Improving the Stability of Stored Fingermarks on Plastic Bags
by

Axis Inversion Development

By

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THESIS

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DEDICATION

This thesis is dedicated to my wife, Sandra Steele. Thank you for your love and support for all the things I do.

ACKNOWLEDGMENTS

I have learned in life that nothing great is created in a vacuum. It is the people who support, encourage and teach us that help us achieve whatever heights we hit. I would like to thank Sandra Steele, my loving wife, for all her support and encouragement. I would like to thank my sister, Dr. Michelle Rebelsky, who has always been there to help and lead. And I would like to thank Samuel Rebelsky Ph.D., my brother-in-law, without whom I might never have had the courage to follow this path in life. Without you all, I wouldn’t be what I am today. Thank you.

I would like to thank Dr. A. Karl Larsen, Ph.D., for allowing me the opportunity to conduct this research and complete this portion of my education. I would like to also thank the additional members of my thesis committee: Adam Negrusz, Ph.D., and Andrew Wheeler, MSFS, for their time and consideration.

CAS

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LIST OF ABBREVIATIONS

LDPE: Low Density Polyethylene

AXI: Axis Inversion

CA: Cyanoacrylate

CIE: Commission International de L'Eclarige

SUMMARY

Low Density Polyethylene (LDPE) bags are used to package a variety of legal and illegal products including illicit drugs such as cocaine and methamphetamine. In addition to scientific confirmation of the materials in the LDPE bags, it is often desirable or necessary to determine who has handled them. A primary way that this is achieved is by developing latent fingerprints on the bag. This can be accomplished effectively with a variety of techniques, most commonly: Black Powder Dusting or Cyanoacrylate (CA) Fuming.

A challenge arises from the fact that a single kilogram of illicit drugs can wind up packaged into hundreds or even thousands of LDPE bags. As a result, when law enforcement personnel arrest persons for sale and distribution of these and other drugs or other contraband substances, they can be faced with an enormous number of samples to process.

This study evaluated Axis Inversion (AXI) Dyeing to develop latent fingerprints on LDPE plastic bags by comparing the durability of latent fingermarks developed by this method with those developed by the common Black Powder Dusting and CA Fuming methods. Under test conditions, fingermarks developed with AXI Dyeing proved more durable than those produced by Black Powder Dusting or CA Fuming.

1. INTRODUCTION

1.1. Background
1.1.1. Low Density Polyethylene Bags

Products like cocaine and methamphetamine can be sold on the street in quantities as low as 0.1g -3g (www.ibtimes.com) and like any other products need appropriate packaging. Zip-lock style, low-density polyethylene (LDPE) bags are ideally suited to the purpose. LDPE is a thermoplastic polymer made from ethylene monomer and has been used industrially since 1933.[1] The polymer is typically non-reactive. It has good chemical resistance and is stable at normal environmental temperatures. (Malpas 2010) Although, it does have a thermal expansion coefficient of up to 220 x 10^{-6} mm/mm/°C. (www.bpf.co.uk)

LDPE bags are inexpensive and readily available. They can be purchased anonymously on-line or at stores that market to hobbyists and crafters. For the forensic scientist, LDPE presents physical challenges. The resin is soft and flexible. Low molecular weight organic molecules, like dyes, will tend to migrate into or out of the polymer under the right conditions. LDPE is also clear and can yellow when it oxidizes. To combat this yellowing, blue colorants are often added to make the resin appear clearer. (Keystone 2005)

[1] LDPE was developed by ICI: Imperial Chemical Industries

1.1.2. Latent Fingerprints

One of the pieces of information forensic scientists can be called on to determine from LDPE bags seized in an arrest is an identification of who handled the bag. This can sometimes be accomplished by the development of latent fingerprints into fingermarks. Although some contemporary sources identify latent fingerprints as accidental impression left by fingertip friction ridges (Zabel 2005) [2] this study limits the definition to non-visible impressions. When a fingertip impacts a surface, the water, oils and other waste material in human sweat can be deposited in the shape of friction ridges and other physical details. A variety of physical and chemical methods exists to visualize deposited sweat and develop the fingermark. (Triplet 2010)

However, methods for developing latent fingerprints on LDPE bags must overcome several challenges. A single arrest can yield an extremely large number of samples to be processed. The substrate of the bag itself is soft, flexible and sensitive to temperature extremes. A suitable process for fingermark development must therefore be rapid and not induce harsh temperature extremes.

[2] This definition would include patent fingerprints which are caused by the transfer of some visible foreign matter from the fingertip to the surface where the fingerprint is deposited.

1.1.3. The Impact and Effect of Color

Simply put, an image needs to be a different color from its background to be visible. If this differentiation is not naturally present it can be accomplished by changing lighting or adding an additional component such as a dye or a pigment. While the color difference does not need to be great, typically an image needs to have enough color difference from the background for the average person to notice it. This color difference can be quantified according to the CIELab system.

1.1.3.1 CIELab Color System

The Commission International de L'Eclarige (CIE) introduced their system (CIELab) for defining "color space" in 1931. Although the system has been refined since, a version of it is still the basis for color communications in many industries. Like other systems before and after it, the CIELab system presented perpendicular axes each representing a different color gradient: White to Black (L), Blue to Yellow (b) and Red to Green (a).

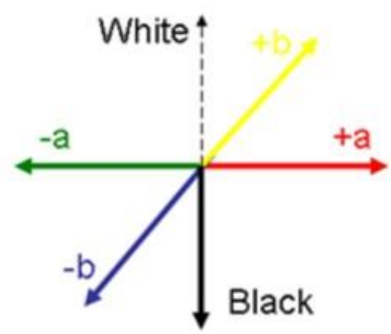


Image 1: CIELab Color Space

According to the CIELab system, changes along one axis do not affect the position in color space along another axis. For example, changing the position on the blue/yellow axis will not affect its position on the red/green axis. When trying to differentiate an image from its background it is useful to adjust along the axis perpendicular to the primary color axis of the background where the minimum amount of added color will have the maximum effect.

With the CIELab system, color difference is described in terms of: ΔL, Δa and Δb, the difference in position along each of the three axes. The net difference between the two points in the 3-dimentional space described is ΔE. (Heidelberg 1999, Sharma 2003)

One of the refinements to the CIELab system has been in how ΔE is calculated. In the original system ΔE was the simply: $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$, with a ΔE of less than 2.0 to 2.5 not being noticeable to the average person. (Sharma 2003) Later refinements the CIElab system incorporated corrections to account for differences in the intensity of perception of different colors by the human eye, predominantly along the yellow/blue axis. In the more recent system an average person wouldn’t notice a ΔE of less than 1.0 to 1.5. (Steele & Westman 1999)

1.2. Methods for Developing Latent Fingerprints

Common methods employed in developing latent fingerprints on LDPE bags include, black powder dusting and cyanoacrylate (CA) fuming. This study also explores a third option, Axis Inversion (AXI) Dyeing, to determine if this method is suitable for latent fingerprint development on LDPE. All three methods used in this study can potentially be used to develop and immediately photograph the image of a fingermark on LDPE bags. But, when determining if a proposed method is suitable, it is important to consider several aspects of its performance. The first aspect being: does it work?

For a system to be said to work it must provide an image of the fingermark distinct enough to be seen. Quantifying this: if a method produces a color shift (ΔE) of greater than 2 according to the equation $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$, it has produced an image distinct enough to be seen.

A system that works must also not distort the existing detail of the fingerprint or allow it to become distorted. In a crime lab, after a sample has been processed, it is placed in storage for later use if necessary. This presents challenges and difficulties to be overcome which are not unique to forensic science.

The simple handling of processed samples can subject them to undesired impact and abrasion. Space in coolers and environmentally controlled units is limited and warehouses can experience undesirable inconsistencies in temperature and humidity. Therefore, when determining the suitability of a proposed method of fingermark development, aspects or environmental stability should also be evaluated.

1.2.1 Cyanoacrylate Fuming

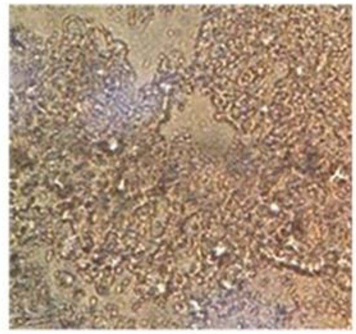


Image 2:
2-Polyethylcyanoacrylate at 400x

Ethyl-2-cyanoacrylate has been used to develop latent fingerprints since 1978. Typical methods heat liquid monomer to a vapor. When the vapors are brought into contact with biological residue, the vapor condenses and polymerizes into poly-ethyl-2-cyanoacrylate. (Image 1) As the Ethyl-2-cyanoacrylate cures into the polymer it forms a transparent globular solid which can be visualized and recorded. (Trozzi 2010, Steele, et.al. 2012) When the vapors into contact a latent fingerprint, the solid poly-ethyl-2-cyanoacrylate forms into the shape of the pattern left by the fingertip.

Regardless of the shape it takes, poly-ethyl-2-cyanoacrylate is a stiff resin with an expansion coefficient of approximately 90×10^{-6} mm/mm/°C. (Permabond 2011) Poly-ethyl-2-cyanoacrylate is also intrinsically a clear resin. Depending on how the rapidly the solid forms, it can be cloudy and easier to visualize.

Studies have shown that chilling the evidence containing the latent fingerprint will cause a greater randomness in the pseudocrystalline structure of the poly-ethyl-2-cyanoacrylate fingermark. As the randomness increases, opacity increases and a greater amount of colorants like rhodamine 6G can also be imparted to enhance the visualization. (Steele, et.al. 2011, Steele, et.al. 2012)

The polymerization of cyanoacrylates is exothermic. The process of polymerizing retards the condensation of additional vapor. In addition, solid, poly-ethyl-2-cyanoacrylate, is a subliming solid. In the presence of sufficient heat it will evaporate. (Steele, et.al. 2011)

One of the risks in CA fuming is the possibility of overdeveloping the fingermark as there is no typical easy way to see if fingermarks have developed while the process is proceeding. Even if it can be determined that fingermarks have been developed, the samples cannot typically be easily removed while the fuming is in process.

One of the ways to improve this process is with the use of colored resins like CN-Yellow or Fuming Orange which allow for easier observation of the developing fingermark. (Hines 2012) These products are colored versions of cyanoacrylate which produce a colored/fluorescent solid upon curing. They can be used in place of traditional poly-ethyl-2-cyanoacrylate, however, these resins are just beginning to be used and do not yet represent the industry standard.

1.2.2 Black Powder Dusting

Black Powder Dusting is one of the oldest and most common methods of latent fingerprint development. The process is simple. Carbon black powder is lightly dusted over the sweat residue, producing a black fingermark. Because carbon black is a pigment, it provides an opaque blocking of the color beneath it.

Carbon black is produced by burning hydrocarbons. There are many manufacturing processes and each uses a specific fuel, typically oil or natural gas, but any organic fuel can be used (www.carbonblack.jp). Each process and fuel produces a slightly different form of carbon black with different physical properties. (Steele, et.al. 2011)

Originally fingerprint powder was the Lamp Black form which was produced by burning oil or wood. Today, most forensic scientists use the Channel Black form, which is a food contact grade version of carbon black, produced by burning natural gas. Channel black has a high level of purity. The process by which it is produced is simple to execute and allows for better control of particle size than other production processes. (Steele, et.al. 2011)

Manufacturers report the “fundamental” particle size of channel black as 10 to 80nm. In practical use though, the particles are really much larger agglomerates of variable sizes up to and exceeding 5,000 nm. However, the “fundamental” particles are held together by Van der Waals forces (Surinder 2010) and can be and are ground to smaller, sub-micron sizes. Submicron sizes can also be manufactured in the laboratory.

The porous nature of channel blacks allows typical particles to absorb better than twice their mass in oil. This makes them excellent pigments for use in fingerprint processing. The pores absorb oil and moisture residue from the latent fingerprint and hydrogen bonding making it adhere to the surface where the fingerprint has been deposited. (Steele, et.al. 2011) Because the pores are at the surface of the pigments, smaller particles will have a greater absorbance.

1.2.3 Axis Inversion Dyeing

The Axis Inversion (AXI) Dyeing method was designed to develop latent fingermarks on plastic tape (Steele & Ball 2003). AXI Dyes are versions of low molecular weight disperse dyes. They have virtually no solubility in water and can be vaporized without breaking down the dye molecule. In the presence of proper solvents or sufficient heat, AXI dyes can be made to invade a variety of substrates, with particular affinity for polymers. Once in the material, the dye crystallizes to form a colored component. This method is used to print polyester, produce colored smoke and perform fume based dyeing and staining (AATCC 1997).

