) around oxidation-resistant substances on metallic surfaces, such as fingerprint residue. On some materials, the remaining residue appears greyish-white against the “clean” surface. This cleaning provides a better visualization of the latent print on the cartridges.

Cartridge cases found at a crime scene help investigators reconstruct a scene and establish a sequence of events. A fired cartridge case could be found in proximity to where it was ejected from the semi-automatic firearm. It is assumed that the “high temperatures, abrasion, and deposition of propellant residue all reduce the chances of recovering” latent prints (Bleay et al., 2017, p. 237). Despite going through the explosive firing mechanism of a firearm, partial latent prints can still be developed on fired cartridge cases. The clarity of the initial latent print is dependent on the deposition pressure used and unintentional distortion applied to the ammunition when being loaded into a magazine. Factors, such as the surfaces it comes in contact with after being ejected from the firearm, can also affect the clarity of the latent print. Acknowledging these possible post-transfer factors that could destroy the latent print can help examiners understand that they would be only processing partial prints or nothing at all.

Previous Research

Acidified Hydrogen Peroxide was used as a step to remove excess gun blue from gun-blue treated cartridge cases (Tritech, n.d.). A glacial acetic acid/hydrogen peroxide/distilled water solution, distilled vinegar/hydrogen peroxide solution, and a concentrated hydrochloric acid/hydrogen peroxide/distilled water solution were observed to see which formulation would remove the overdeveloped gun blue. Cantu et al. (1998) also noted the ability of AHP to visualize latent prints without gun blue and tested the AHP solutions on freshly placed prints. They concluded that the hydrochloric acid solution developed the latent prints faster but also had a tendency to remove the sebaceous oils. The distilled vinegar/hydrogen peroxide solution developed prints on the brass cartridge cases. Due to the reduction-oxidation reactions occurring, after each cartridge case was processed, the solution was discarded to avoid any metal ions redepositing onto the next cartridge case. The authors observed the presence of ridge detail. In conclusion, the best formulation that did not harm the latent print was the distilled vinegar, hydrogen peroxide, and distilled water solution, which are all conveniently available at a local grocery store.

A variation of brass and nickel cartridge cases underwent a sequential processing study, where AHP was combined with reagents used by an agency for cartridge case evidence (Edmiston & Johnson, 2009). The protocol they used was an hour of cyanoacrylate ester fuming with an overnight drying period, black powder, and Rhodamine 6G (R6G). The authors observed different sequences, starting with CA fuming followed by these reagents and AHP. In the first phase of their experiment, the cartridge case was already fired, cleaned of any residue, and then the latent print randomly deposited. The cartridge cases were dipped for 30 seconds in an AHP solution, which consisted of 14.1 mL of 5% vinegar and 20 mL of 3% hydrogen peroxide. The data analysis involved counting the number of ridges present and whether the print was deemed “of value”, meaning it could proceed to comparison analysis. The authors concluded that the best sequence for brass cartridge cases was CA - powder - AHP - R6G, while the best sequence for nickel cartridge cases was CA - R6G - AHP - powder. Their experiment underwent a second phase to test their sequences with a random sample of brass and nickel cartridge cases. They also tested both sequences on shotgun shells. Though an optimal sequence was determined for brass cartridge cases, there were no prints “of value” when examined by a latent print examiner. Their nickel sequence developed a couple samples with “potentially identifiable prints” (Edmiston & Johnson, 2009, p. 1331). The shotgun shells only produced ridge detail when it was viewed with an alternate light source, which is expected since it had a plastic exterior and AHP reacts with a metal surface. They concluded that the best sequence for nickel, brass, and shotgun shells is the CA - R6G - AHP - powder.

Swofford et al. (2013) evaluated the performance of AHP versus CA/R6G, the effect of time exposed to AHP on the cartridge case, and whether AHP interferes with firearm examination. The authors used an amino acid matrix, a sebaceous latent print matrix, and natural oils as fingerprint residue. They processed and observed the brass cartridge cases with 15 minutes of CA fuming, 15 minutes venting, and R6G before moving forward to AHP. They processed the cartridge cases until a latent print developed but not exceeding 75 seconds. The authors concluded that AHP and CA-R6G-AHP were comparable to each other but provided better results than CA-R6G alone. An experiment was conducted to see if there was a correlation between the time the sample is in the solution and the characteristics available for firearm analysis. They concluded that though the samples were deemed “suitable for comparison” by firearm examiners, “some degree of degradation is occurring in as little as 20 seconds” (Swofford et al., 2013, p. 366). Because of this conclusion, the authors believed that AHP is not superior to CA/R6G despite showing more ridge detail. The latter is nondestructive on the microscopic characteristics firearm examiners use for their comparisons while developing latent prints successfully.

Experimental Design

The ammunition chosen is based on what is commonly processed by police. The firearm available to use, the Sig Sauer P226, is a semi-automatic .40 caliber gun, which is a common type of firearm. The size of the cartridge case had a large surface area, which was more likely to yield enough ridges for analysis. Brass, nickel-coated brass, and aluminum ammunition were also used in previous research. Steel ammunition was also another option compatible with the firearm.

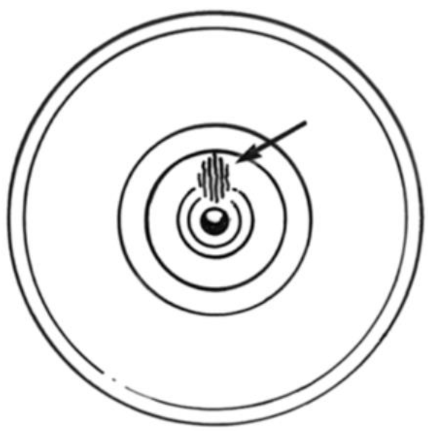
Throughout the entire procedure with the exception of firing the weapon and the donor finger when it was depositing latent prints on the cartridges, gloves were worn. The right thumb was selected as the donor finger. This finger was selected because it is the finger that is used to load a magazine. An area on the thumb was selected based on the number of Galton details present. When depositing the latent prints, a depletion series was used per metal type. By completing a depletion series, the amount of fingerprint residue on the donor finger would lessen after each contact with a surface. When labeling the samples, the sample nomenclature in Table 2 of Appendix B was used, which consisted of the first initial of the metal type, the term it is in the depletion series, and the formula. Experiment #2 followed a similar sample nomenclature with the exception that the initial of the metal type was doubled, as seen in Table 3. For example, B2_3 is the second brass sample processed with the third AHP formula of Experiment #1, while AA1_4 is the first aluminum sample of Experiment #2 going through Sequence #4.

The firing range used was an outdoor, concrete range. For safety purposes, each cartridge was fired and allowed to eject naturally. It fell onto the concrete floor. The sample was retrieved when it stopped bouncing off the surface and the range was made safe. This may explain any additional scratches that appeared on the cartridge case upon examination.

Only one cartridge was loaded into a magazine with the latent print and sample name facing upward. This was to ensure that each latent print was positioned the same way and reflects the natural position of a latent print when one is loading a magazine. Knowing that each cartridge was oriented this way proved to be important since the sample name, written in Sharpie, was obliterated from the cartridge case. This became an obstacle when orienting the samples for photographs. A firing pin drag was found on the headstamp of the cartridge case as seen in Figure 4. Once a firearm is in battery, or is loaded and ready to fire, the trigger is pulled, causing the firing pin to come in contact with the primer, initiating the explosion reaction that propels the bullet forward. The barrel breaks battery for a brief second and drops slightly when the slide of the gun slides backwards. If the firing pin is protruding during this second, it will cause the firing pin to drag upwards at the 12 o'clock position (Legally Armed America, 2018). The drag would be pointing towards the position of the latent print.

Figure 4

Firing Pin Drag (Glossary, n.d.)



The latent prints were deposited onto the cartridges, and the samples that needed to be fired were fired that same day. To ensure the latent print was on each sample before being fired, a Full Spectrum Imaging System (FSIS) was used to photograph in initial print. Post-firing photographs were also obtained to observe if any of the latent prints were visible prior to processing. These images served as a baseline to see how much of the latent print was developed with AHP. The samples were processed over a three-week period, beginning a week after the latent prints were deposited. Experiment #1 was conducted the first week. Cyanoacrylate ester fuming was conducted the second week for all the samples of Experiment #2. The CA fuming would stabilize the print onto the cartridge case. The first week of Experiment #2 consisted of sequences involving CA fuming, dye stains, and AHP. The second week of Experiment #2 involved gun bluing and AHP. Though it is not usual in a realistic scenario to wait a week after CA fuming samples before going onto the next step, this was due to laboratory space availability.

The purpose of Experiment #1 is to observe the latent print development of different AHP formulations. The AHP solution of 14.1 mL of 5% vinegar and 20.0 mL of 3% hydrogen peroxide, used by Edmiston & Johnson (2009), developed latent prints on brass cartridge cases. A second formula, used by Cantu et al. (1998), diluted glacial acetic to 16% with 3% hydrogen peroxide. The last formula is a manufactured AHP from Tritech Forensics. If multiple formulations can produce latent prints on cartridge cases, it would provide examiners formula options based on what chemicals are available to them.

The purpose of Experiment #2 is to find an optimal sequence with AHP and to compare it with an existing protocol for cartridge cases. Formula #2, the diluted glacial acetic acid and hydrogen peroxide combination, had the most Level 2 latent print development from Experiment #1 and was used in Experiment #2. Fired cartridge cases were used for this experiment with the assumption that if latent prints develop on a fired cartridge case, as long as there is minimal post-transfer contact, latent prints will not be obliterated and can be developed with unfired cartridges. The dye stain chosen for this experiment was R.A.Y., which consists of Basic Red, Ardrox, and Basic Yellow (Sirchie, n.d.). Using this dye stain would increase the chances of good contrast. The 97.7 to 2.3 ratio of water to gun blue was adapted from Dominick & Laing (2011).

