LIMITATIONS OF THE COUNTERFEIT DETECTION PEN ON UNITED STATES CURRENCY

by

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A Research Project
Submitted to the
Graduate Faculty
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of
Master of Science
Forensic Science Program

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Bachelor of Science
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DEDICATION

This is dedicated to my wonderful family Phil, Shirley, Adam, and Kenan who taught me to challenge myself in every regard and reach for the stars.

ACKNOWLEDGEMENTS

I would like to thank my friends and fellow colleagues of the United States Secret Service for their invaluable input in this research. To my colleagues in the Treasury Obligation Section, I simply must thank you for the encouragement and patience you have shown me during this lengthy project and the many “word jokes” we have shared.

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LIST OF ABBREVIATIONS AND SYMBOLS

United States ..... U.S.
Video Spectral Comparator..... VSC
Percent..... %

ABSTRACT

LIMITATIONS OF THE COUNTERFEIT DETECTION PEN ON UNITED STATES CURRENCY

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The Counterfeit Detection Pen is one of the most widely used methods of genuine currency authentication and counterfeit currency detection by the public. However, creation of false positives and false negatives severely limit the Pen. This research project determines what creates a false positive reaction on genuine currency and what steps counterfeiters are taking to circumvent the Pen by causing false negative reactions. Laundry starch, French fry grease, and laundry detergent are tested to determine whether they create false positives on genuine currency. Nail polish, oven cleaner, pump and aerosol hairsprays, deodorant, and laundry stain remover are tested to determine whether they create false negatives on counterfeit currency. Application of laundry starch and French fry grease effectively created false positive reactions on genuine currency. Application of nail polish, deodorant, and laundry stain remover effectively created false negatives on counterfeit currency.

CHAPTER ONE - INTRODUCTION

"Counterfeiting of money is one of the oldest crimes in history" ("Know Your Money", 2010, para. 1). Of the estimated billions of dollars in circulation today less than 1/100th of one percent of the genuine currency is counterfeit (The New $100 Note, 2010). With the percentage of counterfeit currency so low, most people will go through their entire lives and never see a counterfeit note unless they work in retail or in a place that handles large volumes of currency. However, counterfeiting currency is a very real problem with real affects. Assistant Special Agent in Charge of the United States Secret Service's Criminal Investigative Division Joe DeSantis states that counterfeiting currency undermines the integrity and people's faith in the government's ability to safeguard the U.S. financial systems (personal communication, October 20, 2011). Therefore, the preservation and authenticity of United States currency is of the upmost importance to the United States government. It is in government, private, and public interest to stay abreast of current counterfeiting methods and attempt to stay one step ahead of counterfeiters. Adding security features to U.S. currency and improving methods of counterfeit detection are necessary to thwart counterfeiting. Common methods of circumvention include adding both paper based and printed security features to currency, devising new technology in currency readers which are used in public and private institutions to authenticate notes and detect counterfeit currency, and increasing public knowledge and

awareness of all these methods. One such invention that attempts to detect counterfeit currency is the Counterfeit Detection Pen. The Counterfeit Detection Pen is one of the most widely used and accepted means of counterfeit detection by the public. Merchants are the primary users of the Pen and use it as their foremost method of counterfeit detection (Securitech, 1996). However, with such great faith placed in the Pen, it is of vital importance to understand the Pen's applications, how it works, and specifically what its limitations are. These applications and unfortunate limitations are gained through an in-depth understanding of the paper making process and the history of paper currency.

Knowledge of the chemical and physical properties of paper and an understanding of the process in which genuine currency is manufactured is vital in the effort to combat counterfeiting of currency (Brunelle & Reed, 1984). The art of making paper money is an age old practice whose intricate process has evolved throughout the centuries. Since the first concept of writing began, mankind has evolved from writing in the sand to writing on cave walls, stone, bones, papyrus, bamboo, cloth, silk, parchment, and finally on what became known as paper (Brunelle & Reed, 1984). Paper's early beginnings commenced in 105 AD with the inventor Ts'ai Lun who attempted to improve the current writing material consisting of bamboo and silk at the time. Lun's process consisted of mixing the shredded bark of a Mulberry tree with scraps of hemp and cloth. He would then saturate the mixture, beat it in to a pulpy porridge, then using a screen and a stretched cloth, he would scoop out a thin layer of the porridge and place it in the sun to dry (Walden's Paper Handbook, 1995). This early process was the first step in the journey and evolution of papermaking. The significance of this discovery was that it was

the first time that man moved from the traditional means of making paper and implemented the component of wood in their paper. Over time however, this practice of making paper from wood was lost and the primary use of making paper from linen and cotton fibers appeared (Walden's Paper Handbook, 1995). Centuries later, in 807 AD, the Chinese government moved away from using gold, silver, silk, bronze, and iron coins as currency in their transfers of money and began to use paper as their means of currency (Smith, 2011). Soon after, other countries began to adopt the same practice of using paper money for their currency.