When used to develop fingermarks on plastic, AXI dyes are vaporized to invade the polymer on all exposed surfaces except where the vapors are blocked. Fingerprint residue on the surface of the plastic prevents the vapors from penetrating. As a result the polymer is colored everywhere except where the latent fingerprint exists, providing a negative image of the fingermark.

The amount of color imparted to the plastic depends on how long the vapors are exposed. A short exposure will provide a weak tint. Long exposures will provide a stronger dyed shade. But in all cases, the AXI dyes are solubilized into the resin so the color is additive to the natural background and durable.

Samples from the original 2003 study were examined prior to beginning this study. The original color shift produced by AXI dyeing was still evident. Most importantly, the ridge detail outlined by the AXI dyeing was still evident.

Image 3: Fingerprint on the smooth side of black electrical tape that had been treated with AXI yellow in 2003.

There are three AXI dyes available on the market. Axis Inversion Blue is a form of Disperse Blue 60, Axis Inversion Yellow is a form of Disperse Yellow 211 and Axis Inversion Red is a form of Disperse Red 60.

Each color is suitable for different colored background. AXI Blue is suitable for red and brown backgrounds like packing tape (Steele & Ball 2003). AXI yellow is a good means for altering the shade of black backgrounds like electrical tape shown above and gel lifters[3] shown below.

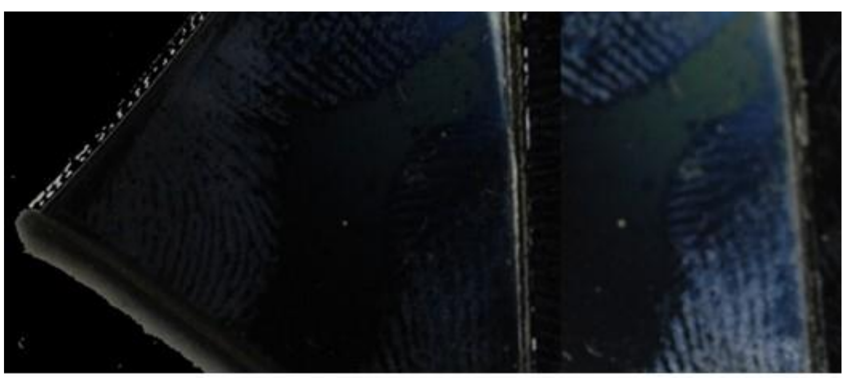


Image 4: AXI Yellow on Gel Lifter

[3] http://anevalinc.blogspot.com/2011/11/me-william-and-gel-lifter-part-2.html

Both of the materials displayed in images 3a and 3b are smooth, black and glossy. Carbon black dusting and CA fuming both produce fingermarks that are difficult to see on this background. By contrast, because the AXI yellow changes the background color, the fingermarks become easier to view, and because the images are the result of a dyeing system rather than a surface color, the image of the fingerprint remains long after the fingerprint has worn away.

However, while AXI yellow provides a good durable image, it is unsuitable for LDPE. LDPE experiences color shifts on the yellow/blue axis through oxidation and bluing agents, a slight increase in the yellowness or blueness of the bag could therefore be missed by an analyst.

The greatest opportunity to enhance visualization with the minimum dye exposure is to add color on the red axis. Therefore AXI Red[4] which has a primary absorption between 475 nm and 575 nm was deemed to be the most appropriate choice from the available pallet.

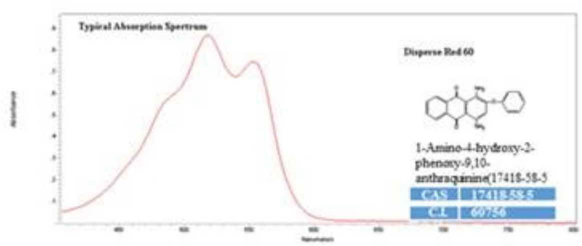


Image 5:
Typical Absorbance Spectra of AXI Red

[4] Optical absorption measurements were made by C.A. Steele using a Cary 3.

1.2.4 Observer Bias in Latent Fingerprint Analysis

Significant errors, like the misidentification in the 2004 Madrid Bombing case (Office of the Inspector General 2006) have prompted the legal and scientific communities to question the reliability of fingerprint evidence. In its critiques of the forensic sciences, the National Research Council stressed the need for accuracy in fingerprint examination. (NRC 2009) Most recently, in his address to the National Commission on Forensic Science, the Honorable Harry T. Edwards specifically pointed out that the courts are accepting fingerprint evidence on precedent rather than scientific validity. (Edwards 2014)

Even if one accepts the prevailing belief that fingerprints are unique to each person, one must still realize that it is solely the latent fingerprint examiner who determines if there is sufficient detail in a developed fingermark to make a valid identification and to present that identification to the court. In theory this decision is based solely on knowledge and experience. Knowledge can be tested and experience can be quantified. However, because the match is based on a visual comparison, one must also consider observational bias and visual acuity.

Observer bias is not a unique issue to any specific human endeavor. In cases of ambiguity people tend to see what they expect to see. (Giannelli 2007) With fingerprint and fingermark comparisons however, expectations of outcome can be the difference between a proper comparison and a false match or false exclusion. In one study, experts were given samples without being told that they had already declared them as matches. The experts were told the sample were part of a case of misidentification. Under these conditions more than one expert declared these samples as exclusions. (Dror, et al. 2006) Elimination of observer bias based on expectation is therefore a realistic necessity.

The most obvious way to counter observer bias is to test all samples ignorant of context. However in practice, this is not often possible. Researchers usually know what study they are working on. Bench scientists working for police departments usually know where their evidence came from.

One approach available to latent fingerprint analysis is to have all samples reviewed by a second person who is ignorant of the conclusion made by the first person. The philosophical approach of having samples reviewed by a second laboratory (Koppl et. al. 2008) may not be possible, but protocols can still be developed for blind testing by additional observers.

That leaves visual acuity. Human beings have different levels of color and forms acuity. Simply put, not every person can distinguish shapes and colors equally well. Color vision can be tested[5]. There are a variety of tests available. The Ishihara Color Test, which has been used since 1917, simply uses colored spaces to obscure numbers. (www.colormatters.com) People with specific color blindness will see or not see the numbers. For a more quantitative measure of a person's color perception a Farnsworth-Munsell 100 HueColor Vision Test can be used. (www.color-blindness.com) In the Farnsworth-Munsell test, the subject has to place colors in order along a gradient indicating how precise their color vision is along that gradient.

Color based analysis can be augmented with spectrophotometric equipment, optical filters and special cameras, but that only helps if the analyst knows to use them. A person who doesn't notice that a fingerprint is present because the color is below their visible threshold may not think to examine the spot with electronic aids.

Forms acuity however, presents a more serious challenge. Pattern and forms blindness have been shown to be the most important predictor of a person's ability to compare and evaluate

[5] http://www.colour-blindness.com/colour-blindness-tests/ishihara-colour-test-plates/

fingerprints. (Bertram 2009) Unfortunately to date, only limited resources are available to establish forms acuity and few of these have been rigorously tested. (testcogpro.com)

It is true that simple shapes can be measured and quantified. Fingerprints however are not simple shapes. The geometry of the impression can be affected by the pressure and force directionality of the application. Multiple observers are still therefore one of the best ways to corroborate a visual assessment.

2. EXPERIMENTS

2.1. Sample Preparation

Fingerprints were deposited on LDPE bags by smoothly pressing a thumb or finger against them when they were at rest on a solid smooth surface. The bags were inspected with oblique light for the presence of a useable latent fingerprint. The bags that did not have a useable latent fingerprint on them were discarded. The remaining bags were allowed to dry and then processed according to the three methods under test.

2.1.1 Processing of Carbon Black Samples

Each of the sample bags were opened and placed on a clean smooth surface and lightly dusted with a common channel black powder, using a fresh fiberglass brush (Arrowhead Part # A-2497) and then photographed to record the image of the fingermark for future comparisons. A numbered strip was placed in each bag to identify it and then the bags were divided up to be used in the various tests.

2.1.2 Processing of Cyanoacrylate Samples

For bulk samples, such as hundreds of small LDPE bags, laboratories would typically place them in a fuming chamber and introduce clear ethyl-2-cyanoacrylate vapors. However, initial experiments determined that this approach produced an undesired variability in the quality of the fingermarks developed.

A fuming wand[6] was therefore used to administer the ethyl-2-cyanoacrylate. A fuming wand heats a cartridge of cured poly-ethyl-2-cyanoacrylate into a vapor form that can be easily directed over the desired spot. Each of the sample bags were opened and hung up in groups of 20 in a fume hood. The wand was ignited. Once it was producing a steady vapor stream, the wand was waved in front of each LDPE bag for 10 seconds, in a manner that allowed the vapor stream to flow over the bag. After the bags were treated with cyanoacrylate they were put aside for an hour to allow for the resin to fully cure.

At the end of the hour, each bag was then photographed to record the image of the fingermark for future comparison. A numbered strip was placed in each bag to identify it and then the bags were divided up to be used in the various tests.

2.1.3 Processing of the Axis Inversion Red Dye Samples

Axis Inversion Red is available in a liquid and powder form both of which are intended for chamber fuming similar to the method used for CA fuming. However, attempts with chamber fuming encountered similar consistency issues as were seen with CA fuming. Therefore fuming wand cartridges were produced for this experiment loaded with AXI red and wand fuming was performed.

[6] FUME-A-WAND™ by Porta-Lab™

Each of the sample bags were opened and hung up in groups of 20 in a fume hood. The wand was ignited. Once it was producing a steady vapor stream, the wand was waved in front of each LDPE bag for 2-3 seconds, in a manner that allowed the vapor stream to flow over the bag. As soon as the fuming was done the bags were photographed to record the image of the fingermark for future comparison. A numbered strip was placed in each bag to identify it and then the bags were divided up to be used in the various tests.

2.2. Experiment 1: Ease of Development

2.2.1 Background

Although it should be stated that ease of use should not be the sole determinant of what test is best to use, it is true that people will tend to gravitate toward the easier protocols. Each method under test therefore was selected for this study because of its relative simplicity. None of the three tests required exotic equipment or difficult to master laboratory techniques. The physical actions necessary to perform the three tests under study were sufficiently similar in that manual dexterity was not deemed to be a factor in the ease of development of the latent fingerprints. Visual acuity however was considered significant. The processing time and associated effort was directly impacted by how well the developing fingermark could be seen.

2.2.2 Method

The three methods under test were evaluated for how much time was required to process each sample and how easy it was to determine if a fingermark had been fully developed.

2.2.3 Results

Table i: Ease of Development Results

Rank	Method	Notes
1	Axis Inversion Red	Many bags could be processed simultaneously. Fingerprints images could be photographed immediately.
2	Cyanoacrylate	Many bags could be processed simultaneously. Fingerprints images could be photographed after an hour.
3	Carbon Black	Bags had to be processed one at a time. Fingerprints images could be photographed immediately.

Dusting with carbon black was by far the most labor intensive as each bag had to be individually handled. If one only considers the time spent to process each bag it is also the slowest. However, there are certain advantages. Development of fingermarks with carbon black could be seen as they occurred. It was therefore easy to know when to stop so that fingerprints were not over worked. In addition, once they were dusted, the bags could be photographed immediately.

Cyanoacrylate processing was the second fastest as many bags could be processed simultaneously. However, during the processing step it was difficult to tell if a fingermark was developing or not and the bags had to be left to stand for at least an hour to ensure the polymer was finished curing.

The quickest process was Axis Inversion dyeing. Like cyanoacrylate fuming, many bags could be processed simultaneously. Like carbon black dusting, the images could be photographed immediately.

2.2.4 Discussion

While this exercise determined that the AXI dyeing was the “easiest” to execute, it should be noted that the concept of ease and speed is relative to the number of samples and the established work flow of the laboratory. This study is considering the case where there are many samples to process. If, however, there were only one sample, an analyst may choose to use black powder dusting because it can be done without ventilation and speed is no longer a factor. Likewise, if a small set of samples is being processed and the laboratory is already set up for cyanoacrylate fuming, it may be more time efficient to process the LDPE bags with ethyl-2-cyanoacrylate.

Therefore the three methods under test, as well as the myriad of additional tests available to the forensic scientist should all be considered “tools in the box.” The decision as to which is easiest and most practical to execute should be done in context to the number of samples and laboratory setup.