Materials and Methods

Materials

- Shooting range

- Donor finger
- Chemical hood
- Cartridge cases (.40 S&W)
- Brass: Federal Ammunition, American Eagle, 180 grain, MPN: AE40R3
- Nickel: Federal Premium Law Enforcement, 165 grain, MPN: P40HST3
- Steel: TulAmmo 40 S&W, 180 grain, MPN: TA401800
- Aluminum: Federal Ammunition, 180 grain, MPN: CAL40180
- Alcohol prep pads (Medline, 70% isopropyl alcohol)
- Storage bin
- Egg cartons (5 x 6 slots)
- Adhesive bandage (Bain-Aid, skin-flex)
- Knife
- Sig Sauer P226 firearm
- Extra magazines
- Ultra-fine sharpie
- Gloves (Halyard, Sterling SG nitrile, powder-free)
- Fingerprint ink
- Ink slab
- Ink roller
- 8.5in x 11.5in white paper
- Ten-print card
- Full Spectrum Imaging System (Arrowhead Forensics)
- Clamp stand

- Face shield
- iMac
- Nikon Camera Control Pro 2
- Distilled white vinegar (Great Value, 5%)
- 3% hydrogen peroxide (CardinalHealth)
- Glacial acetic acid (Fisher Chemical, A35-500)
- Distilled water (dH_2O)
- Manufactured acidified hydrogen peroxide (Tritech Forensics)
- Brown Paper
- Legos
- 5 cm Scale
- Superglue (Omega-Print Cyanoacrylate Fuming Compound)
- Metal tin
- Misonix CA-6000D Cyanoacrylate Fuming Chamber
- Wire rack
- R.A.Y. with spray nozzle (Sirchie)
- Acetate sheet
- Birchwood Casey Liquid Gun Blue
- Two 20 mL beakers
- 250 mL beaker
- 10 mL graduated cylinder
- 25 mL graduated cylinder
- 50 mL graduated cylinder

- 6-watt Coherent TracER Laser
- Orange barrier filter
- Orange filter goggles
- Nikon D610 DSLR with a 60 mm Nikon Lens
- Lab coat
- Stopwatch
- HP Computer with Adobe CC Photoshop and Illustrator

Methods

Sample Preparation

1. Brass, nickel, steel, and aluminum ammunition were obtained and cleaned with alcohol prep pads to remove any residue or possible fingerprints on the surface.
2. The thumb was selected as the donor finger and rolled onto a sheet of paper and a ten-print card. A fingerprint examiner selected an area with at least 12 Galton details.
    a. To ink a finger for printing, a small dot of fingerprint ink was applied to an ink slab. An ink roller was used to spread the ink across the slab. The finger was rolled onto the ink and then rolled onto the paper or ten-print card.
        i. Because the right thumb was used, the finger was rolled towards the body from the right nail bed to the left nail bed.
3. With a knife, an opening the size of the selected area was cut on one of the adhesive flaps of a band aid.
4. The band aid was carefully placed on the selected area of the thumb.
    a. To confirm that the opening was placed in the correct area, the donor finger was re-inked, stamped on the paper, and cleaned with an alcohol prep pad.

5. Each sample was labeled on the body of the cartridge case towards the rim with an ultra-fine sharpie, giving enough room to deposit a fingerprint between the label and the mouth of the cartridge case (See Appendix B).
6. The egg carton slots were labeled so each slot housed a single cartridge.
7. The donor finger was coated with sebaceous oils by swiping it across the forehead.
8. A fingerprint was deposited on the first brass sample of the first set in the vacant space above the label and returned to the appropriate sample slot.
9. Without swiping the finger across the forehead again, a fingerprint was deposited on the second brass sample and returned to its slot.
10. Without swiping the finger across the forehead again, a fingerprint was deposited on the third brass sample and returned to its slot, completing the depletion series for the metal type of this set.
11. Steps 7-10 were repeated with the nickel, steel, and then aluminum samples of this first set.
12. Steps 7-11 were repeated for the remaining 12 sets.
13. One set remained unprinted and was used as negative controls.
14. Photographs were taken of the initial fingerprints of all cartridges with the FSIS with the 254nm light and 254nm barrier filter.
15. Egg cartons containing sets 1-4 and 10 of Experiment #1 and Sequences 1-4 for Experiment #2 were taken to the range to be fired with the semi-automatic pistol.
16. The first sample was carefully loaded into the magazine, only touching the bullet and cartridge case head, with the sample label facing upward as a guide to locate the print.

17. The magazine was loaded into the firearm, the cartridge was chambered, and the weapon was fired at a target, utilizing a two-handed grip.
18. The spent cartridge case was ejected onto the concrete. It was retrieved by only touching the mouth and the head of the cartridge case to avoid smearing any surviving ridges and returned to its associated sample slot.
19. The magazine was removed from the firearm.
20. Steps 16-19 were repeated for the remaining samples.
21. The samples were stored in a storage bin for transport.
22. On the same day the fingerprints were deposited on the cartridge cases, the donor finger impression was recorded with fingerprint ink placed on an ink slab.
23. The following known impressions were collected:
    a. The donor finger with the band aid on a flat surface,
    b. The donor finger with the band aid on a paper wrapped around a cartridge case,
    c. And the donor finger rolled print on a flat surface without a band aid.

Experiment #1 Method

1. Photographs of the fired samples were taken with the FSIS.
    a. The 254nm UV light (shortwave UV light) was used, and the respective 254nm filter was used on the camera.
    b. For safety purposes, a face shield was worn before operating the FSIS to protect the eyes from UV light exposure.
    c. To prevent the sample from rolling when the photographs were taken, it was placed on a Lego.

   d. The scale was placed on an adjustable clamp stand and leveled with the apex of the cartridge case with the print area in focus.
   e. The labels were obliterated on some samples. The firearm created a firing pin drag mark in the 12 o'clock position, which aided in orienting the cartridge case.
2. The workspace in the chemical fume hood was covered with brown paper.
3. The AHP Formula #1 working solution was prepared with the following ratios: 14.1 mL of distilled vinegar and 20.0 mL of 3% H_2O_2 in a 250 mL beaker.
4. One 20 mL beaker was filled with roughly 15 mL of solution, enough to fully submerge the cartridge case.
5. A control sample was placed in one of the beakers. The sample remained fully submerged until latent print development occurred, not exceeding 75 seconds.
6. While the reaction was occurring, a second 20 mL beaker was filled with tap water.
7. When the latent print developed, or after 75 seconds, the solution was poured into the sink and the sample was placed in a second 20 mL beaker water bath for 2 minutes to cease the reaction. After 2 minutes, the sample was air dried.
8. Steps 4-7 were repeated for the remaining positive and negative controls.
9. Once the samples were dry, they were returned to their appropriate sample slots.
10. When the positive and negative controls confirmed that the formula was successful, Steps 4-8 were repeated for the fired and unfired samples for Formula #1.
11. Steps 3-9 were repeated with the next formulae:
    a. Formula #2: 10 mL of glacial acetic acid, 20.0 mL of 3% H_2O_2, 52 mL of dH_2O
    b. Formula #3: manufactured AHP

12. After all the samples have dried and returned to their sample slots, photographs were taken of the samples with the FSIS with the 254nm light and 254nm barrier filter.
13. The photographs were reviewed with a fingerprint examiner for any Level 1, 2, and 3 details.

Experiment #2 Method

- Cyanoacrylate ester fuming step: samples were placed upright on a wire rack in the fuming chamber. A dime-sized drop of superglue was placed on a metal tin. The tin was placed on the heating plate in the chamber. A positive control latent print deposited on a small piece of acetate sheet was added into the chamber. The samples were fumed with the humidity at 75% for 6 minutes and purged for 12 minutes. Photographs were then taken with the FSIS with the 254nm light and 254nm barrier filter.
- AHP step: Formula #2 was selected from experiment #1. The working solution was prepared with 10 mL of glacial acetic acid, 20.0 mL of 3% H_2O_2, and 52 mL of dH_2O. The sample was placed in a 20 mL beaker containing roughly 15 mL of solution and was submerged for 75 seconds. The AHP solution was drained from the beaker. The sample was removed from the first beaker and transferred into a water bath in a 20 mL beaker for 2 minutes, and then air dried. Photographs were then taken with the FSIS with the 254nm light and 254nm barrier filter.
- R.A.Y. step: The samples were sprayed until the entire surface was covered with the fluorescent dye and air dried. Photographs were taken with the Laser at 532nm and DSLR camera with the orange barrier filter.
    - The DSLR camera was attached to the iMac and the settings were modified through the Nikon Camera Control Pro 2 software.

    - For safety purposes, orange filter goggles were used to protect the eyes from exposure to the LASER's light.

- GB step: In a 250 mL beaker, 97.7 mL of dH_2O and 2.3 mL of gun blue were combined. In a 20 mL beaker, the sample was submerged into roughly 15 mL of the solution. The sample remained submerged until print development occurred. When latent print development occurred, the GB solution was drained from the beaker and the sample was directly transferred into a water bath in a second 20 mL beaker for 2 minutes to halt the reaction. Photographs were then taken with the FSIS with the 254nm light and 254nm barrier filter.
    - A positive control was tested by using an extra unfired cartridge with a fingerprint prepared the same time as the experimental samples.

1. Each sequence tested a set of 3 fired samples of each metal type ammunition. The following sequential steps were tested:
    a. Sequence #1: CA fuming, R.A.Y., AHP
    b. Sequence #2: CA fuming, AHP, R.A.Y.
    c. Sequence #3: CA fuming, AHP, GB
    d. Sequence #4: CA fuming, GB, AHP
    e. Sequence #5: AHP Formula #2-treated samples from experiment #1, CA fuming, R.A.Y.

Data Analysis

Both categorical and numerical data was collected over the course of both experiments. The categorical data collected was based on the levels of detail established by Ashbaugh (1999) and were confirmed by a fingerprint examiner. The numerical data was collected by tracing the visible ridge paths on a sample and recording the sum of all paths for every sample, as seen in Figures 5 and 6. The programs used to obtain the measurements were Adobe Creative Cloud Photoshop and Illustrator (See Appendix A). Percent yields were calculated from the initial measurements collected prior to processing or firing to the value collected after processing.