As using paper as a form of currency became more commonplace, changes in the consistencies and characteristics of the paper currency changed and evolved over time. Each country used different materials to produce their currencies and many currencies varied in thickness, size, and color. However, the principle concept of making paper from linen and cotton fibers remained the same. Shortly after paper currency conception, countries began to devise methods to increase a currency's validity through the introduction of the first paper based security features. In 1282 the Italian government became the first European country to incorporate paper based watermarks as additional paper security (Walden's Paper Handbook, 1995). The use of a watermark in paper currency became a very popular technique and added an additional layer of complexity to currency. The placing of watermarks in currency as a paper based security feature is currently used throughout many of the world's currencies today and this age old practice is still one of the hardest features to simulate effectively for a counterfeiter (Y. Monson, personal communication, October 21, 2011). By 1423, the paper making process had

spread throughout Europe and countries were incorporating watermarks in to the process (Walden's Paper Handbook, 1995).

By the time the concept of using paper currency made its first appearance in the New World it was 1690 and much of the Old World had centuries of experience in the concepts and principles of making and issuing paper currency. Early colonists made several attempts at using paper currency to finance military expeditions and the Revolutionary War. These first currencies were backed by commodities such as corn, grain, cattle, silver, and gold ("History of Colonial Money", 2011). Most of these currencies failed. From the period of 1790 to 1865 the number of currency paper issuers grew from only a handful to over 8,000 banks and institutions producing their own currency (Goldsmith, 2007). Problems with this currency generated around the fact there were too many variations in circulation, specific institutions would only accept their own currency, and there was no official standard thus allowing counterfeiting of currency to take hold. Finally, with the passing of the Act of July 17, 1862 and to fill the financial needs of fighting the Civil War, Congress authorized the 1st successful issue of paper currency printed and circulated by the United States Treasury ("Know Your Money", 2010). This paper was manufactured by the Crane Paper Making Company who has held the sole contract on U.S. currency paper making with the U.S. government to present day. Within a few years, counterfeiting had become so rampant that approximately one-third of all currency in circulation was counterfeit ("Know Your Money", 2010). With levels of counterfeit currency rising and the public's faith in the currency falling, under Abraham Lincoln's charge on July 5, 1865 the United States Secret Service was created.

First attempts at the prevention of early counterfeiting came through intricately printed designs on paper such as leaf patterns which were hard to simulate (Goldsmith, 2007). Phrases such as “To Counterfeit Is Death” were found on the early Pound and Shilling notes of the later 1750’s (Grubb, 2006). As U.S. currency became standardized and security features were added to notes, improvements in technology allowed for better detection of counterfeit notes. One such detection method presently used is the Counterfeit Detection Pen.

According to Midwest Fraud Prevention, the first predecessors of the Counterfeit Detection Pen included a pH testing pen and a calcium detection pen. The pH pen checks the pH level of paper. As U.S. currency contains a high pH level a counterfeit bill with a low pH level would be revealed as fake. However, several paper manufactures create papers with a high pH level therefore false negatives were easily generated. Calcium detection pens checked for levels of calcium which is found in U.S. currency. However, old versions of currency did not contain calcium thus generating false positives. Finally, the current version of the Counterfeit Detection Pen was introduced (2009).

The current Counterfeit Detection Pen utilizes a starch-iodine chemical reaction test for its detection of counterfeit currency. When the Pen is applied to paper, the iodine from the Pen will react with the any substance on the surface of the paper thus causing a visible color reaction. With genuine currency, a pale yellow color reaction indicates that the currency is legitimate. If the resulting color reaction is brown or black, then the currency is suspicious or counterfeit (Securitech, 1996). The color reaction from the Pen is immediate but on genuine currency can often fade quickly (Corwin, 2005). Therefore,

immediate observation of the color is important. The principle behind the color reaction is that genuine U.S. currency contains 75% cotton and 25% linen (Pierce, 1977). Non-currency papers contain wood pulp which contains starch in its base or they use chemical additives of starch for sizing (Brunelle & Reed, 1984). Therefore, when the iodine from the Pen comes in to contact with the starch from the paper a dark color reaction is formed. The Pen is hailed as the ultimate means of consumer counterfeit detection by both its inventors and most consumers in the general public. Securitech Sales LTD is one company that distributes the Counterfeit Detection Pen. They make claims that the Pen is "90% accurate and as accurate as any other detection method used" (1996, pg. 6). They also claim that it is 100% accurate on all types of money made from office color copiers, that it detects suspect bills instantly, and that it is good for up to 8,000 uses (1996).