2.3. Experiment 2: Quality of Image
2.3.1. Background

Alteration of the fingermark can occur because the process damages or distorts the residue left on the bag, or damages or distorts the bag itself. As stated above, any method being evaluated needs to produce an image that does not alter, nor allow to be altered, the details of the fingermark.

LDPE bags are non-reactive to many common solvents and chemicals. But, low molecular weight compounds can migrate into or out of the plastic. Temperature changes can alter the shape of the bag. High temperatures can soften or even melt a LDPE bag irreversibly altering the shape and detail of a fingermark on it. Even low temperatures can potentially cause uneven shrinkage in the resin, resulting in distortion.

In addition, any method should produce a color shift (ΔE) of greater than 2 according to the equation $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$. It should be noted that this requisite color shift can be caused in many different ways. The ambient light can be altered so that only specific wavelengths are incident, exploiting specific refractive qualities. The test method can be followed with one or more coloration steps to enhance a fingermark once it has been detected, and of course, the test itself can provide the desired color shift.

Consider by way of example the use of ethyl-2-cyanoacrylate for CA fuming. Many options exist for coloring the polymer formed by the use of this monomer. An alcohol solution of rhodamine 6G can be washed over the cured polymer to provide a fluorescent color. Optionally, evidence temperatures can be altered so that the polymer forms with an increased level of randomness causing greater opacity. (Steele, et.al. 2012)

Likewise, carbon black powder can be mixed with optical brighteners to allow for fluorescent detection or viewing with specific light sources. Of course, methods can be combined. A fingerprint can be fumed with ethyl-2-cyanoacrylate while carbon black particles are produced. (Steele, et.al. 2011) Each addition to the base methods increases the required time and chance for error. For the purposes of these experiments therefore, each test will be considered in terms of the color shift it directly produces, rather than the possible outcome with additional steps.

2.3.2 Method

Each sample from the methods under test produced in section 2.1 was examined visually with a hand held magnifier for any distortion. Each photograph taken was also examined. Distortion was determined in two ways. First, obvious breaks, stretches of the actual ridge detail were noted. Second, the entire image of the fingermarks were examined for voids or smudges that could be attributed to the method of developing the fingermark.

The fingermarks were rated according to a simple scale ranging from excellent to unusable.

Table ii: Quality of Image Scale

Evaluation	Score	Description
Excellent	4	Complete ridge detail, no smudging or substantial defect
Good	3	Weak, Faint but still easily visible ridge detail, no smudging or substantial defect
Fair	2	Difficult to see but entirely present ridge detail, no smudging or substantial defect
Poor	1	Missing ridge detail. Potential defects or smudges
Unusable	0	Insufficient detail to perform an accurate match

Once the integrity of the print was established, the relative visibility was determined by scanning the fingermarks with an X-Rite Color DPT22 diode array spectrophotometer and comparing the averages of all of the color curves generated by each sample under test for each group to those of an untreated LDPE bag.

Three sets of scans were taken for each of three unprocessed LDPE bags against a white background. These scans were averaged and provided baseline L, a and b for LDPE. Each sample produced in section 2.1 was also scanned three times against a white background. The scans from each sample were averaged with the others from its set (AXI, CA or CB) to provide a range and average the L, a and b value for the fingermarks produced by each method under test.

From these data an average ΔL, Δa and Δb for each method under test was determined and used as a means of ranking the quality of the fingermarks produced.

2.3.3 Results

2.3.3.1 Image Detail

Table iii: Samples Processed with Axis Inversion Red

AXI Sample	Score	Description
1	4	Excellent: Complete ridge detail, no smudging
2	4	Excellent: Complete ridge detail, no smudging
3	4	Excellent: Complete ridge detail, no smudging
4	4	Excellent: Complete ridge detail, no smudging
5	4	Excellent: Complete ridge detail, no smudging
6	1	Poor: Faint ridge detail, some void areas where no detail was present, no smudging
7	4	Excellent: Complete ridge detail, no smudging
8	3	Good: Faint ridge detail, no smudging
9	4	Excellent: Complete ridge detail, no smudging
10	4	Excellent: Complete ridge detail, no smudging
11	4	Excellent: Complete ridge detail, no smudging
12	4	Excellent: Complete ridge detail, no smudging
13	4	Excellent: Complete ridge detail, no smudging
14	4	Excellent: Complete ridge detail, no smudging
15	3	Good: Faint ridge detail, no smudging
16	4	Excellent: Complete ridge detail, no smudging
17	4	Excellent: Complete ridge detail, no smudging
18	4	Excellent: Complete ridge detail, no smudging
19	4	Excellent: Complete ridge detail, no smudging
20	4	Excellent: Complete ridge detail, no smudging
21	3	Good: Faint ridge detail, no smudging
22	3	Good: Faint ridge detail, no smudging
23	4	Excellent: Complete ridge detail, no smudging
24	4	Excellent: Complete ridge detail, no smudging
25	4	Excellent: Complete ridge detail, no smudging
26	4	Excellent: Complete ridge detail, no smudging
27	4	Excellent: Complete ridge detail, no smudging
28	4	Excellent: Complete ridge detail, no smudging
29	4	Excellent: Complete ridge detail, no smudging
30	4	Excellent: Complete ridge detail, no smudging
31	1	Poor: Faint ridge detail, some void areas where no detail was present, no smudging
32	4	Excellent: Complete ridge detail, no smudging
33	4	Excellent: Complete ridge detail, no smudging
34	4	Excellent: Complete ridge detail, no smudging
35	4	Excellent: Complete ridge detail, no smudging
36	3	Good: Faint ridge detail, no smudging
37	3	Good: Faint ridge detail, no smudging
38	4	Excellent: Complete ridge detail, no smudging
39	4	Excellent: Complete ridge detail, no smudging
40	4	Excellent: Complete ridge detail, no smudging
41	4	Excellent: Complete ridge detail, no smudging
42	4	Excellent: Complete ridge detail, no smudging
43	4	Excellent: Complete ridge detail, no smudging
44	4	Excellent: Complete ridge detail, no smudging
45	4	Excellent: Complete ridge detail, no smudging
46	4	Excellent: Complete ridge detail, no smudging
47	3	Good: Faint ridge detail, no smudging
48	4	Excellent: Complete ridge detail, no smudging
49	4	Excellent: Complete ridge detail, no smudging
50	4	Excellent: Complete ridge detail, no smudging

Table iv: Samples Processed with 2-Ethylcyanoacrylate

CA Sample	Score	Description
1	3	Good: Faint ridge detail, no smudging
2	3	Good: Faint ridge detail, no smudging
3	3	Good: Faint ridge detail, no smudging
4	3	Good: Faint ridge detail, no smudging
5	3	Good: Faint ridge detail, no smudging
6	3	Good: Faint ridge detail, no smudging
7	1	Poor: Faint ridge detail, some void areas where no detail was present, no smudging
8	4	Excellent: Complete ridge detail, no smudging
9	3	Good: Faint ridge detail, no smudging
10	3	Good: Faint ridge detail, no smudging
11	3	Good: Faint ridge detail, no smudging
12	3	Good: Faint ridge detail, no smudging
13	3	Good: Faint ridge detail, no smudging
14	3	Good: Faint ridge detail, no smudging
15	1	Poor: Faint ridge detail, some void areas where no detail was present, no smudging
16	3	Good: Faint ridge detail, no smudging
17	3	Good: Faint ridge detail, no smudging
18	3	Good: Faint ridge detail, no smudging
19	3	Good: Faint ridge detail, no smudging
20	3	Good: Faint ridge detail, no smudging
21	3	Good: Faint ridge detail, no smudging
22	3	Good: Faint ridge detail, no smudging
23	3	Good: Faint ridge detail, no smudging
24	3	Good: Faint ridge detail, no smudging
25	3	Good: Faint ridge detail, no smudging
26	3	Good: Faint ridge detail, no smudging
27	3	Good: Faint ridge detail, no smudging
28	3	Good: Faint ridge detail, no smudging
29	4	Excellent: Complete ridge detail, no smudging
30	3	Good: Faint ridge detail, no smudging
31	3	Good: Faint ridge detail, no smudging
32	1	Poor: Faint ridge detail, some void areas where no detail was present, no smudging
33	3	Good: Faint ridge detail, no smudging
34	3	Good: Faint ridge detail, no smudging
35	3	Good: Faint ridge detail, no smudging
36	3	Good: Faint ridge detail, no smudging
37	3	Good: Faint ridge detail, no smudging
38	3	Good: Faint ridge detail, no smudging
39	1	Poor: Faint ridge detail, some void areas where no detail was present, no smudging
40	1	Poor: Faint ridge detail, some void areas where no detail was present, no smudging
41	3	Good: Faint ridge detail, no smudging
42	3	Good: Faint ridge detail, no smudging
43	3	Good: Faint ridge detail, no smudging
44	3	Good: Faint ridge detail, no smudging
45	3	Good: Faint ridge detail, no smudging
46	3	Good: Faint ridge detail, no smudging
47	3	Good: Faint ridge detail, no smudging
48	3	Good: Faint ridge detail, no smudging
49	4	Excellent: Complete ridge detail, no smudging
50	3	Good: Faint ridge detail, no smudging

Table v: Samples Processed with Carbon Black Powder

CB Sample	Score	Description
1	4	Excellent: Complete ridge detail, no smudging
2	3	Good: Faint ridge detail, no smudging
3	4	Excellent: Complete ridge detail, no smudging
4	4	Excellent: Complete ridge detail, no smudging
5	3	Good: Faint ridge detail, no smudging
6	4	Excellent: Complete ridge detail, no smudging
7	4	Excellent: Complete ridge detail, no smudging
8	4	Excellent: Complete ridge detail, no smudging
9	3	Good: Strong ridge detail, no smudging but excess powder present
10	4	Excellent: Complete ridge detail, no smudging
11	3	Good: Faint ridge detail, no smudging
12	3	Good: Faint ridge detail, no smudging
13	4	Excellent: Complete ridge detail, no smudging
14	4	Excellent: Complete ridge detail, no smudging
15	3	Good: Faint ridge detail, no smudging
16	4	Excellent: Complete ridge detail, no smudging
17	4	Excellent: Complete ridge detail, no smudging
18	1	Poor: Faint ridge detail, some void areas where no detail was present, no smudging
19	3	Good: Faint ridge detail, no smudging
20	3	Good: Faint ridge detail, no smudging
21	1	Poor: Faint ridge detail, some smudging
22	3	Good: Faint ridge detail, no smudging
23	1	Poor: Strong ridge detail, some smudging
24	4	Excellent: Complete ridge detail, no smudging
25	4	Excellent: Complete ridge detail, no smudging
26	4	Excellent: Complete ridge detail, no smudging
27	4	Excellent: Complete ridge detail, no smudging
28	1	Poor: Faint ridge detail, some smudging
29	1	Poor: Faint ridge detail, some smudging
30	4	Excellent: Complete ridge detail, no smudging
31	4	Excellent: Complete ridge detail, no smudging
32	4	Excellent: Complete ridge detail, no smudging
33	4	Excellent: Complete ridge detail, no smudging
34	1	Poor: Some good ridge detail, substantial smudging
35	4	Excellent: Complete ridge detail, no smudging
36	4	Excellent: Complete ridge detail, no smudging
37	4	Excellent: Complete ridge detail, no smudging
38	4	Excellent: Complete ridge detail, no smudging
39	4	Excellent: Complete ridge detail, no smudging
40	3	Good: Faint ridge detail, no smudging
41	4	Excellent: Complete ridge detail, no smudging
42	4	Excellent: Complete ridge detail, no smudging
43	4	Excellent: Complete ridge detail, no smudging
44	4	Excellent: Complete ridge detail, no smudging
45	4	Excellent: Complete ridge detail, no smudging
46	4	Excellent: Complete ridge detail, no smudging
47	4	Excellent: Complete ridge detail, no smudging
48	4	Excellent: Complete ridge detail, no smudging
49	4	Excellent: Complete ridge detail, no smudging
50	4	Excellent: Complete ridge detail, no smudging

2.3.3.2 Color Difference

The scans of the LDPE bags produced the following baseline values: L = 86.98, a = 0.55 and b = 0.96. The color data from the fingermarks that had been processed by the various methods are summarized in the table below.