Figure 5

Sample N2_5, Post AHP, in Adobe Illustrator

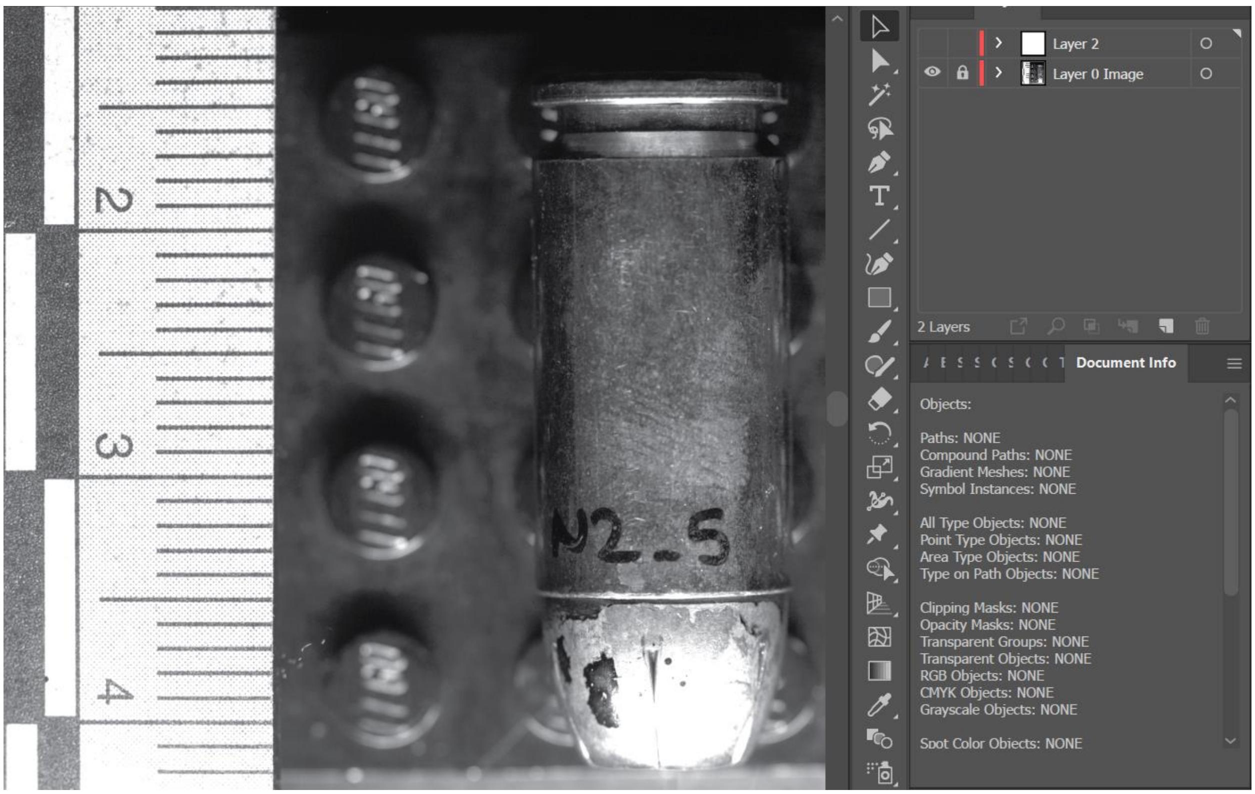
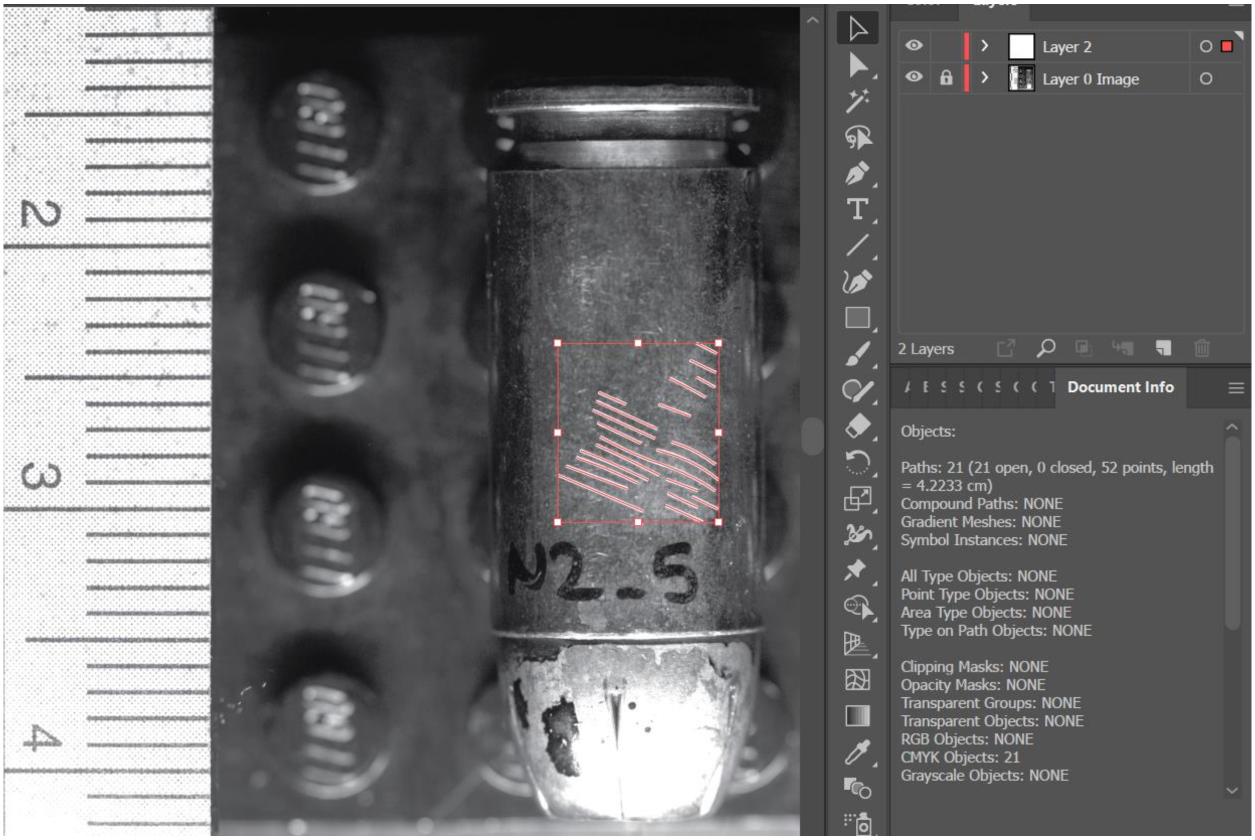


Figure 6

Sample N2_5, Post AHP, in Adobe Illustrator with Measurements



Experiment #1

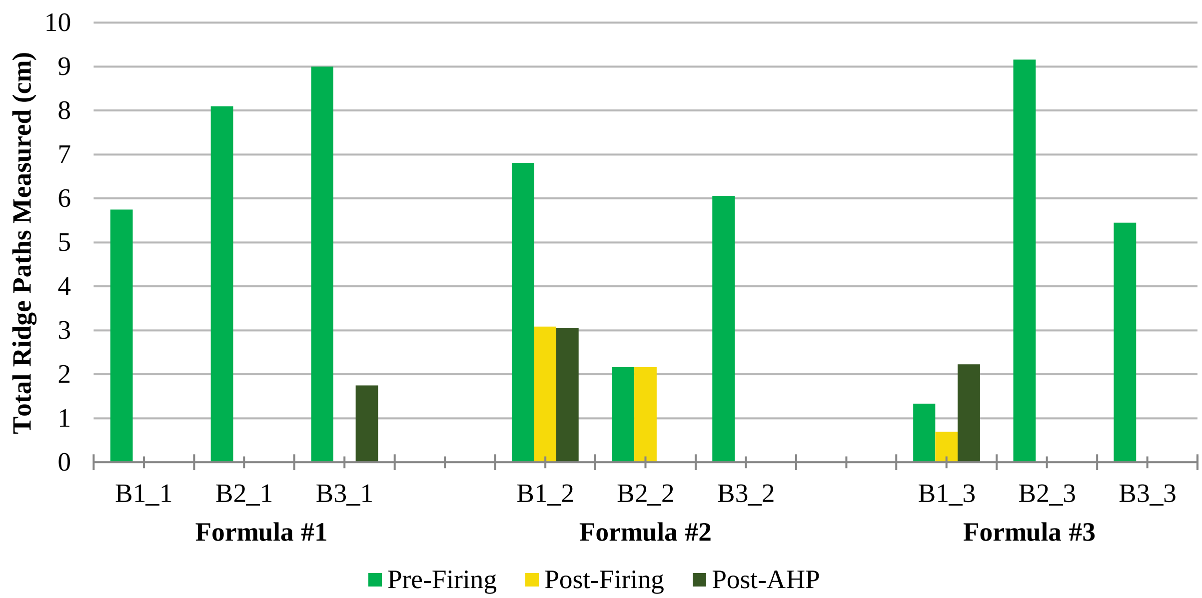
Overall, there were 84 tested samples, 36 fired samples and 48 unfired samples. Of the 84 samples, 54 samples had at least Level 1 detail, and 48 samples had Level 2 detail. Of the 54 samples, 15 fired samples and 39 unfired samples had Level 1 detail. Of the 48 samples, 13 fired samples and 35 unfired samples had Level 2 detail. Only six unfired samples had Level 3 detail. A common observation was that the common locations where ridge paths were recorded was towards the edge of the latent print area. This could have been due to the deposition pressure variation on a cylindrical object. Ashbaugh described extreme deposition pressure, “the outer edge of this print was not exposed to direct pressure from the digit bone” (1999, p. 123). The center of the latent print had heavy to extreme pressure deposition while the outer edges had medium pressure deposition due to the landscape of the cartridge and the elasticity of skin. Another observation noted was that there was discoloration that occurred on the brass samples due to the alcohol wipe used to clean the samples. The discoloration did not affect the analysis.

Brass Samples

For fired, brass cartridge cases, one sample for each formula had measurable Level 2 detail as seen in Figure 7.

Figure 7

Total Ridge Paths Measured on Fired, Brass Cartridge Cases

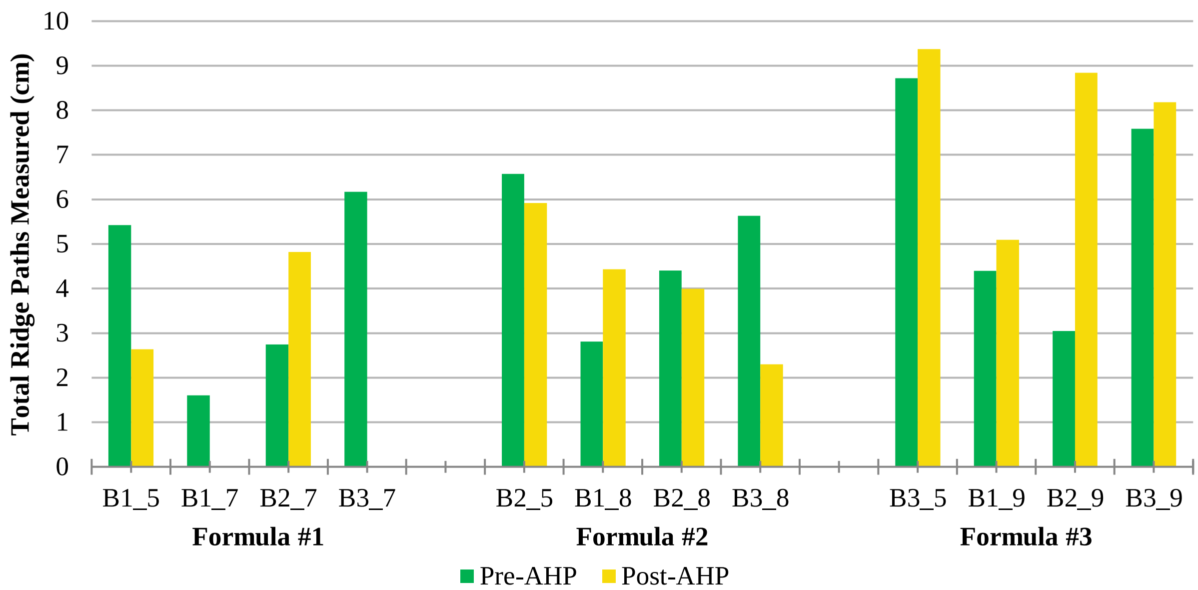


The Formula #3 set had the highest individual percent yield at 167% and had the highest set average percent yield of 56%. The Formula #1 set had the lowest percent yield set average at 6%. Sample B3_1 had no visible ridges when it was photographed after being fired. After the sample was processed with AHP, around 19% of the latent print was developed. The only Formula #2 brass sample, B1_2, reported a 45% percent yield after it was processed with AHP.

For unfired, brass cartridges, each formula had samples with measurable Level 2 detail. The Formulae #2 and #3 sets both had four samples with measurable ridges while the Formula #1 set only had two samples, as shown in Figure 8.

Figure 8

Total Ridge Paths Measured on Unfired, Brass Cartridge Cases



The Formula #3 set provided the highest average percent yield of measured ridge paths at 155% while the Formula #1 and #2 sets reported the lowest average at 56% and 94%, respectively. The high average percent yield in the Formula #3 set was due to all the samples reporting above 100% percent yields. Though it is not possible to develop more ridges than deposited, each samples' post-AHP images were individually evaluated. The Formula #3 set had the highest number of samples with Level 3 detail at 3 samples. This set contributed to half of the reported number of samples containing Level 3 detail. The Formula #2 set had one sample with Level 3 detail.

Though Formula #3 had the greatest recorded percent yield, when the individual samples were evaluated, as seen in Figure 9, the clarity of the sample processed with Formula #2 was better. In Figure 10, the clarities of Formula#3-developed, unfired cartridges were greater than the ones developed by the other formulae.

Figure 9

Fired, Brass Cartridge Cases A) Formula #1, B) Formula #2, C) Formula #3

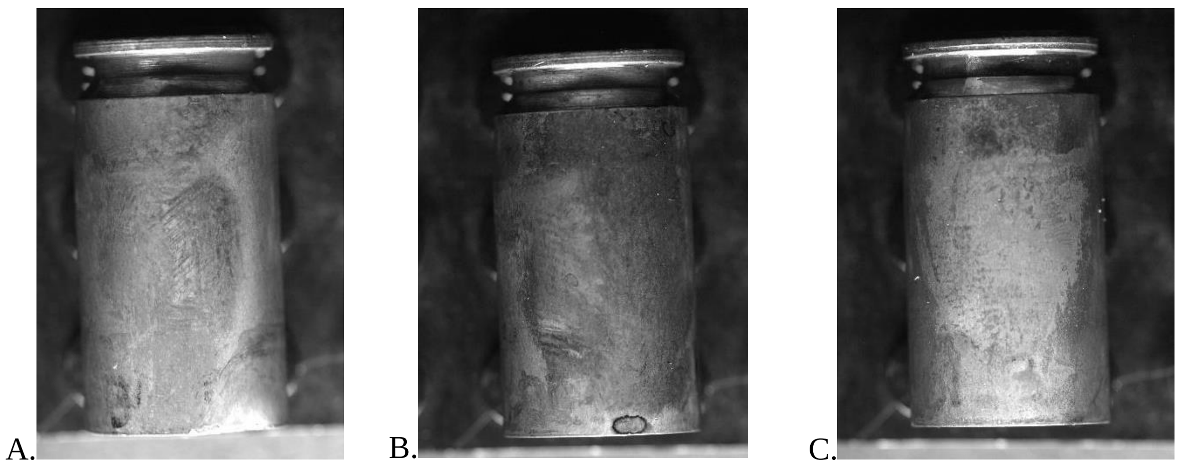


Figure 10

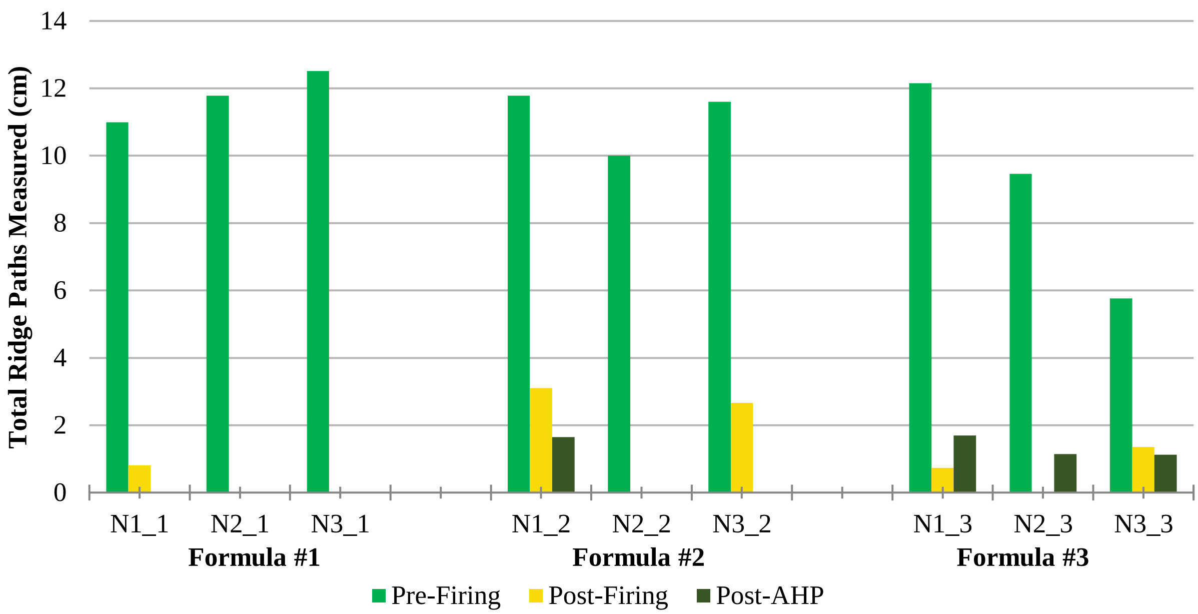
Comparison of Formula #2 (Left) and Formula #3 (Right) Unfired, Brass Cartridges

Nickel Samples

Only Formulae #2 and #3 developed measurable Level 2 detail on fired, nickel samples, as seen in Figure 11. The Formula #3 set developed latent prints on three samples while the Formula #2 set had one sample.

Figure 11

Total Ridge Paths Measured on Fired, Nickel Cartridge Cases

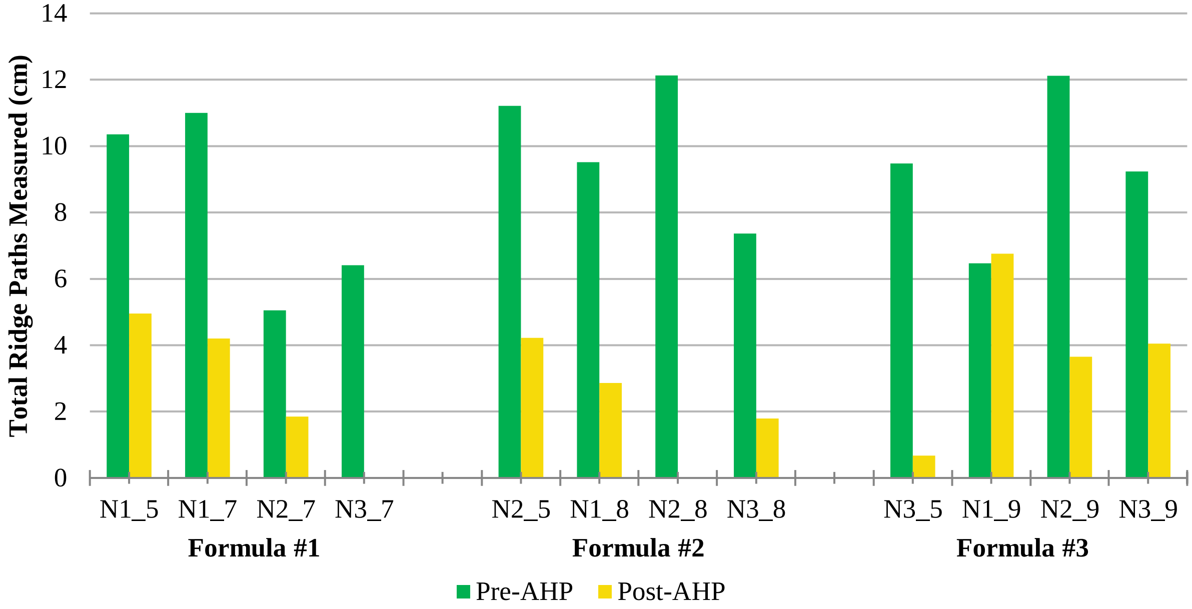


The Formula #2 set had only one sample that had a 14% percent yield. The Formula #3 set had measurable ridge paths on all three samples, with an average of 15% percent yield, the highest average yield of all the formulas for this metal type and condition. Formula #1 did not develop any ridges.

In Figure 12 of unfired, nickel cartridges, all three formulae had at least three samples with measurable Level 2 detail.

Figure 12

Total Ridge Paths Measured on Unfired, Nickel Cartridge Cases



Formula #3 developed Level 2 detail on all four samples and provided the highest average ridge path percent yield at 46%. Though the Formula #1-processed samples all had at least Level 1 detail, only three of those samples had measurable Level 2 detail. This set had an average of 31% percent yield. This set contained a sample with Level 3 detail. The Formula #2 set had three samples that had measurable Level 2 detail and reported an average of 23%. The Formula #3 set had all four samples with measurable Level 2 detail. Despite containing a sample with a percent yield that exceeded 100%, Formula #3 still developed the most measurable ridge paths for unfired, nickel cartridges.

Both fired and unfired, nickel cartridges developed the most ridges after being processed with Formula #3. This was the only formula that developed measurable ridges on all its samples. It developed the best clarity on unfired samples, as seen on Figure 13.