Table vi: Average Color Data

Method	$L_{(avg)}$	ΔL	$a_{(avg)}$	Δa	$b_{(avg)}$	Δb	ΔE
Axis Inversion Red Dyeing	82.81±5.4	-4.70	9.22 ± 2.2	8.67	0.04±0.01	-0.92	9.66
2 ethyl-2-cyanoacrylate Fuming	86.35±0.3	-0.63	0.84±0.1	0.29	0.90±0.1	-0.06	0.70
Carbon Black Dusting	60.69±9.6	-26.29	0.44±0.1	-0.11	1.42±0.5	0.46	26.29

2.3.4 Evaluation of Observer Bias

The samples evaluated in section 2.3 were prepared and interpreted by the author who is also the inventor of the AXI dyeing system. As such, there is the possibility of unintentional observer bias in the rating of the developed images. To eliminate this potential bias, three sets of images from each method under test were submitted to blind evaluation by uninvolved parties.

Twenty images of samples from each method under test were chosen to emulate the quality distribution ratings by the author in section 2.3.3.1. These images were posted on-line for review by volunteers.[7]

Twenty-two volunteers evaluated the quality of the images according to the scale set forth in section 2.3. The volunteers crossed a spectrum of training and experience. Five volunteers were professional fingerprint examiners with at least 5 years experience. Two volunteers were professionally familiar with fingerprint analysis but had no professional experience actually analyzing fingermarks. The remaining fifteen individuals had no prior training in fingerprint analysis.

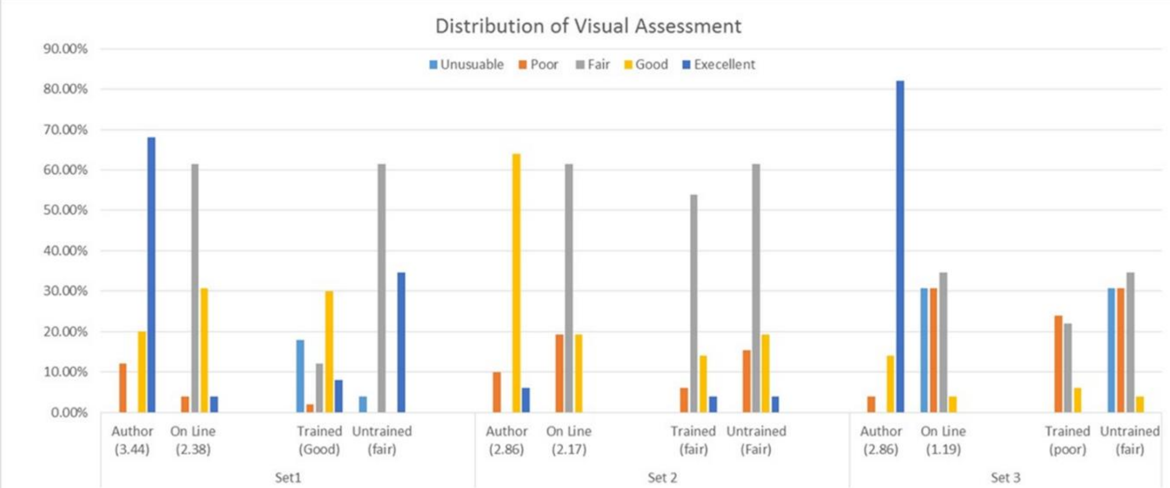
The ratings of the on-line volunteers were averaged with the following results. Overall, the fingermark images were rated one to two categories lower by the on-line observers than by the author. This may be due to many factors including: the amount of time taken per image, the quality of computer monitor used and the visual acuity of the volunteer. The assessment of the on-line observers was also a combination of color intensity and presence of clear detail.

[7] http://www.anevalinc.com/fingermarkstudy.html

Nonetheless, the carbon black samples were still rated the most visible with an average score of 2.38. The AXI red samples were rated the second most visible with an average score of 2.17. The CA samples were rated the least visible with a score of 1.19.

The greatest consistency between the trained and untrained volunteers was in the assessment of the samples in set 2, the AXI red samples. Overall both trained and untrained observers rated these as fair. The most pronounced difference was in the evaluation of group 3 where the untrained on-line observers rated 30% of the samples unusable while the trained observers had no samples rated unusable.

Chart 1: On-Line Evaluations



Shown in the parenthesis for the author and the entire on-line volunteer population is the average score for the set. Shown in the parenthesis for the trained and untrained on-line volunteers is the category they most often assigned.

While the average ratings of the entire on-line community support the assessments of the author, there was substantial variation between the trained and untrained observers. Carbon black samples for example, were given an average score of 2.83 with the greatest number of samples being rated as good by the volunteers who were trained and 2.28 with the greatest number of samples being rated as fair by the volunteers that were untrained.

It is important to realize that correlating the average rating of 2.83 to the average rating of 2.28 is only a valid comparison if one assumes a gradient of value for fingerprint quality from ratings of 0 to 4 where the quality of the fingermark is relative to the score. In such cases, an average “fair” fingermark which receives a rating of 2 would be half the quality of an average “excellent” fingermark receiving a rating for 4. Under these parameters, the standard deviation for all the on-line observers is approximately 0.9, showing substantial observer to observer variation.

Moreover, repeat samples did not consistently receive the same score from the same volunteer irrespective of training. In each set there were also six repeat samples. The repeated samples were only given the identical scoring 40% of the time by the untrained group of volunteers and 38% of the time by the trained group of volunteers. An image was typically rated lower if it followed an image of better quality. Likewise it was rated higher if it followed an image of lower quality.

Continuing with the presumed validity for the 0 to 4 continuum further allows a quantification for the differences in the impressions of the fingermark images between the trained observers and the untrained observers shown in Chart 1. Using the standard deviation to eliminate the outlier values, an average value for each fingermark image was established for both the group of trained observers and untrained observers. A T-Test analysis of these averages yields a p value of 0.00143 indicating a substantial dissimilarity between the ratings applied by each group.

2.3.5 Discussion

Table vii: Quality of Image results

Rank	Method	Notes
1	Carbon Black	The easiest fingerprints to see and record were the carbon black fingerprints
2	Axis Inversion Red	The Axis Inversion Red provided good contrast, adding 1-2 red shade unites to the clear LDPE, which has residual color along the yellow/blue axis. However, as the fingerprint detail is in the form of a void, it less easily examined
3	Cyanoacrylate	Because Poly-Cyanoacrylate is a transparent resin and the LDPE bags are clear, the fingerprints developed with cyanoacrylate fuming were the hardest to detect. Additional post processing of the fingerprints with some colorant would be recommends.

Only the carbon black samples required physical contact and as a result only the carbon black samples showed any signs of smudging. However, most samples had excellent detail and could be easily read. Only six samples were deemed to be of poor quality and even these had areas of sufficient detail to allow for a reasonable identification.

The worst of the samples (CB 34) is shown at the side. As can be seen in the image, substantial areas of the fingermark are visible but the greatest bulk was smudged in processing.

Image 6:
Carbon Black Fingerprint Sample 34

However, the visual contrast between the fingermarks developed with carbon black and the LDPE bags was greater than the other two methods. The ΔE generated with this method is entirely along the “L” axis, darkening the image to improve visibility. However, carbon black has absorption along the entire visible spectrum[8] and can be viewed by any light source. And while the calculated ΔE, 26.29 is so high that a precisely accurate number cannot be given, it can be said to be extremely visible.

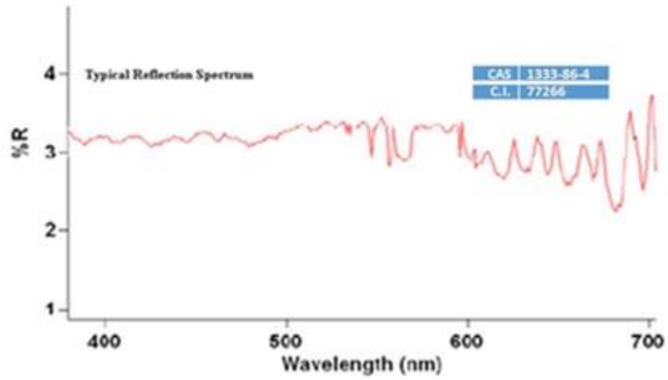


Image 7:
Typical Absorbance Spectra of Carbon Black

Only two of the AXI red samples were rated as poor. The worst of these was sample AXI 31. The image was light and hard to evaluate. In addition, there were a few spots on the fingermark where there was very little contrast between the ridge detail and the LDPE bags making it almost impossible to examine without electronic enhancement.

Image 8:
Axis Inversion Red Fingerprint Sample 31

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[8] Optical reflection measurements were made by C.A. Steele using a Cary 3.

However, most of the AXI red samples were rated excellent (or good by the on-line observers) and had extremely clear, well defined detail. The average color difference produced by this method was ΔE = 9.66. The primary contribution was on the "a" (red/green) axis but the process did also make the area around the fingermark almost 6% darker.

Because poly- ethyl-2-cyanoacrylate is a transparent resin and the LDPE bags are clear, the fingermarks developed with CA fuming were the hardest to detect. Sample CA 15, shown at the side was rated poor because the details were faint and needed electronic enhancement to fully visualize. Even once visualized, there were areas in the fingermark where no poly-ethyl-2-cyanoacrylate had formed.

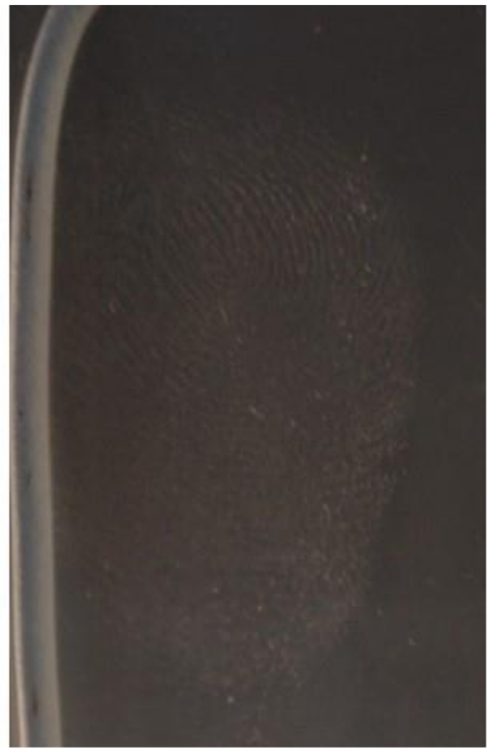

Image 9:
Cyanoacrylate Fingerprint Sample 15

Most of the samples were rated as good. The detail even though faint was complete. Additional post processing of the fingermarks with some colorant would be recommended.

Based on these samples, carbon black was rated as the most visible. It produced the greatest chromatic difference with the LDPE bag. Although these samples did have the most "smudging" caused by the brush during processing the other two processes are also vulnerable to similar technique issues.

CA processing is vulnerable to under fuming which may cause the lack of important detail. CA processing can also result in over fuming causing details to become indistinguishable. Likewise, AXI dyeing can be over or under done if the timing is off.

Considering these possibilities, the fact that technique based errors damaged a few carbon black samples does not seem to be vastly different than the potential damage from processing by the other two methods. Therefore carbon black dusting and AXI printing were judged to produce equally defined images, both of which were better than those produced by CA fuming.

The final determinant for which method produced the best quality image between AXI dyeing and carbon black dusting was the intensity of the color difference between the fingermark and the LDPE bag. In this category, carbon black was the clear winner. Not only was the ΔE significantly higher, the image produced by AXI dyeing was in the form of a negative.

The detail produced by AXI dyeing was in the voids rather than the colored area. This may be difficult for some analysts to adjust to. Comments from the on-line volunteers support this idea. Several volunteers indicated that they rated the AXI images lower because the details of the fingerprints themselves were "lighter" than the background. Image can of course be inverted electronically but that would be an extra step and outside the scope of this investigation.

Nonetheless, the on-line volunteers support the observations of this study that carbon black produced the highest quality image. AXI dyeing had the second highest quality. And of the three methods under test, CA fuming developed the hardest to view fingermarks.

2.4. Experiment 3: Dry Crocking

2.4.1. Background

Small bags of drugs placed in a box with other small bags of drugs and placed on a shelf will experience some amount of jostling and abrasion from rubbing against other samples. If one assumes that the scientists, technicians and storage clerks exercise the maximum amount of care, one can also assume that the samples will receive only minimal amounts of rubbing against other samples. But, even minimal rubbing is unwanted physical contact and has the potential to damage fingermarks during storage.

The AATCC dry crocking test simulates casual rubbing by placing a sample under a supported head and gently passing it back and forth ten times. (AATCC 1997) The rubbing head is fitted with white cotton lawn cloth which will easily show color transfer and minimize abrasion from the apparatus used. When used for textiles, the purpose of the test is to determine how much color would transfer onto a surface that the colored object was rubbed against. However, as the test simply simulates casual rubbing it can also be used to evaluate the damage done to the rubbed surface.