Figure 13

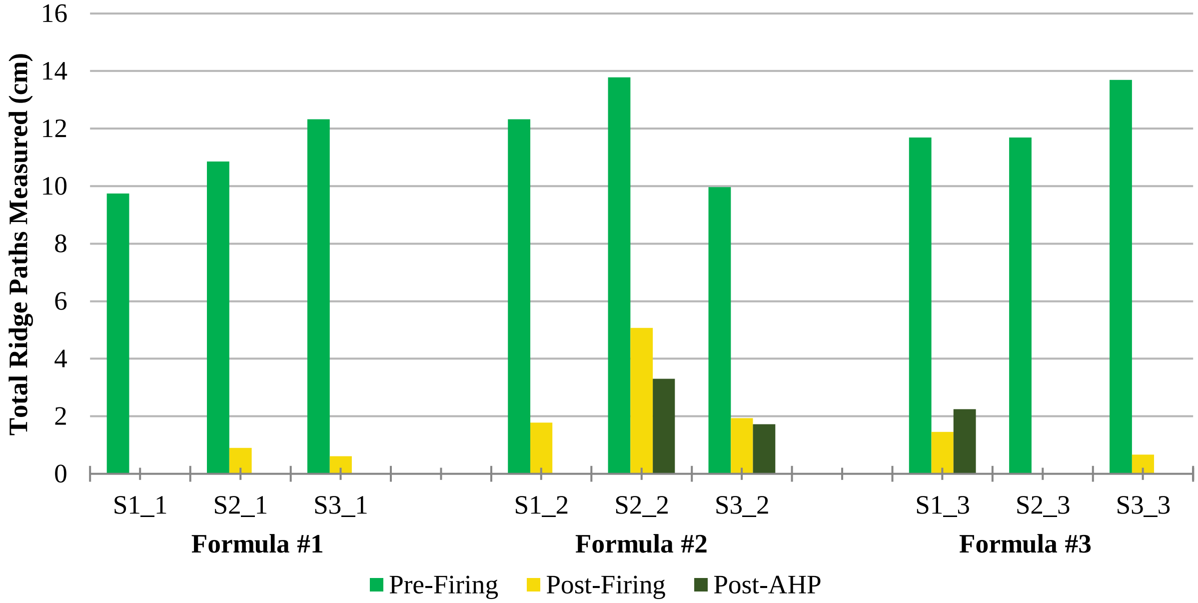
Sample N1_9, Unfired, Nickel Cartridge Processed with Formula #3

Steel Samples

On the fired, steel cartridge cases, Formula #2 developed latent prints on two samples and Formula #3 developed on only one steel sample (See Figure 14).

Figure 14

Total Ridge Paths Measured on Fired, Steel Cartridge Cases

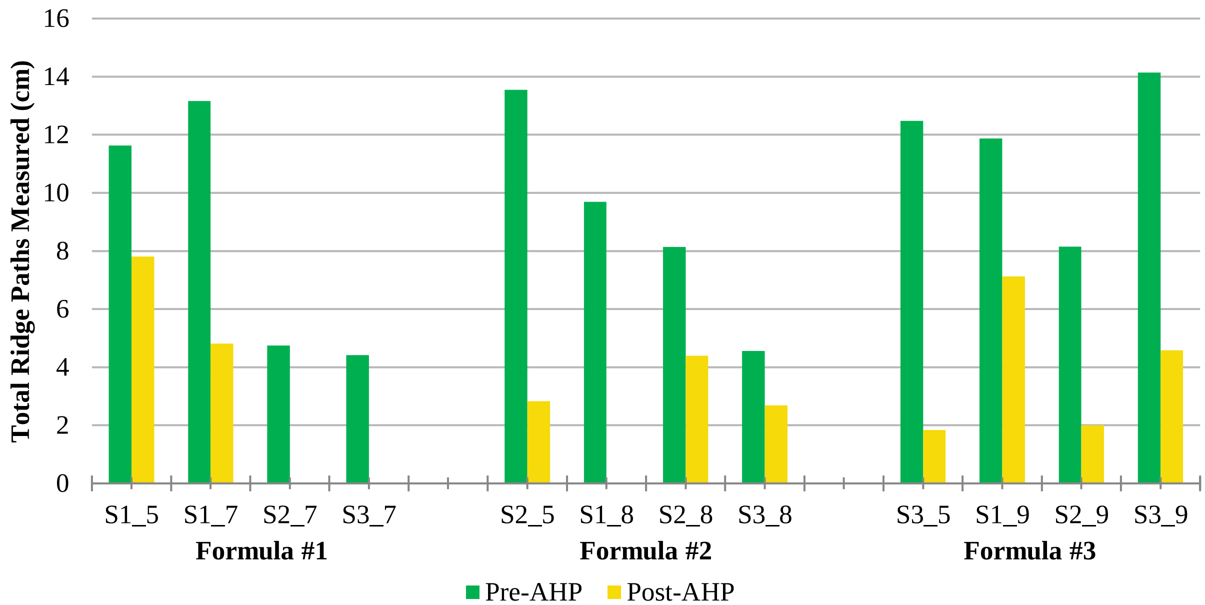


The Formula #1 set did not have any samples that were successful in developing any measurable ridges. The Formula #2 set had two samples with measurable Level 2 detail. The set produced an average percent yield of 14%. Between the two samples that produced ridges, it had an average percent yield of 21%. The Formula #3 set had only one steel sample with a 19% percent yield.

For unfired, steel cartridges, all the formulae developed latent prints with Formula #3, the only formula to develop latent prints on all its samples, as seen on Figure 15. Formula #2 provided the highest average ridge paths developed.

Figure 15

Total Ridge Paths Measured on Unfired, Steel Cartridge Cases



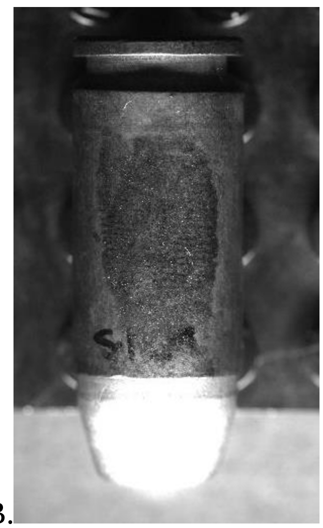
Of the four samples, only two steel samples processed with Formula #1 had both Level 1 and Level 2 details. The average percent yield of this set was 26%. Between the two samples that were measured, the average percent yield is 52%. One sample contained Level 3 detail. The Formula #2 set had all four samples containing Level 1 detail, but only three of those four samples contained Level 2 detail. This set had an average of 34% percent yield and a 45% average percent yield between the samples that had Level 2 detail. The Formula #3 set had all four samples containing both Level 1 and Level 2 details after AHP processing with an average percent yield of 33%.

Formula #2 developed the most latent prints on fired steel cartridges while Formula #3 developed the most latent prints on unfired steel cartridges, as seen in Figure 16.

Figure 16

A) Formula #2-Processed Fired, Steel Cartridge Case, B) Formula #3-Processed Unfired, Steel Cartridge

A. 

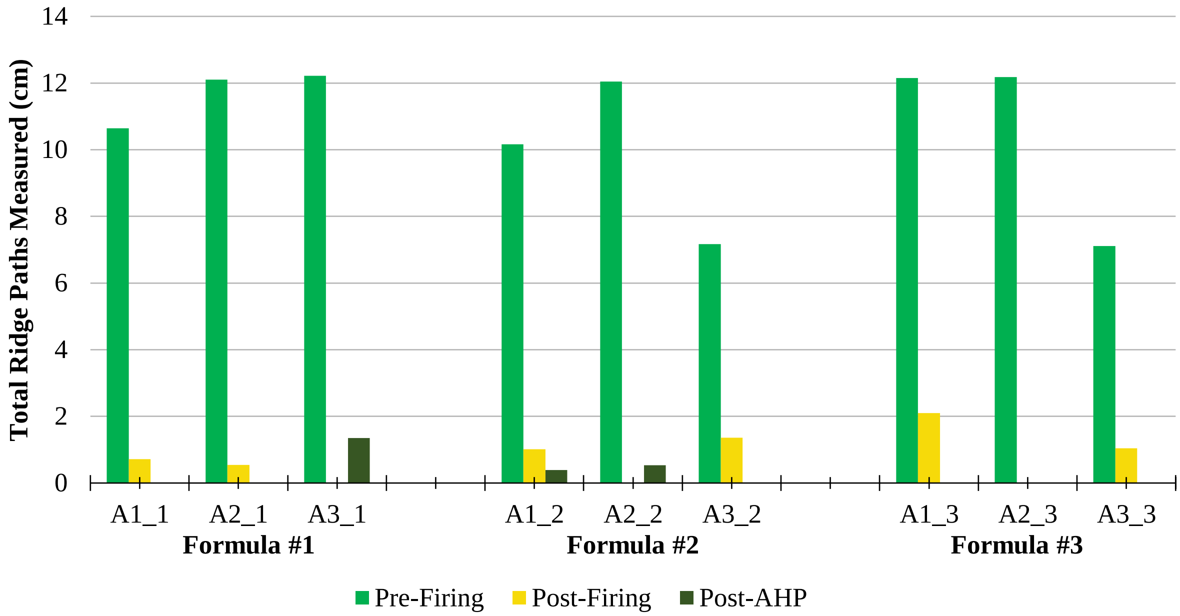
B. 

Aluminum Samples

For fired, aluminum cartridge cases, the Formula #1 set provided the highest average percent yield of latent print developed at 4%. Though the Formula #1 set had a higher percent yield average, Formula #2 developed latent prints on two aluminum samples versus Formula #1 developing a latent print only on one sample, as shown on Figure 17.