2.4.2 Method

Ten samples (41-50) from each set (AXI, CA and CB) were subjected to a modified AATCC dry crocking test to simulate casual rubbing[9]. (AATCC 1997) The focus of this study was not the color transfer itself. Rather, this study focused on the damage done to the fingermarks by rubbing against them. Each sample was therefore mounted below the supported rubbing head and the rubbing head was fitted with white cotton lawn cloth which would soften the abrasion and allow for easy evaluation of transferred color if it was deemed necessary.

Each sample was then subjected to ten passes back and forth of the rubbing head. The sample bags were then removed and examined for damage.

2.4.3 Results

Table viii: Dry Crocking Results

Rank	Method	Notes
Pass	Axis Inversion Red	10 passes of the crocking head. The fingerprints developed with Axis Inversion red were unaffected by crocking. It should be noted that the originally deposited fingerprint residue can be rubbed away or smeared by crocking and over dyeing with Axis Inversion dye will cause a build-up of undissolved dye on the surface of the bag. In sufficient quantity, this dye can smear ruining the image of the fingerprint. None the less, Axis Inversion Dyes were more resistant to casual rubbing.
Fail	Carbon Black and Cyanoacrylate	The fingerprints developed with Carbon Black and Cyanoacrylate were substantially rubbed away after 10 passes of the crocking head.

[9] The method used was an adapted form of AATCC Test Method 8 which omitted the sample conditioning which is used for textiles.

Each of the carbon black and cyanoacrylate samples were substantially obliterated by ten passes with the rubbing head. By contrast, none of the AXI red samples were damaged by this test.

2.4.4 Discussion

Although the fingermarks developed with Axis Inversion Red were unaffected by ten passes with the crocking head, it should be noted that the originally deposited fingerprint residue can be rubbed away or smeared by crocking. More importantly, perhaps, is the fact that over exposure to the AXI red during fuming will cause excess dye to be deposited on the surface of the LDPE bag and not be able to migrate into the plastic of the bag.

If this situation occurs, the extra dye on the surface can potentially be rubbed into the plastic by casual abrasion. This is especially true if the underlying biologic residue is rubbed away in the process. It is be possible to gently wash away any excess AXI dye on the surface of any test bags, but this would add an additional step and cause the loss of biologic matter.

The above concerns aside, Axis Inversion Dyeing is more resistant to casual rubbing than the other two methods under test.

2.5. Experiment 4: Environmental Stability
2.5.1. Background

Environmental stability testing is a common challenge that is a part of many quality systems. If a product, sample or item is to be stored for later use, it is critical to know if it will survive that storage. To help determine this, a series of tests designed to emulate the conditions that can reasonably be expected to be encountered should be run on test samples. (Steele & Westman 1999, Steele 2001)

Environmental stability tests can take several forms. Simple tests may involve subjecting a sample to extremes of heat or cold. More involved tests may include simulated sunlight or weather exposure. However, neither sunlight nor weather is a reasonable condition in normal storage.

Storage stability focuses on conditions that would be encountered in a typical warehouse or shipping container. For economic reasons, most trailers and warehouses are not climate controlled. Temperatures can reach as high as 60°C (140°F) or as low as -10°C (14°F) or colder depending on location and time of year. Items may experience multiple freeze/thaw cycles or be exposed to high humidity. It is important therefore, than any environmental stability study take these conditions into account.

In practical terms, common stability tests run samples at elevated temperatures of 60°C for a few days or 40°C for an extended period of time. Three to five freeze/thaw cycles adequately cover the amount of times a sample is brought into and out of the cold during shipping and storage. If ambient humidity is thought to be a problem a sample can be left at 90% humidity or better for a few days or 80% for an extended period of time. (Steele 2001)

2.5.2 Method

Forty samples (numbers 1-40) from each method under test AXI, CA and CB) were subjected to a thirty day environmental stability test. Ten samples from each method were chosen at random and sealed in a vapor tight, plastic food container. The containers were then placed in each of four environments: Room Temperature, Freezer, High Heat and High Humidity.

Condition selection was determined by pretesting and the limitation caused by available equipment. The LDPE bags were seen to distort at temperatures approaching 50°C. An extended test of 30 days at 40°C[10] was therefore selected for both the High Heat and the High Humidity samples. In each of the high humidity samples a water reservoir was added to keep the humidity level at 80%[11]. The freezer samples were subjected to five freeze /thaw cycles at -15°C ± 2°C, over a thirty day period. The room temperature samples were left in the lab at 22°C ± 2°C.

The samples were removed from the test environment on Day 2, Day 7, Day 14, Day 21 and Day 30 and allowed to come to ambient temperature (22°C ± 2°C) then the fingermark on the LDPE bags was photographed. Once photographed, the LDPE bags were returned to their test environment.

The photographs taken were compared to the initial images collected in section 2.1 and to each photograph taken on previous testing days as the study progressed. Changes in the appearance or quality of the fingermark were recorded.

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[10] The high heat and high humidity samples were both run at 40°C. Based on the performance range of the incubator used the practical range of variation was of 35°C to 45°C.
[11] Humidity was monitored with a terrarium hygrometer.

2.5.3 Results

2.5.31 Room Temperature 22°C

Table ix: Samples Processed with Axis Inversion Red after 30 Days at Room Temperature

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
1	No Change	No Change	No Change	No Change	No Change
10	No Change	No Change	No Change	No Change	No Change
11	No Change	No Change	No Change	No Change	No Change
12	No Change	No Change	No Change	No Change	No Change
13	No Change	No Change	No Change	No Change	No Change
14	No Change	No Change	No Change	No Change	No Change
20	No Change	No Change	No Change	No Change	No Change
22	No Change	No Change	No Change	No Change	No Change
26	No Change	No Change	No Change	No Change	No Change
30	No Change	No Change	No Change	No Change	No Change

Table x: Samples Processed with 2-Ethylcyanoacrylate after 30 Days at Room Temperature

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
1	No Change	No Change	No Change	No Change	No Change
2	No Change	No Change	No Change	No Change	No Change
8	No Change	No Change	No Change	No Change	No Change
11	No Change	No Change	No Change	No Change	No Change
16	No Change	No Change	No Change	No Change	No Change
19	No Change	No Change	No Change	No Change	No Change
30	No Change	No Change	No Change	No Change	No Change
32	No Change	No Change	No Change	No Change	No Change
39	No Change	No Change	No Change	No Change	No Change
40	No Change	No Change	No Change	No Change	No Change

Table xi: Samples Processed with Carbon Black Powder after 30 Days at Room Temperature

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
1	No Change	No Change	No Change	No Change	No Change
9	No Change	No Change	No Change	No Change	No Change
11	No Change	No Change	No Change	No Change	No Change
14	No Change	No Change	No Change	No Change	No Change
15	No Change	No Change	No Change	No Change	No Change
16	No Change	No Change	No Change	No Change	No Change
17	No Change	No Change	No Change	No Change	No Change
25	No Change	No Change	No Change	No Change	No Change
26	No Change	No Change	No Change	No Change	No Change
27	No Change	No Change	No Change	No Change	No Change

2.5.3.2 Freezer -15°C

Table xii: Samples Processed with Axis Inversion Red after 30 Days in Freezer

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
2	No Change	No Change	No Change	No Change	No Change
3	No Change	No Change	No Change	No Change	No Change
9	No Change	No Change	No Change	No Change	No Change
16	No Change	No Change	No Change	No Change	No Change
17	No Change	No Change	No Change	No Change	No Change
27	No Change	No Change	No Change	No Change	No Change
36	No Change	No Change	No Change	No Change	No Change
37	No Change	No Change	No Change	No Change	No Change
40	No Change	No Change	No Change	No Change	No Change
38	No Change	No Change	No Change	No Change	No Change

Table xiii: Samples Processed with 2-Ethylcyanoacrylate after 30 Days in Freezer

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
6	Cracked	Same	Same	Same	Same
10	Cracked	Same	Same	Same	Same
13	Cracked	Same	Same	Same	Missing Pieces
14	Cracked	Same	Same	Same	Same
24	Cracked	Same	Same	Same	Same
26	Cracked	Same	Same	Same	Missing Pieces
31	Cracked	Same	Same	Same	Missing Pieces
33	Cracked	Same	Same	Same	Same
34	Cracked	Same	Same	Same	Same
35	Cracked	Same	Same	Same	Missing Pieces

Table xiv: Samples Processed with Carbon Black Powder after 30 Days in Freezer

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
3	Decreased color st	Same	Same	Same	Same
4	Decreased color st	Same	Same	Same	Same
5	Decreased color st	Same	Distorted Detail	Same	Same
6	Decreased color st	Same	Same	Same	Same
7	Decreased color st	Same	Same	Same	Same
8	Decreased color st	Same	Same	Same	Same
13	Decreased color st	Same	Same	Same	Same
36	Decreased color st	Same	Same	Same	Same
37	Decreased color st	Same	Same	Same	Same
38	Decreased color st	Same	Same	Same	Same

2.5.3.3 High Heat 40°C

Table xv: Samples Processed with Axis Inversion Red after 30 Days at High Heat

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
8	No Change	No Change	No Change	No Change	No Change
23	No Change	No Change	No Change	No Change	No Change
24	No Change	No Change	No Change	No Change	No Change
28	No Change	No Change	No Change	No Change	No Change
29	No Change	No Change	No Change	No Change	No Change
31	No Change	No Change	No Change	No Change	No Change
32	No Change	No Change	No Change	No Change	No Change
33	No Change	No Change	No Change	No Change	No Change
34	No Change	No Change	No Change	No Change	No Change
35	No Change	No Change	No Change	No Change	No Change

Table xvi: Samples Processed with 2-Ethylcyanoacrylate after 30 Days at High Heat

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
4	No Change	Less Resin	Resin Evaporated	na	na
9	No Change	Less Resin	Resin Evaporated	na	na
12	No Change	Less Resin	Resin Evaporated	na	na
15	No Change	Less Resin	Resin Evaporated	na	na
21	No Change	Less Resin	Resin Evaporated	na	na
23	No Change	Less Resin	Resin Evaporated	na	na
25	No Change	Less Resin	Resin Evaporated	na	na
28	No Change	Less Resin	Resin Evaporated	na	na
36	No Change	Less Resin	Resin Evaporated	na	na
38	No Change	Less Resin	Resin Evaporated	na	na

Table xvii: Samples Processed with Carbon Black Powder after 30 Days at High Heat

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
10	No Change	same	Smudgy and voids	Agglomerates formed	Agglomerates Worsened
12	No Change	Void filled in	same	same	Improved Detail
18	No Change	Missing Area	same	Improved Detail	Same
19	No Change	same	same	same	Improved Detail
21	No Change	Missing area	Blurred	same	same
22	No Change	same		same	same
23	No Change	same	Improved Detail	same	Agglomerates formed
24	No Change	same	same	same	same
34	No Change	same	same	Smudge worsened	same
40	No Change	same	Improved Detail	same	Improved Detail

2.5.3.4 High Humidity 40°C, 80% Humidity

Table xviii: Samples Processed with Axis Inversion Red after 30 Days at High Humidity

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
4	No Change	No Change	No Change	No Change	No Change
5	No Change	No Change	No Change	No Change	No Change
6	No Change	No Change	No Change	No Change	No Change
7	No Change	No Change	No Change	No Change	No Change
15	No Change	No Change	No Change	No Change	No Change
18	No Change	No Change	No Change	No Change	No Change
19	No Change	No Change	No Change	No Change	No Change
21	No Change	No Change	No Change	No Change	No Change
25	No Change	No Change	No Change	No Change	No Change
39	No Change	No Change	No Change	No Change	No Change

Table xix: Samples Processed with 2-Ethylcyanoacrylate after 30 Days at High Humidity

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
3	No Change	Less Resin	Resin Evaporated	na	na
5	No Change	Less Resin	Resin Evaporated	na	na
7	No Change	Less Resin	Resin Evaporated	na	na
17	No Change	Less Resin	Resin Evaporated	na	na
18	No Change	Less Resin	Resin Evaporated	na	na
20	No Change	Less Resin	Resin Evaporated	na	na
22	No Change	Less Resin	Resin Evaporated	na	na
27	No Change	Less Resin	Resin Evaporated	na	na
29	No Change	Less Resin	Resin Evaporated	na	na
37	No Change	Less Resin	Resin Evaporated	na	na

Table xx: Samples Processed with Carbon Black Powder after 30 Days at High Humidity

Sample	Day 2	Day 7	Day 14	Day 21	Day 30
2	Increased color st	same	same	Improved Detail	same
20	Increased color st	same	same		Improved Detail
28	Increased color st	same	same	Improved Detail	Same
29	Increased color st	Missing Spot	same	Smudge worsened	same
30	Increased color st	same	More detail	same	same
31	Increased color st	same	Smudgy is readable	same	same
32	Increased color st	same	Print Blurred	New Agglomerate	same
33	Increased color st	same	Print Blurred	New Agglomerate & smudge	same
39	Increased color st	same	New Detail	New Agglomerate & smudge	same
35	Increased color st	same	same	New Agglomerate & smudge	same

2.5.4 Evaluation of Observer Bias

The second place in this study where observer bias may be a factor is in the evaluation of the environmental samples. As seen in section 2.3.4, while the author and the on-line volunteers agreed in the relative ranking of the quality of images, the specific rating of each specific image was typically lower for the on-line viewer. In addition, marginal samples were more often than not rated not only by their own quality but in reference to the quality of the image that preceded it.

To address the question of whether or not the degradation of samples, as recorded by the author, would be seen by other observers, images of fingermarks from different times in the study were also included in the base set of twenty images for each group. In all cases, samples that were seen by the author to be affected (better or worse) by the environmental study were rated similarly better or worse by the on-line viewers.

The samples deemed unchanged by the author were within one category of their original rating by each on-line observer, although the samples were still only identically rated approximately 40% of the time. Just as with the results in section 2.3.4, samples that followed a better quality sample were rated on average, lower that samples than samples that followed higher quality samples. Samples that followed a better quality samples were rated on average lower than samples following a lower quality sample.

2.5.5 Discussion

Table xxi: Environmental Stability Results

Environment	Notes
Room Temperature	All of the samples remained intact during the study.
Freezer	Cyanoacrylate samples showed cracking and some loss of resin and fingerprint details. Carbon Black samples lost color intensity but all detail remained visible. Axis Inversion Red samples remained in-tact
Incubator	Carbon Black samples continued remained in-tact. Cyanoacrylate samples evaporated. Axis Inversion Red samples remained in-tact.
High Humidity	Carbon Black samples continued to develop. Weal samples became stronger, strong impressions became over developed and blurred. Cyanoacrylate samples evaporated. Axis Inversion Red samples remained in-tact.

At room temperature none of the fingermarks produced by the methods under test experienced any change over the thirty days of the study. The other three environments all had some effect on the fingermarks that had been developed with CA or carbon black. Some of the changes altered detail on the fingermark and some of the changes did not.

The CA and carbon black samples were affected to a minor extent by the extreme cold. Cracks formed in the poly-ethyl-2-cyanoacrylate after a short exposure to the cold. By the end of the study one of the samples had even lost a section of resin from the surface of the bag. In general, the cracks were microscopic and would not be confused for ridge detail.

The exact cause of the cracking was not determined, but two likely contributors are the difference in rigidity and expansion coefficient between poly-ethyl-2-cyanoacrylate and LDPE. Poly-ethyl-2-cyanoacrylate is a stiff polymer, especially when cold, while LDPE remains soft and pliable even at the temperatures in the freezer test.

There is also almost a 2:1 ratio in the coefficient of thermal expansion between LDPE and poly-ethyl-2-cyanoacrylate. Therefore, the greater the cold the greater the disparity in the shrinkage between the developed fingermark and the LDPE bag. And, as the poly-ethyl-2-cyanoacrylate is on top of the biological residue this might prove to be enough to allow the poly-ethyl-2-cyanoacrylate to come off, if the temperature change is sufficient.

The effect of the freezer on the carbon black samples was that the color strength of the developed fingermark substantially weakened. ΔL for these samples decreased by almost 50%. Two possible causes for this were considered. The first is that the dry air of the freezer allowed some of the moisture from the fingerprint to evaporate. The second is the cold caused an expansion in the fingermark residue which forced it out of the pores of the carbon black particles allowing them to simply fall of the fingermark.

To evaluate which possibility was more likely, a separate study was concurrently run with fingerprints placed on LDPE bags and placed in the freezer for a series of freeze/thaw cycles to see if the fingermarks developed from fingerprints that had been frozen were weaker than those that have been left at room temperature. No change in color upon initial development was noticed, but the samples did weaken in the freezer after they had been developed just as the initial stability samples had.

The samples in the High Heat and High Humidity environments experienced the most alteration. The samples developed with cyanoacrylate lost virtually all detail.

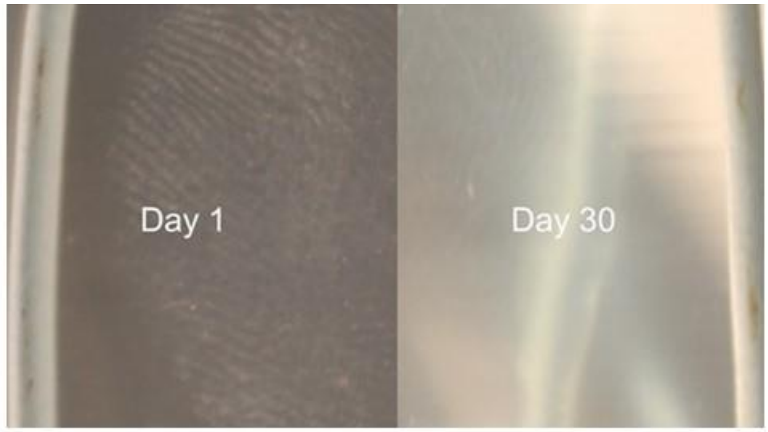

Image 10:
Cyanoacrylate Fingerprint Sample 18 After 30 Days

It was considered that the heat was causing the fingerprint residue to evaporate. But the fact that a similar loss of detail was not seen in the carbon black samples makes this unlikely. The example shown here is from sample CA 18 which was exposed to heat and humidity for 30 days.

It was concluded therefore that the heat caused the resin to either sublime or disassociate from the LDPE bags after a few days. To test this supposition, samples that had lost all of the resonated fingermark detail were reprocessed with black powder, AXI red and ethyl-2-cyanoacrylate. All three methods were successful in redeveloping the missing fingermark.

The carbon black samples continued to develop in both the high heat and high temperature samples. Weak fingermarks became stronger and more defined. Strong fingermarks had the potential to over develop and blur or form agglomerates. Shown at the side is sample CB 35 from the High Temperature and High Humidity Environmental test.

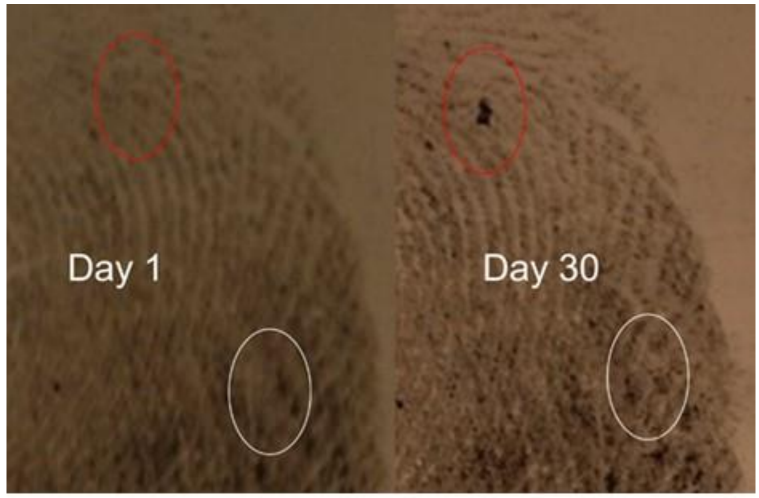

Image 11:
Carbon Black Fingerprint Sample 35 After 30 Days

As stated above, the oils and moisture that form the fingerprint are absorbed into the carbon black particles causing the particle to adhere to the fingerprint residue. At elevated temperatures the viscosity of the water/oil mixture will decrease allowing for greater penetration into the carbon.

Under these conditions more individual particles will separate from the larger agglomerates and adhere individually to the fingerprint increasing the total surface area of exposed pigments. This will give a greater color strength.

This mechanism could also explain the formation of agglomerates. Where an excess of carbon black powder has been deposited, the thinner viscosity of the warm fingerprint residue may leak out of one particle and invade a nearby neighbor causing them to move around and stick together.

Likewise when the temperature gets colder enough the viscosity will decrease causing the opposite of what was seen with elevated temperatures. In addition, the volume of the water component will increase potentially pushing carbon particles off of the fingermark.

None of the fingermarks developed with the AXI red were damaged or altered by the various environmental conditions. Even high heat and high humidity environment had no impact on the AXI red developed. The image shown at the side is sample Red 39 from the high heat and humidity test environment.

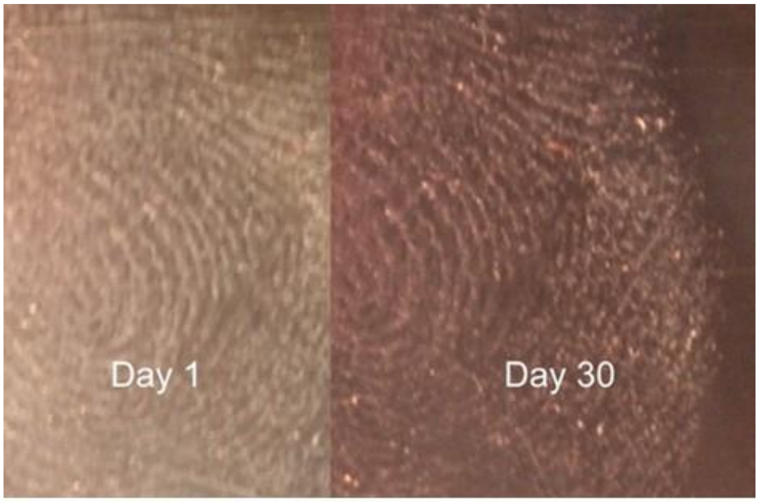

Image 12:
Axis Inversion Red Fingerprint Sample 39
After 30 Days

2.6. Experiment 5: Combining AXI dyeing with other methods

2.6.1 Background

Image 13:
Nano-Black Fingerprint Sample

The common methods of CA fuming and Carbon Black dusting are compatible with other techniques. For example CA fuming is frequently followed by coloration with dyes or dusting powders. Carbon black can even be produced in the forming poly-ethyl-2-cyanoacrylate by burning the appropriate fuel and directing the smoke over the fingerprint while it's being fumed with ethyl-2-cyanoacrylate. (Steele et.al. 2011)

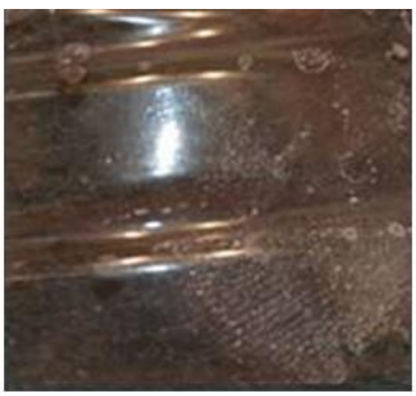

Image 14:
CA Fingerprint on PET Bottle Augmented with AXI Red

Even AXI Dyes have been used in combination with CA fuming to enhance visualization. Shown at the side is a PET water bottle which was first fumed with cyanoacrylate and then with AXI red[12]. As can be seen the AXI dye invades the PET to provide background color but provides little or no coloration to the poly-ethyl-2-cyanoacrylate.

To this point, no one has combined AXI dyeing with carbon black dusting. However the crocking test performed in chapter 2.4 indicated that light contact does not distort the image produced with AXI red.

[12] http://www.anevalinc.com/forensicproducts/aired.html

2.6.2 Method

LDPE bags were fumed with AXI red following the methods in section 2.1.3. The bags were then dusted with carbon black to see if a clear image was formed.

2.6.3 Results

All of the bags that were treated with AXI red were subsequently dustable with carbon black.

2.6.4 Discussion

AXI dyeing produces a negative image that can be difficult to work with. Subsequent treatment with carbon black may offer a means of making the fingermark more visible.

3. Conclusions

Beyond the assessment of processing latent fingerprints on LDPE bags with AXI red, the findings of this research have implications for other research. The observation that fingermarks produced with carbon black continued to develop in hot and humid environments may be expandable into a method of improving unusable fingermarks post processing. If the mechanism suggested herein is indeed correct, then a study on multiple substrates may yield an additional option to improve the quality of evidence.