Figure 17

Total Ridge Paths Measured on Fired, Aluminum Cartridge Cases

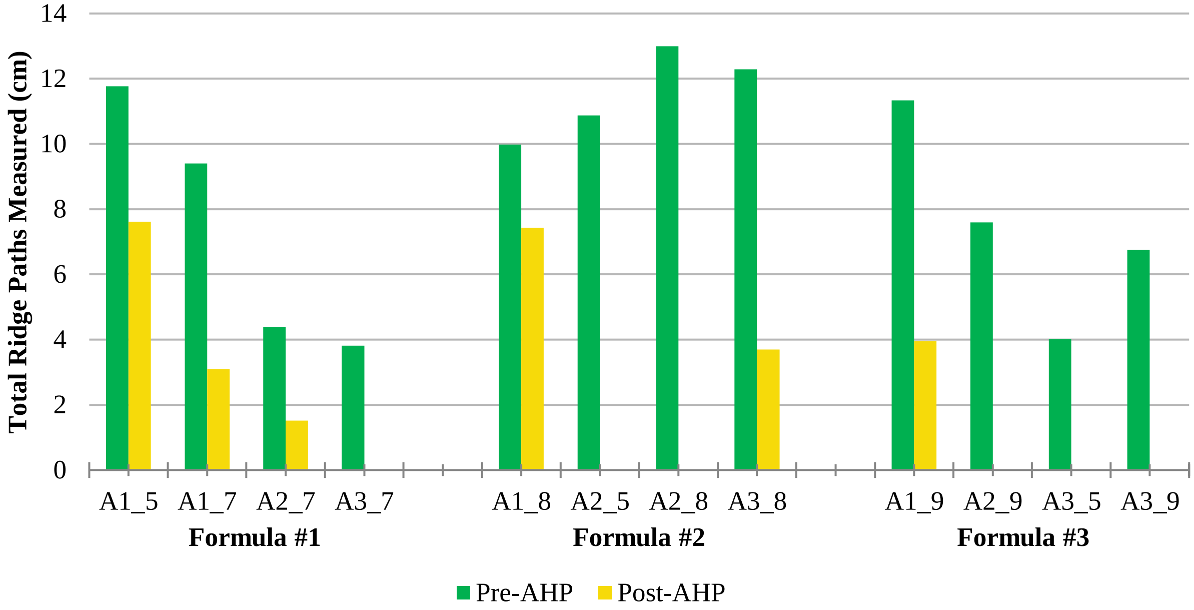


Formula #1 only developed measurable Level 2 detail on one sample, A3_1, reporting a 11% percent yield. Three samples from the Formula #2 set had Level 1 detail. Only two of these three samples had measurable latent prints after being processed with AHP. Between these two measurable samples, they had an average of 4% percent yield. Formula #3 did not develop any latent prints on any of its samples.

For unfired, aluminum cartridge cases, the Formula #1 set had the most samples with developed latent prints at three samples, while the Formula #3 set had the least number of samples at one sample, as seen in Figure 18.

Figure 18

Total Ridge Paths Measured on Unfired, Aluminum Cartridge Cases



The Formula #1 set provided the highest average percent yield of latent print developed at 33%. Formula #1 developed on average 33% of the original latent prints on three samples. Formula #3 developed the lowest average at 9% with only one sample, A1_9. This sample had a 35% percent yield. The Formula #2 set had a sample with the highest percent of developed latent print at 74% percent yield for all the unfired, aluminum cartridges. The set average for this formula was 26% and between the two samples with measurable ridges, it had a 52% percent yield. Each formula developed latent prints on at least one sample.

For both fired and unfired, aluminum cartridges, Formula #1 is the preferred AHP formula to develop latent prints.

Overall Results for Experiment #1

Fired, steel cartridge cases reported the greatest count of samples, containing Level 2 detail regardless of the formula type, at five samples. Fired, brass and aluminum reported the lowest counts, at three samples.

Unfired, brass and nickel cartridges both had the greatest counts of samples that produced Level 2 detail regardless of formula type, at ten out of twelve samples. The unfired metal type with lowest number of samples was aluminum, at six out of twelve samples. Unfired, brass cartridges produced the most samples with Level 3 detail. Three out of the four samples with Level 3 details were brass samples produced with Formula #3.

Overall, the formula that had the most samples with Level 2 detail was Formula #3, regardless of metal type or whether it was fired or not. Though Formula #3 developed latent prints on the greatest number of fired samples, it did not develop Level 2 detail on Aluminum. It produced at most Level 1 detail in one sample. When observing the clarity of each sample, Formulae #2 and #3 were comparable. The appearance of the ridges was more visible on samples processed with either of these two formulae compared to the samples processed with Formula #1. Formula #2 also developed latent prints across all metal types, fired and unfired, as seen on Table 1. With this, Formula #2 was selected as the AHP formulation for Experiment #2.

Table 1

Totals of Level 2 Detail in Experiment #1

	Brass	Nickel	Steel	Alum	Total
			Fired		
Formula #1	1	0	0	1	2
Formula #2	1	1	2	2	6
Formula #3	1	3	3	0	7
Total	3	4	5	3	15
			Unfired		
Formula #1	2	3	2	3	10
Formula #2	4	3	3	2	12
Formula #3	4	4	4	1	13
Total	10	10	9	6	35
			Fired and Unfired		
Formula #1	3	3	2	4	12
Formula #2	5	4	5	4	18
Formula #3	5	7	7	1	20
Total	13	14	14	9	50

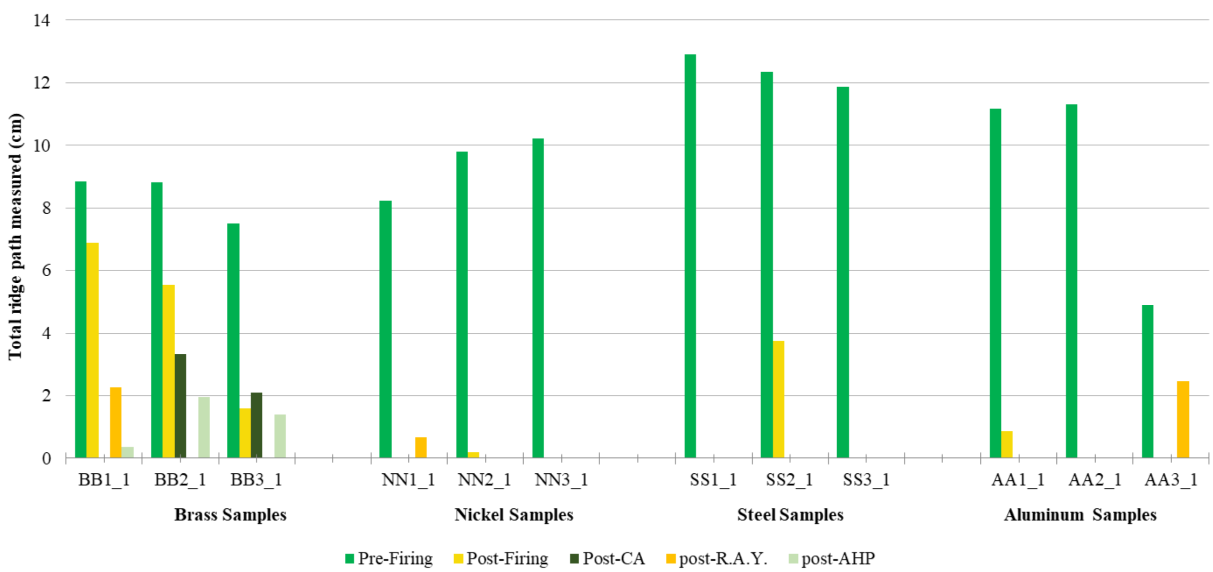
Experiment #2

Sequence #1

The only samples in this set that produced any ridges were the all three brass samples, as seen in Figure 19.

Figure 19

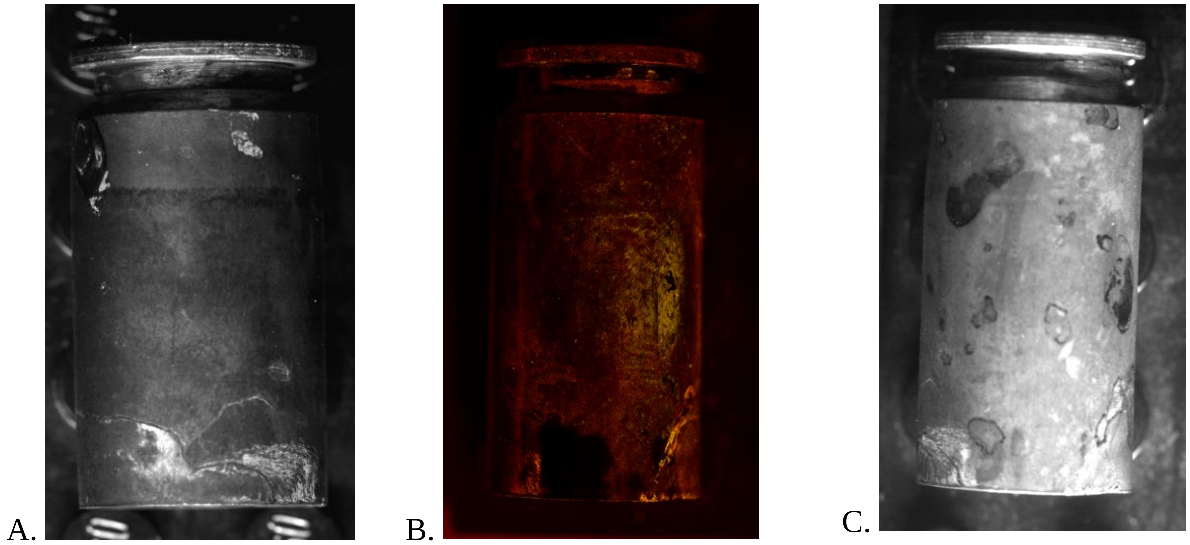
Total Ridge Paths Measured in Fired Cartridge Cases Processed with Sequence #1



All these samples had measurable ridges after they were fired. From the pre-firing measurement through the AHP processing step, the brass set had an average percent yield of 15%. Sample BB1_1 was not visible with CA fuming alone but was visible with R.A.Y. This sample had more ridge paths measured after R.A.Y. than after AHP (See Figure 20). The other two brass samples were not visible with R.A.Y. but were visible with CA fuming. The total ridge paths measured were higher after CA fuming than after AHP.