The variation seen in the impressions of on-line volunteers on the quality of images was substantial within the limitations of this study. A more exhaustive study that can give more meaningful statistics would be useful. Quantifying and correlating the differences between how a lay juror understand pattern evidence and the way an expert does may provide an insight as to how to communicate technical results accurately to an untrained audience.

Finally, AXI dyeing has now been tested on plastic tape and LDPE bags. In both cases it has shown the ability to color the background around fingerprints. This technique should be evaluated on other polymer evidence types like: Eyewear, CDs and drinking bottles.

In comparing AXI dyeing to the existing carbon black dusting and CA fuming, it has been shown that AXI dying has several advantages. AXI dyeing has the speed and ease of CA fuming and produces a strong color difference. Although the color difference was not as strong as that produced by carbon black dusting it is well above the visibility threshold for noticeability. AXI fuming is compatible for use post-CA fuming and pre-carbon black dusting. In both cases it can increase visibility.

Axis Inversion Dyeing does have an advantage that carbon black dyeing does not. The color strength is controlled by the amount of dye deposition rather than the amount of deposition of the biological material from the fingerprint itself. Because the fingerprint simply serves to block the dye from entering the surface upon which the fingerprint has been deposited, as long as sufficient residue is present, the analysts can select how much color they want to add to the background.

Each method under test has the advantage of being easy to execute and all three methods are suitable for providing good quality fingermarks on LDPE bags when executed correctly. Developing fingermarks with carbon black requires the least amount of equipment and produces an easily seen image. Developing fingermarks with poly-ethyl-2-cyanoacrylate is rapid and many labs are already equipped to perform the method. However, if long term storage is required, fingermarks developed with AXI red have a greater resistance to accidental or environmental damage.

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5. VITA

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Section 1: Summary

I am a product development and analytical consultant through my own company Aneval Inc. Until 2009 I was also the Laboratory Manager and Quality Manager for Keystone Aniline Corporation, a dye and pigment company servicing many industries. My professional and scientific experience, through these corporations, expands into several industries with my primary focus being in cosmetic chemistry, plastics and forensic science.

At Keystone Aniline Corporation I was primarily responsible for designing and implementation of laboratory practices and procedures for several laboratories as well as product research and development. I was the primary architect of the corporate wide ISO and Quality Control/Quality Assurance system which resulted in a 67% decrease in production overruns.

Through Aneval Inc. I provide product and process development consulting as well as analytical testing services. Primary services of the consultancy include: design and implementation of necessary methods to test the validity of patent claims both prior to patent filing and in defense of existing patents; Design and execute custom training programs in various technical areas from basic science to industry specific technology; Lead university and corporate research teams; Perform custom and standard analytical testing; Product design and development.

I have developed a variety of products and necessary laboratory support and my research has contributed to the areas of: Cosmetics, Fingermarking, Compostable Plastics, "Green" Wood Colorants, Lightfastness, Security Tagging and Cosmetic Formulations. Notable products have included Fuming Orange, a one step fuming and multi-wavelength excitable fluorescent coloring system for finger prints; Perma-Print - Axis Inversion Dyes, a method for permanently coloring the background behind fingermarks; A method for permanently coloring wood through incorporated pigmenting through the entirer bulk; Eco-friendly water based massage treatments; the DataTrax™ Encoded Microparticle and Hair Dyes for Active Women.

Section 2: Primary Education

University of Illinois at Chicago *Forensic Science*	9/2013-Present
University of Illinois at Chicago *Criminalistics*	9/95 to 6/97
University of Illinois at Chicago B.S. *Physics*, (Minor in Chemistry)	9/91 to 12/94
Triton College	Spring 1990
University of Chicago	Summer 1988
Triton College	Fall, 1986
Illinois Institute of Technology	8/84 to 12/85
Fenwick High School	9/80 to 6/84

Section 3: Additional Education, Seminars & Workshops

Society of Cosmetic Chemists *Hair Color*	June, 2002
Packaging Manufacturers Institute *Packaging Line Security*	February, 2002
Society of Cosmetic Chemists *Ethnic Hair and Basic Hair Care*	March 2001
McCrone Research Institute *Hair Microscopy*	May, 1993
McCrone Research Institute *Microscopy of Man Made Fibers*	July, 1992
Newberry Library *Writing Fiction*	Fall 1988

Section 4: Employment History

Aneval Inc. *President*
1996 to Current

Through Aneval Inc. I have worked as a private consultant doing analytical testing, patent claims validation and product and process development. In addition to personal care products, I have worked with accompanies like Tracking Technologies to develop security tagging products capable of meeting evidentiary requirements. I have also been employed as an expert witness in cases of product liability claims and patent infringement.

In addition to providing commercial services, Aneval Inc. is also actively engaged in researched and internal product development. Recent products have included the Mr. Lloyd's line of massage and bath treatments, Fuming Orange color fumes for fingermarks (patent applied for) and the Perma-Print Axis inversion dyes.

Purdue University (North Central Campus)
Limited Term Lecturer
Summers 2012 to current

Physics Instructor

Keystone Aniline Corporation
Laboratory Manager/Quality Manager/Product Chemist
1995 to 2009

At Keystone, my administrative responsibilities included: supervision of personnel, monitoring of workflow for thee laboratories, authoring operating procedures and upgrading laboratory capabilities. In addition to these, I also provide technical service to a variety of companies and government agencies in the United States and abroad. Technical responsibilities include: product line development, setting quality control practices and approximately 130 customer projects per year.

Among my achievements at Keystone have been the development of a product line for hair dyes including a technical guide and formulary, the development of a new automotive leak tracer (patent applied for), the development of a new chemistry of now polymerized non-staining dyes (patent applied for) the development of a method to permanently pigment exterior grade wood (patent applied for).

Princeton Review
Instructor
1995 to 1996

Instructor for ACT/SAT review classes

Section 5: Significant Publications & Presentations

Forced Condensation of Cyanoacrylate with Temperature Control of the Evidence Surface to Modify Polymer Formation and Improve Fingermark Detection/Visualization
Journal of Forensic Identification, July/August 2012, Vol. 62, No. 4

Tests involving temperature control of both the cyanoacrylate fuming environment and the evidence surface temperature performed at Mountain State University Forensics Program, Beckley West Virginia, have identified conditions to improve visualization of fingermarks. Proper temperature controls resulted in increased cyanoacrylate deposition, modification of the pseudo-crystalline structure and increased contrast. This research program has identified a controlled micro-crystalline structure modification of the polymer formation specific to latent fingermarks. The cyanoacrylate polymer structure can be controlled to yield a much more visible form due to the crystalline structure under these temperature controlled environments. This research also empirically suggests that the forced condensation of the cyanoacrylate deposition follows a specific heat capacity linear curve based on the evidence material type. In other words glass absorbs heat at a different rate than copper; copper absorbs heat at a different rate than steel, etc. Different material types have demonstrated this phenomenon in controlled temperature tests and we forecast that the polymer deposition could be forced to behave in certain ways based on type of evidence material with temperature control of the evidence surface.

The use of these forced condensation techniques via temperature control should add visual detection sensitivity to evidence processing protocols.

Synergistic Value of Complimentary Techniques in Fingermark Processing
2012 NIJ Technical Conference, Washington DC June 2012

Abstract

Fingermarks can be processed with a variety of techniques the selection of which, is usually left to the individual examiner’s experience and training. Our research has shown that by combining multiple techniques significantly greater resolution can be achieved revealing finger marks which would otherwise be missed and allowing easier collection of normally feint marks.

Specific Heat Capacity Thermal Function of the Cyanoacrylate Fingermark Development Process

2011 NIJ 2009-DN-BX-K196

Multiple methods were explored to increase the resolution of fingermarks obtained through cyanoacrylate (CA) fuming, or improve the ease of resolving fingermarks.

The first method explored was the development of sublimation based co-polymerized coloring. This research stream is an expansion of the work which produced CN-Yellow with an attempt to stretch the excitation range of the fluorescent effect to 530 nm so that it can be used with existing lasers. Many different colorants were evaluated for appropriate fluorescent responsiveness. Once appropriate colorants were identified, they were co-fumed with CN-Yellow in a closed chamber and evaluated with an ALS for detection at 530nm. Colored CA Fingermarks, detectable with a 530nm laser, were successfully produced.

The second method explored was the modification of evidence temperature. Samples of multiple materials were cooled 6°F-20°F below ambient and were CA fumed side by side with fingermarks which had not been cooled. The resulting fingermarks were weighed, tested for opacity and color uptake via dye staining. Our research as shown improvements in visibility: due to increase in opacity and color uptake, of CA fingermarks when the evidence is cooled 6°F-20°F.

The third method explored was the use infrared detection. Fingermark samples were prepared on Plexiglas and aged for two weeks to allow them to fade. The samples were then examined with infrared cameras at ambient temperature and cooled to force condensation and improve infrared visibility. While methods did yield fingermarks, no prints were resolved which would not have been detectable by more economical visible light means.

The fourth aspect of the research was to find a way to disperse nano-particles onto CA prints. Nano-particles can be applied in a variety of ways ranging from spraying liquid dispersions to creating dust clouds. However, when the particles are produced on the fingermark itself, it is possible to lock the color into the CA matrix with subsequent fuming. Carbon black nano-particles were therefore produced by burning oil and directing the vapor stream onto the print.

The final aspect of the research was to develop a commercially viable temperature and humidity controlled chamber to chill the evidence and allow for standard fuming. A unit was developed and can be purchased through Sirchie Corporation.

Polymer Coloration in Fingermarking Applications
2010 SPE RETEC, Nashville TN

Abstract

Unlike many consumer products, in forensic applications like fingermarking, polymer color is more than just an aesthetic feature. It is a functional property that allows for the identification and use of physical evidence. Therefore, methods of coloring subliming cyanoacrylates, the resins commonly used in fingermarking, are critically important. Traditional methods of polymer coloration have been employed for years. However, this study introduces improvements over the existing technology including methods for co-subliming color and the development of a pre-colored cyanoacrylate which maintains the sublimation properties of the base polymer.

Nonmigratory Colorants for Polylactic Acid
2009 SPE RETEC, Savannah GA

Abstract

Millions of disposable plastic items, like drinking bottles are filling waste disposal areas. Compostable resins like Polylactic Acid (PLA) can be used to make these items and save the ever diminishing space in landfill. However, like many applications, available color is a significant factor in determining the potential use of resins. A full color pallet is needed and colorants used for food and beverage packaging must be tested and confirmed as non-migratory according to relevant sections in 21 C.F.R. Therefore, a pallet of dyes has been injection molded into PLA and subjected to migration testing for indirect food contact meeting or exceeding the FDA guidance.

Specific Heat Capacity Thermal Function of the Cyanoacrylate Fingermark Development Process
2009 NIJ 2007-DN-BX-K242

Abstract

The use of cyanoacrylate, or superglue, fuming to develop latent fingermarks on non-porous evidence has been utilized by forensic investigators since the early 1980's when Ed German, a U.S. Army investigator, discovered his Japanese counterparts using the technique. Since then the application methodologies have expanded from vacuum chambers, torches with sublimation tips and rapid dispersion devices of the cyanoacrylate vapor, all moving us forward with the focus of increased of sensitivity of fingermark development. In an attempt to comprehend and improve the polymerization process of cyanoacrylate fuming, we embarked on an avenue of research that focused on temperature and humidity variations of both the environment in which the fuming occurs and also temperature variations were used on the actual evidence itself in an attempt to understand and optimize the development of latent fingermarks utilizing cyanoacrylate.

Our premise was that the temperature of the substrate material during the fuming event, combined with the relative humidity is crucial in obtaining the best possible fingermark development, and that the specific heat capacity and thermal conductivity of the evidence substrate material would guide the temperature parameters of the polymerization process involved with cyanoacrylate fuming. The numerous tests that we have performed on various non-porous materials commonly found at crime scenes utilizing diverse temperature and relative humidity parameters have proven this assertion correct.

On identical materials with deposited latent fingermarks developed simultaneously but at different substrate temperatures, we have been able to show that there is a substantial increase in polymerization which is easily observed visually and supported by measurable weight increases when the evidence is cooled to a temperature relative to the substrate's specific heat capacity. The weight variations as shown in the data files serve as support to the visualization properties which is the main concern of latent fingermark examiners. We have shown that we can increase the polymerization on the fingermark ridge site by cooling the temperature of the substrate in a correlative manner to its known specific heat capacity.