Figure 20

Fired, Brass Cartridge Cases A) Post-Firing, B) Post-R.A.Y., C) Post-AHP



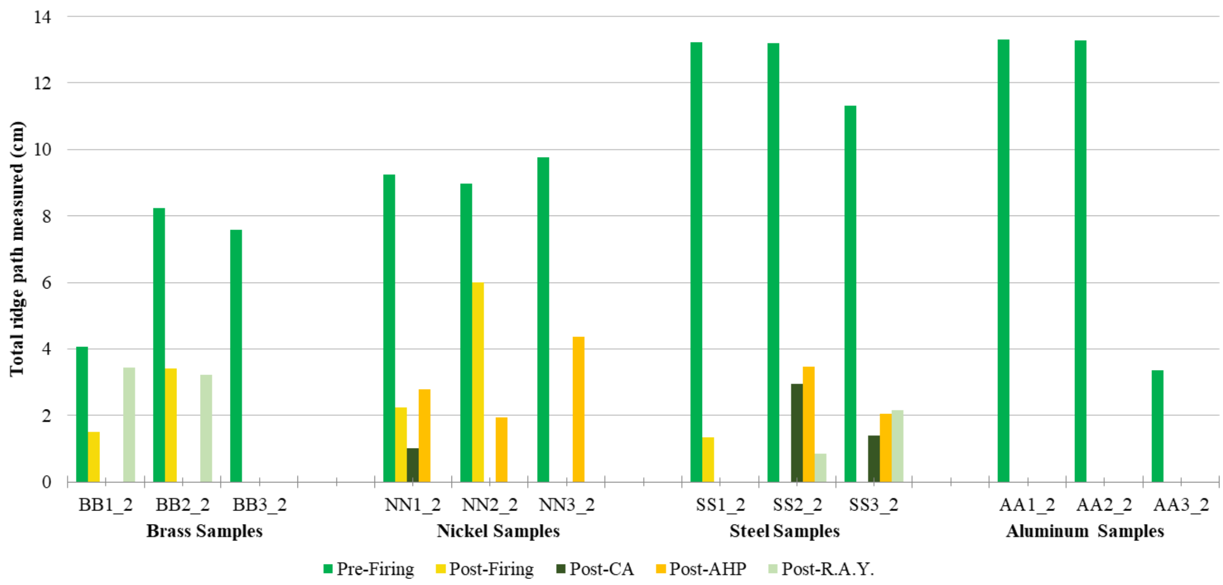
R.A.Y. developed ridges on one nickel sample and one aluminum sample, NN1_1 and AA3_1, respectively. Sample NN2_1 had at most Level 1 detail after R.A.Y. and AHP. Sample SS3_1 had at most Level 1 detail after CA fuming but did not develop any ridges in the following steps. Sample AA1_1 had measurable ridges post firing. Level 1 detail was seen on this sample after R.A.Y. but not after AHP. AA3_1 had only Level 1 detail present after AHP.

Sequence #2

In this set, the only two metal types that AHP developed ridges on were nickel and steel (See Figure 21).

Figure 21

Total Ridge Paths Measured in Fired Cartridge Cases Processed with Sequence #2



Two of the three steel samples had measurable ridges at every processing step. AHP yielded the highest total ridge paths compared to CA fuming and R.A.Y. There was an increase in total ridge path measured from the CA fuming step to the AHP step by an average of 5%. The total ridge paths per sample measured from AHP to R.A.Y. decreased by 9%.

Though nickel was one of the metal types that yielded measurable Level 2 detail at the AHP processing step, it did not yield any measurable Level 2 detail after being processed with R.A.Y. In the nickel sample, NN1_2, the total ridge path measured increased by 19% from CA fuming to AHP. The other two samples did not have any measurable ridges after the CA fuming step.

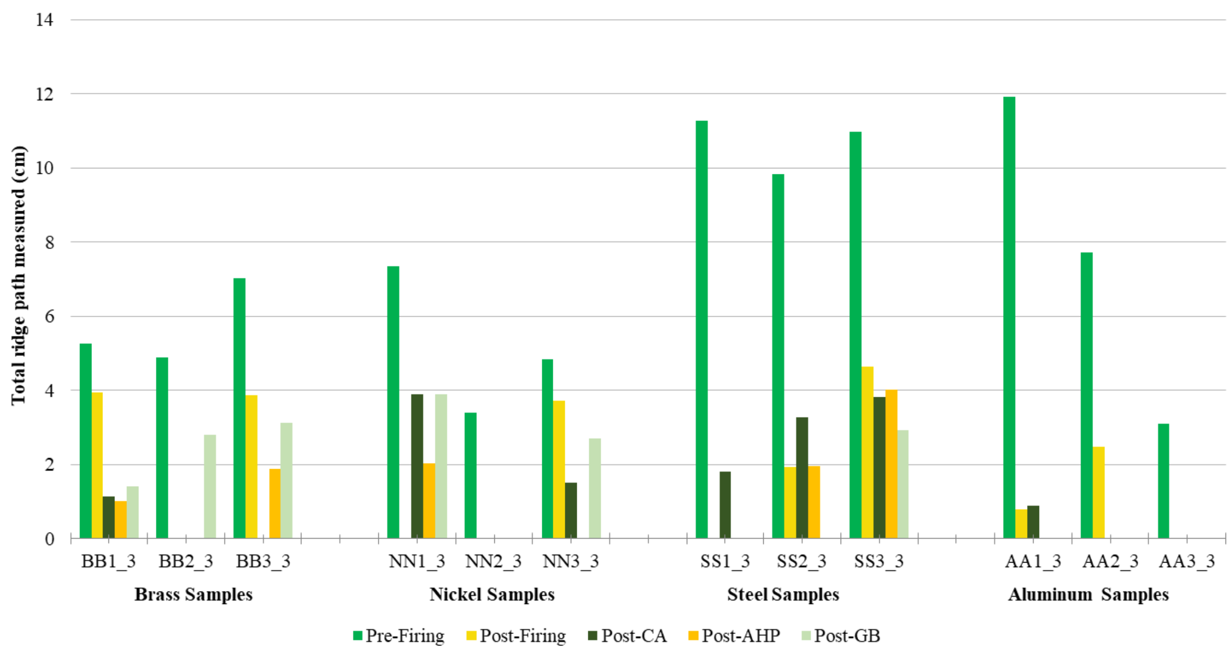
The brass samples did not show any measurable Level 2 detail at the AHP processing step but did contain Level 1 detail in one of its samples. Two samples contained ridges that were measurable at the R.A.Y. step. Since all three samples contained at least Level 1 detail after CA fuming, the presence of measurable Level 2 detail indicated that AHP does not etch away the CA polymers that the R.A.Y. is adhering to.

Sequence #3

The metal types that had developed ridges after AHP processing were brass, nickel, and steel samples (See Figure 22).

Figure 22

Total Ridge Paths Measured in Fired Cartridge Cases Processed with Sequence #3



AHP developed measurable Level 2 detail on two brass samples. After GB, all three samples had measurable Level 2 details. The total ridge paths measured increased the AHP step to the GB step by 28%.

Only one sample, NN1_3, produced measurable Level 2 detail in this sequence. The ridge path sum decreased from post-CA fuming to post-AHP. The values rose by 25% after the samples were processed with GB. Sample NN3_3 had ridge paths measured after CA and after GB, but no ridges were observed after being processed with AHP.

Based on the set averages on the steel samples, CA fuming had the highest average ridge path total of any of the processing steps. AHP had a higher average total ridge path than GB. Individually, there was one sample, SS3_3, that had a higher AHP value than GB. This sample also was the only sample that had measurable ridges post-GB in this sequence. Visually, AHP had more complete ridge paths than the ridges seen after GB processing, as seen in Figure 23 of sample SS3_3.

Figure 23

Sample SS3_3, A) Post-AHP, B) Post-GB

A. 

B. 

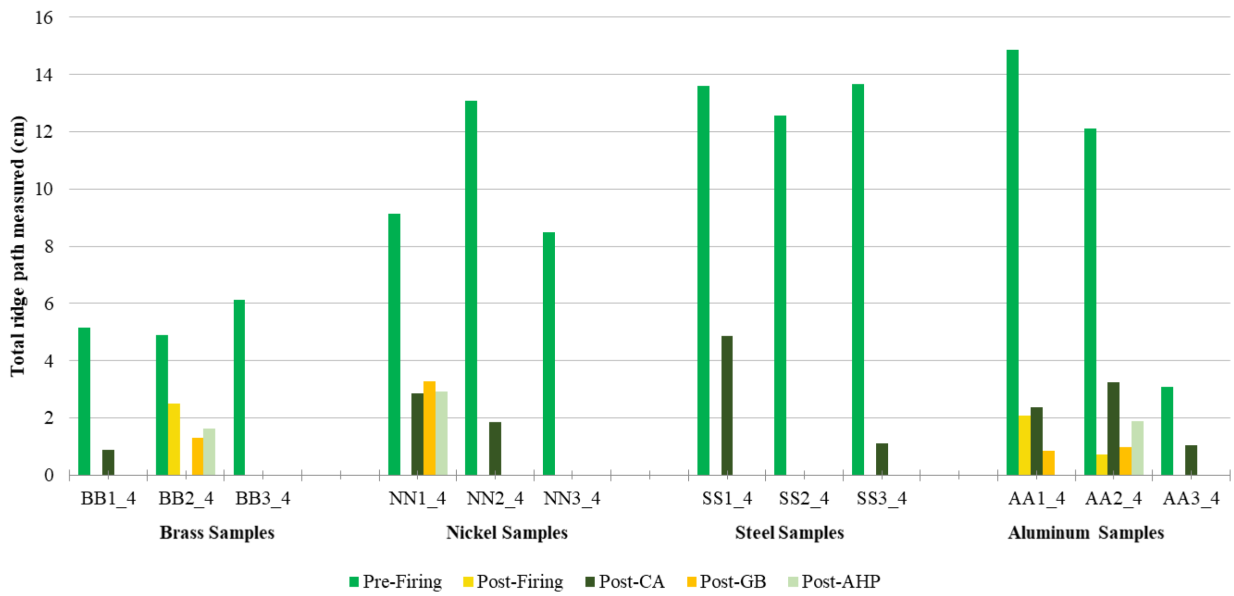
There was only one aluminum sample, AA1_3, that had measurable ridges after CA fuming. Level 1 detail was observed after GB for this sample. Samples AA1_3 and AA2_3 had Level 1 detail after the AHP step but did not have any levels of detail after GB. Though there were no levels of detail observed after the AHP step, AA2_3 had Level 1 detail after CA fuming and after GB. AHP was not able to develop visible details on this sample.

Sequence #4

Only three samples produced measurable ridge paths after the AHP step in this sequence: brass, nickel, and aluminum, as seen in Figure 24.

Figure 24

Total Ridge Paths Measured in Fired Cartridge Cases Processed with Sequence #4



Nickel and aluminum had ridges measured throughout all the processing steps. The nickel sample had the smallest differences between each step, increasing from after CA fuming to GB by 5% and decreasing after processed with AHP by 4%.

One brass sample, BB2_4, had a slight increase of 6% in ridges measured from the GB step to after AHP processing. BB1_4 had measurable ridge paths after CA but did not have any after the succeeding steps. On average, the ridges measured increased from CA fuming to GB. The average continued to increase by 2% after the set was processed with AHP.

Nickel had only one sample, NN1_4, which had measurable ridge paths at all the processing steps. The value increased after GB by 5% but decreased after AHP by 4%. Though the value decreased at AHP, the value was higher than the measurement collected after CA fuming. NN2_4 had measurable ridge paths after CA but did not have any after the succeeding steps.

One aluminum sample, AA2_4, had measurable ridge paths at all the processing steps. The value decreased from CA fuming to the GB step by 19% and increased slightly after AHP by 7%. AA1_4 developed measurable ridge paths after CA fuming and GB processing but did not have any measurable ridge paths after the AHP step.

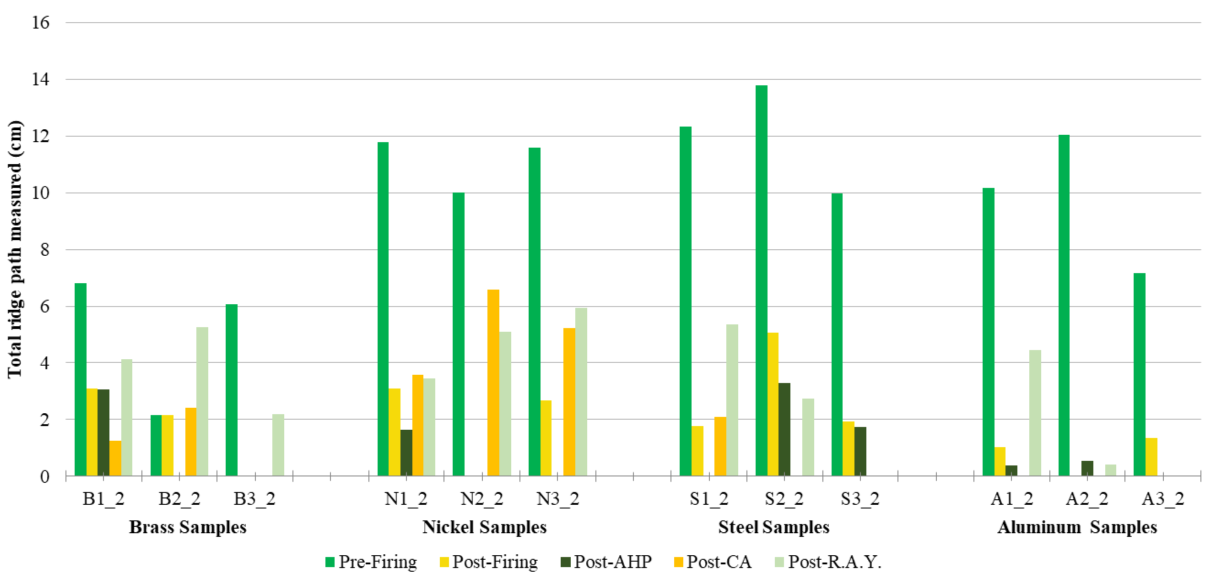
Two steel samples, SS1_4 and SS3_4, had measurable Level 2 detail after CA fuming. Only Level 1 detail was observed on samples SS2_4 and SS3_4 after being fired from the weapon.

Sequence #5

All the metal types produced at least one sample after being processed with AHP from Experiment #1. By the end of the processing sequence, brass and nickel samples still developed measurable ridges compared to two samples of aluminum and steel (See Figure 25).

Figure 25

Total Ridge Paths Measured in Fired Cartridge Cases Processed with Sequence #5



Two brass samples, B1_2 and B2_2, were able to show measurable Level 2 detail after CA fuming. Though B3_2 did not have measurable Level 2 detail, it did have Level 1 detail. R.A.Y.

was able to develop ridges on all three samples. B1_2 had more ridge paths available after R.A.Y. than after being processed with AHP. This showed that AHP may not be destructive to the latent print at the maximum length of exposure, 75 seconds.

Only one nickel sample had Level 2 detail after being processed with AHP from Experiment #2, N1_2. After CA fuming, all samples had measurable Level 2 detail. On average, this metal type had the smallest decrease from the CA step to the R.A.Y. step, decreasing by 1%. Though there was only one sample that developed after the AHP step, there were still ridges present that CA polymers can bind with, which resulted in ridges becoming visible with R.A.Y.

Two steel samples, S2_2 and S2_3, had measurable Level 2 detail. Sample S3_2 did not show any ridges at any of the following steps. Sample S3_2 ridges were observed after the R.A.Y. step. Though Sample S3_2 did not have ridges that developed with AHP, it did have measurable Level 2 detail after CA fuming and R.A.Y.

Two aluminum samples, A1_2 and A2_2, had ridges that were developed by AHP. They did not have any measurable ridges after CA fuming, but they were developed with R.A.Y.

Overall Results for Experiment #2

Sequence #5 had the highest total of samples that reported measurable ridges at the end of the processing sequence at ten samples. Sequence #3 followed with six samples. Sequence #5 was also the only sequence that contained samples with measurable Level 2 detail across all the metal types at the end of the processing sequence. Sequences #1 and #4 had the least number of samples that developed ridges after the last step of their respective sequences at three samples each. Sequence #1 only developed ridges on brass samples at the end of its sequence while Sequence #4 recovered one sample of three metal types.

When evaluating which sequence developed successfully with which metal type, each sequence had varying results. Sequence #1 processed brass samples the best while Sequence #2 worked on steel samples. Sequence #3 processed brass and nickel samples successfully. Despite its low count, Sequence #4 developed latent prints across brass, nickel, and aluminum samples. Sequence #5 developed latent prints on all the metal types tested.

Conclusion

The hypothesis that AHP would develop latent prints on unfired brass and nickel cartridges, while it will not develop any latent prints on fired cartridge cases, has shown to be partially true. AHP was able to develop latent prints across all the metal types. Some metal types yielded more samples than others. In this study, unfired brass and nickel samples had the most counts of samples with developed Level 2 details. Though the counts were low, AHP was still able to develop Level 2 details on fired samples.

The sequence of cyanoacrylate ester fuming, R.A.Y. and then AHP was hypothesized as the most successful method for recovering latent prints. This hypothesis has shown to be false. Not only did it have one of the smallest totals of samples by the end of the processing sequence, it only yielded one brass, one nickel, and one aluminum sample after being processed with R.A.Y. It was only successful on brass samples. The most successful sequence overall was Sequence #5, AHP, cyanoacrylate ester fuming, and then R.A.Y.

There were limitations present during this research. There were inconsistencies in obtaining the sample images to best show the latent print on the cartridges. The pre-firing/pre-processing images were initially serving as proof that the initial latent print was present. Because of these inconsistencies, the values reported varied, which resulted in percent yields over 100%. These high yields were common on the reflective metal types. The tracing method had its limitations due to its unknown error rate on how accurate the measurements were to the actual length of ridges. When tracing the ridges on the fired cartridge cases, there was an assumption that the surface was not morphed. This could have impacted the measurement slightly since the tracing was conducted on a 2-dimensional image of a 3-dimensional object. This method was just used as a tool to visualize the changes in quantity after each step.

Overall, Acidified Hydrogen Peroxide was successful in developing latent prints on various metal type cartridge cases, fired and unfired. Though all three formulae worked, the formulae that consisted of concentrated chemicals manually diluted or the one manufactured already “cleaned” better than the solution made of store-bought items. This technique also worked on its own, but the results showed that combined with other processing techniques, it was possible to recover more latent prints than with just AHP alone. This study showed that following the established protocol of cyanoacrylate ester fuming and dye stain was not as successful than the modified processing sequence of Sequence #5. This modified processing sequence could be evaluated to be used on casework and increase the chances of recovering latent prints on cartridge cases, fired or unfired.

Future Directions

For future directions, testing the manufactured Acidified Hydrogen Peroxide with other processing techniques may increase the number of samples with developed latent print. By using processing techniques with samples processed with the distilled vinegar/hydrogen peroxide AHP formula can also develop more ridges than AHP alone.

Due to the destructive nature of the acidic solution on metal surfaces, AHP was not advised by Swofford et al. (2013) as a latent print development technique on cartridge cases. A future study could focus on ascertaining whether or not this solution is that destructive to interfere with firearm analysis.

The data collected by this study can also be revisited with the use of a software that can flatten a three-dimensional object into a proportionately shaped two-dimensional image to obtain accurate measurements. The data quantification method was developed to be used as a tool to visualize the increase and decrease of Level 2 detail in each sample after every processing step. A future direction can be conducting study on using this as another data analysis method in latent print research.

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Appendix A

Data Quantification Method

1. Using a computer with Adobe CC Photoshop, the photographs were cropped to the length of the scale and the cartridge case.
    a. Upon review, the initial cartridge case images lacked a scale. An image of the same metal-type cartridge case with a scale was used to resize and crop the image without the scale.
2. The contrast and brightness were adjusted if there were some samples that needed enhancing to determine if ridges were present.
3. The image was reopened on Adobe CC Illustrator.
4. The default unit of measurement was changed to centimeters by going to the Edit menu > Preferences > Units.
5. The layer with the image was resized proportionately to be 1:1 with the scale in centimeters. After resizing, the layer was locked.
6. Another layer was created, and the curvature tool was selected. The background color was turned off and the foreground color was set to white for brass, nickel, and steel samples and black to aluminum samples to distinguish the traced path from the image's colors.
7. A path was created by placing an anchor point at the beginning of a ridge and placing anchors along the ridge. The shape of the path was modified by adjusting the direction points to curve in the same direction as the ridges.
8. When a path was completely traced, it was deselected before starting another path.

9. When all the paths were traced on the image, the Lasso tool was selected, and a loop was created to encompass all the traced paths and anchors.
10. Under the Document Info tab on the Panel dock, the Objects option of the panel menu was selected. The sum of the path lengths in centimeters was shown and the value was recorded.
11. Steps 1-10 were repeated for each sample's pre-firing, post-fired, and processing step images.

Appendix B

Sample Nomenclature Used for Experiments #1 and #2

Table 2: *Sample nomenclature for Experiment #1*

Metal type	Depletion series term	Formulas
B = brass N = nickel S = steel A = aluminum	1 = first print after swiping the forehead for sebaceous oils 2 = second print without re-swiping the forehead 3 = third print without re-swiping the forehead	1 = Formula #1, fired 2 = Formula #2, fired 3 = Formula #3, fired 4 = no prints deposited, not processed, fired 5 = positive control samples, unfired with print 6 = extra unfired samples with prints 7 = Formula #1, unfired 8 = Formula #2, unfired 9 = Formula #3, unfired 10 = extra fired samples with prints 11 = negative control samples, unfired without prints

Table 3: *Sample nomenclature for Experiment #2*

Metal Type	Depletion series term	Sequences
BB = brass NN = nickel SS = steel AA = aluminum	1 = first print after swiping the forehead for sebaceous oils 2 = second print without re-swiping the forehead 3 = third print without re-swiping the forehead	1 = CA fuming, R.A.Y., AHP 2 = CA fuming, AHP, R.A.Y. 3 = CA fuming, AHP, GB 4 = CA fuming, GB, AHP 5 = AHP Formula #2 samples, CA fuming, R.A.Y.