Compostable Colorants for Bio-Plastics
2008 SPE RETEC, Detroit MI

Abstract

Efforts made by industry to move toward recyclable and compostable materials require biodegradable colorants. To meet this need, a variety of dyes and pigments were subjected to a standard composting protocol in both their raw form and in Polylactic Acid. From these results a range of compostable colorants is determined.

Use of Dyes in Nylon for Industrial Applications
2008 SPE RETEC, Detroit MI

Abstract

Polyamide resins are frequently used in consumer and industrial applications. They are chosen for these applications for a variety of reasons including their durability, chemical resistance and its ability to perform under high-heat working conditions. Therefore the dyes used in these applications must hold up under these extreme conditions. A full pallet of nylon stable dyes was subjected to migration, heat and moisture fastness testing under a variety of conditions for three different Polyamide resin systems. The resulting data is used to determine the suitability of dyes for various applications.

Enhancing Contrast of Fingermarks on Plastic Tape
Journal of Forensic Science, November 2003, Vol. 48, No. 6

Abstract:

Many of the currently available fingermarking methods have limited ability to visualize fingermarks on plastic tape without expensive equipment or significant handling of the sample. This is especially true for visualizing fingermarks on black electrical tape. This study sought a hands-off method to produce easy visualization of fingermarks on different types of plastic tape, including black electrical tape, without the need for expensive equipment. The methods selected were to sublime disperse dyes into the tape, both with and without the fuming of cyanoacrylate, everywhere except for where the fingermark was applied. The resulting color contrasts provided enough differentiation to visualize fingermarks on plastic tape under ambient light. Sequential fuming with cyanoacrylate followed by disperse dyes provided the best visualizations on all tapes, and cyanoacrylate followed by disperse yellow 211 clearly visualized fingermarks on black electrical tape.

Locational Variations as an Obstacle to Single Point Reference Light Fade Studies
AATCC Review April 2003

Abstract:

This study evaluates the validity of light-fastness predictions based on standardized reference models that rely on a single testing environment. Light-fastness of identical sample sets were evaluated for the same duration of exposure to sunlight in five different locations around the North American Continent.

This study shows that identical samples in different locations fade to differing degrees even when exposed to a consistent duration of irradiance. Furthermore the relative fade rate was inconsistent from one sample type to another. Therefore, an accurate color fastness prediction for a specific colorant must be determined by testing that colorant, under the actual conditions of use, in the intended environment of use.

Relative Light-Fastness of the Colors Formed From Oxidation Dye Intermediates
Presented 2002 SCC Technical Showcase, New York, USA

Abstract:

As part of an ongoing study, combinations of oxidation dye intermediates were categorized according to the light-fastness of the color they produced on human hair.

Five sets of virgin blond human hair tresses were dyed with one of six commonly employed primary intermediates in combination with either a secondary or primary intermediate, on a 1:1 M.W. basis. One set of these dyed tresses was retained as a control, with the remaining sets being treated as required to emulate various environmental conditions/states and then subjected to UV light (employing an Atlas SunChex) in order to accelerate their potential for light instability. The environmental states evaluated included

the following: dry hair; wet hair; hair wet with perspiration; hair wet with "swimming pool" water.

After UV exposure, each tress was evaluated both for the direction of the color shift and the decrease in overall color intensity according to the AATCC gray scale. Based on these data, the dye intermediate combinations were grouped according to their potential for light instability.

An Evaluation of Security Marking And Tagging Systems For Polymers and Polymer Products
Presented 2002 SPE RETEC, Toronto, Canada

Abstract:

Product Identity Fraud (PIF) is a general term encompassing **Alteration, Counterfeiting** and **Diversion** of raw materials and finished goods. PIF has always existed but in recent years improvements in production technology have caused the magnitude of these crimes to exceed two hundred billion dollars annually. In addition, these crimes have an incalculable impact on long-term brand equity and pose a genuine health and safety risk to people around the world.

One of the ways corporations are trying to secure their products against PIF is to include **Security Marking** and **Security Tagging** systems into manufactured goods and raw materials. Often these security systems are incorporated directly into the polymers that comprise the finished product. However, not all approaches are equally beneficial. Inappropriate systems can be expensive and still not provide the desired level of security. Poorly designed or implemented systems can actually increase vulnerability to PIF.

This paper therefore explains differences between marking and tagging systems, establishes the requirements for Durability, Readability and Uniqueness for valid systems and evaluates several systems for their use in securing polymers and polymer systems.

Testing of Hair Dye Products:
Presented 2000 James Robinson Agents Conference, Brampton, UK

Abstract:

The testing of hair dye products is intertwined with the formulating process. Before formulating can even be initiated, preliminary testing must be performed to insure that the materials used are of consistent and sufficient quality. Then during to the formulating process itself, a variety of testing is done to determine the formulation's compliance with predetermined goals. Finally after a formulation is arrived at it has to be validated and tested for efficacy and stability.

Keystone Quality Hair Dyes Technical Guide and Formulary

Summary:

Written as both an educational manual and a laboratory bench reference, the Keystone Quality Hair Dyes Technical Guide and Formulary presents an overview of the chemistry of hair dye products, technical information on the colorants used, and formulations for dozens of typical and novel products.

Section 6: Current Research and Pending Publications

Fingermark Detection Expansion to 530nm in tandem with Cyanoacrylate Processing
To be submitted 2014
Abstract

CN-Yellow is a colored form of cyanoacrylate that provides a "hands-off" system for evolving fluorescent color fingermarks in a singe fuming step. The system works well with visible and UV light, however, the fluorescent excitation of CN-Yellow is not compatible with some of the common lasers used in the forensic industry. NIJ Grant 2009-DN-BX-K196 directed research to expand the excitation of CN-Yellow to 530nm to allow for compatibility with exiting light sources. This expansion of the excitation wavelength was achieved by incorporating Sublaprint Red R70011, a subliming dye, into the fuming process.

Oil Blue A as a Replacement for Oil Red O for Fingerprint Detection on Porous Materials
In progress
Abstract

Methods using Oil Red O can be used to develop light pink to red fingerprints on porous materials like paper. However, the use of red shades on materials in the red to red-brown color space like manila envelopes and colored paper limits the resolution capability of the method to minor shade differences and variances in color intensity. This study adds Oil Blue A and Oil Yellow 202 to extend the pallet of available colors for the Oil Red O dyeing methods.

Expanding the Beers-Lambert Law
In Progress
Abstract

The Beers and Lambert Law, A = $\mathcal{E}$lC, provides the basis for convenient and well-validated spectrophotometric methods for determining chemical concentration. Unfortunately, the A and $\mathcal{E}$ generated on one spectrophotometer will in most cases not match those generated on another and the Beers and Lambert Law does not provide a relationship between data generated on two or more different machines. The lack of this relationship is a detriment to the chemical industry where customers and formulators often want to rely on Absorption (A) and Extinction Coefficient ($\mathcal{E}$) data from vendors or other laboratories and as a result often obtain erroneous results. To assist in these cases, this study determined that by expanding the equation to A = S$\mathcal{X}$lC + b, where S is the efficiency of the spectrophotometer, $\mathcal{X}$ *is* the absorptivity of the sample and b is a constant, information may be communicated between different spectrophotometers.

Section 7: Technical Bulletins & White Papers

From 2000 to 2008, I headed up the production of Keystone Aniline Corporation's technical data; serving as editor for more than 245 publications. In addition I have authored or coauthored the publications listed below for industrial applications ranging from decorative dyeing to security tagging.

Acid Dyes For Feathers
© 2000 Keystone Aniline Corporation
Products and dyeing methodologies

Color Control in Paper Making
© 2000 Keystone Aniline Corporation
Overview of color control process

Color Formed from Oxidation Dye Intermediates
© 2000 Keystone Aniline Corporation
Listing of reaction products from combinations of hair dye intermediates

Dyes for Antifreeze
© 2000 Keystone Aniline Corporation
Lists of dyes suitable for antifreeze formulations

Dyes for Xerographic Photo Copy Toners
© 2000 Keystone Aniline Corporation
Listing of products and physical properties

Keyacid Rhodamine WT Liquid
© 2000 Keystone Aniline Corporation
Water tracing method

Keyphos Phosphorescent Colorants

© 2000 Keystone Aniline Corporation
Catalogue of physical properties

Ochre for Paper
© 2000 Keystone Aniline Corporation
Technical data

Optical Brighteners for Textiles
© 2000 Keystone Aniline Corporation
Methods for overcoming yellowing of textiles

Strength vs. Purity
© 2000 Keystone Aniline Corporation
Descriptive essay on terminology

Tags, Taggants and Markers
© 2000 Keystone Aniline Corporation
Overview of types and requirements of tagging and marking systems

Certified Colorants D&C and FD&C
© 2001 Keystone Aniline Corporation
Technical and applications data of certified colorants

Color Enhancing Hair Care Products
© 2001 Keystone Aniline Corporation
Formulation methods for cationic hair dyes

DataTrax. Application Report
© 2001 Keystone Aniline Corporation
Results of stability testing of particulate taggants in a variety of substrates

DataTrax. Encoded Microparticles
© 2001 Keystone Aniline Corporation
Product technical data

Dyeing Methods for Acid Dyes
© 2001 Keystone Aniline Corporation
Dyeing methods for textiles, fibers and resinous materials

Dyes for Aqueous Inks & Coatings
© 2001 Keystone Aniline Corporation
Listing of acid dyes for water based applications

Dyes for Carpet "Touch-Up"
© 2001 Keystone Aniline Corporation
Dyes and application methodology

Dyes for Heat Transfer Printing
© 2001 Keystone Aniline Corporation
Overview of heat transfer printing process

Dyes for the Seed Treatment Industry
© 2001 Keystone Aniline Corporation
Listing of available and allowable products

Dyes for Water Tracing
© 2001 Keystone Aniline Corporation
Description of methodologies and available dyes

Flaw and Strain Detection
© 2001 Keystone Aniline Corporation
Use of solvent yellow 43 for non-destructive testing

pH Indicators for Water-Based Applications
© 2001 Keystone Aniline Corporation
Listing of dyes useable as non-standard pH indicators

pH Stable Dyes for Water-Based Applications
© 2001 Keystone Aniline Corporation
Catalogue of chemically stable dyes

Keystone Nerosol Dyes
© 2002 Keystone Aniline Corporation
Technical data and applications for wood stains and coatings

Oil Dyes for Candles
© 2002 Keystone Aniline Corporation
Product list and formulation methods

Keystone Fluorescent Dyes
© 2003 Keystone Aniline Corporation
Catalogue of dyes and physical properties

Section 8: Patents

Leak Detection Materials and Methods
United States Patent no. 7,943,380

Abstract
material into a fluid system such as a climate control system, an engine oil system, or a fuel system is described. The leak detection material can be a dye delivery composition including a mixture of leak detection dye and a semi-solid carrier.

Method for preparing a co-sublimation pigment
Applied for 2011

Abstract
A co-subliming pigment containing a subliming colorant and subliming resin that will resinate and color fingermarks is manufactured and ground alone and in situ in a dispersion.

Kit for Detecting the Presence of Oil in Water
Applied for 2010

Abstract
A water permeable material is impregnated with a water insoluble fluorescent indicator which will dissolve in oil and placed in partially clear containers into which water is added. When the water is added the container is illuminated with a suitable light source and examined visually for fluorescent glow indicating the presence of oil in the water down to a detection limit of less than one part per billion.

Section 9: Copyrights

Sketches from My Audio Notebook
© 2006 Charles A. Steele PAU003048045

The Collection Includes: *A Million Miles; Enchantress, The; Bowing Out; Good Life, The; Tuesday in Neuman; Windmills*

From my Music Room: More Songs by Charles A. Steele
© 2011 Charles A. Steele SRu1-018-923

The Collection Includes: *Actress, The; Beneath Blue Skys; Daydream Star; Drunken Sailor; Enchantress, The; Everyday Darkness; Face of Clay; Faces in the Bombsite; Finger's of Time; For Jimmy Heart Song; Hell and Heaven's Gate; History of Our Age, The; Hunter's Moon; If you Want Someone Who'll Love you; Last Call; Leader of the People, The;Pathfinder; Patriot; Pilgrim Waiting; Purgatory; Snapshot; Waiting for something to Begin; Way of the Warrior, The; Windy City Gladiator*

Section 10: Professional Associations

The Society of Cosmetic Chemists (SCC)
The Society of Plastics Engineers (SPE)
International Association for Identification (IAI)
American Association of Textile Chemists and Colorists (AATCC)
Broadcast Music, Inc. (BMI)