The principle behind the Counterfeit Detection Pen is based off the fundamental consistency of materials used to produce genuine currency and traditional paper. According to "The First 175 Years of Crane Papermaking", traditionally, genuine currency consisted of 75% linen and 25% cotton and the linen was made from discarded rag paper which was purchased from area housewives. Shortages during World War I and II however led to a drop in the percentage of linen from 75% to 50% and an increase in the percentage of cotton from 25% to 50%. Finally, in 1956, the Treasury Department dropped the percentage of linen from 50% to 25% and increased the percentage of cotton to 75%. This percentage of 25% linen and 75% cotton is the standard for what is used today (Pierce, 1977).

Major developments created within the paper industry in later years led to a revolution in traditional paper making. Creation of paper transformed from the use of cotton and linen fibers to paper made from wood pulp (Pierce, 1977). Today, paper is made from a combination of natural materials such as wood pulp, clays, cellulose fibers, and from recycled consumer waste (McGaw, Szymanski, & Smith, 2009). Consistencies of papers can vary depending on the purpose the paper is suited to match. Examination of the physical and chemical properties of the paper can be used for the determination of class characteristics in paper comparisons (LaPorte, Stephens, & Beuchel, 2010). The physical examinations consist of color, size, weight, opacity, watermark examination, and fluorescent properties. The chemical examinations consist of fiber type, chemical analysis, and trace element profiles (Kumar, 2011). Additionally, different chemical additives in coatings, loading, and sizing of papers are added that can differentiate paper. Coatings consist of clay, talc, titanium dioxide, barium sulfate, and calcium sulfate. Loading of papers consists of white pigments or fillers of clay, calcium carbonate, and titanium dioxide. Sizing materials consist of rosin, synthetic resins, proteins, and starch (Brunelle & Reed, 1984). It is the presence of starch used either in the sizing of the paper or found in the wood pulp making up the paper that will be tested against the Counterfeit Detection Pen.

The importance of knowing about the paper making process and the chemical and physical additives that can be added to papers provide the base for understanding why several different papers made from varying consistencies are being tested in this experiment. Determination will be made on whether papers made with different material

consistencies and chemical additives will have a different effect on the Counterfeit Detection Pen.

CHAPTER TWO – TERMS AND CATEGORIZATION

2.1 Munsell Color Chart

Colors produced from the starch-iodine reactions will be classified on the Munsell Color Chart. Typically the Munsell Color Chart is used in forensic laboratories for the color classification of soils and mineral evidence (Thornton, 2008). It is also often used in determining color differences in the study of skeletal remains and the changes of color on bones after burial (Huculak & Rogers, 2009). The same color principles that guide those studies can also be applied to the starch-iodine reaction produced by the Counterfeit Detection Pen.

The Munsell Color Chart (Figure 1) is based off the principle that any color is comparable as long as it is viewed under the same light source and on the same surface ("Colorimetry"). Under this principle, the Munsell Color Chart was developed as an ordering scheme to specify colors where three quantities were chosen; hue, value, and chroma. The numbers 1-10 are used to divide the hue's range, the value is equal to the lightness, and the chroma is equal to the saturation or purity of each color. In the "5Y" scale, "5" is halfway between a low intensity "1" and a high intensity "10" and "Y" stands for yellow. Therefore, the 5Y chart is used for comparison of the reactions caused by the Pen and is designated for a mid-range yellow hue. The arrangement of the chart is organized in equal steps with the intensity either increasing or decreasing in both values

and chromas between each hue as you move down or across the chart ("Colour Science"). On this scale the darkest hue of value 2.5/chroma 1 appears to be black/brown and the lightest hue of value 9/chroma 1 a white/yellow. Therefore, as starch-iodine color reactions are produced on the paper by the Pen, the colors will be compared on the 5Y hue scale for the appropriate value and chroma. Thus, the reactions will be classified and sorted.

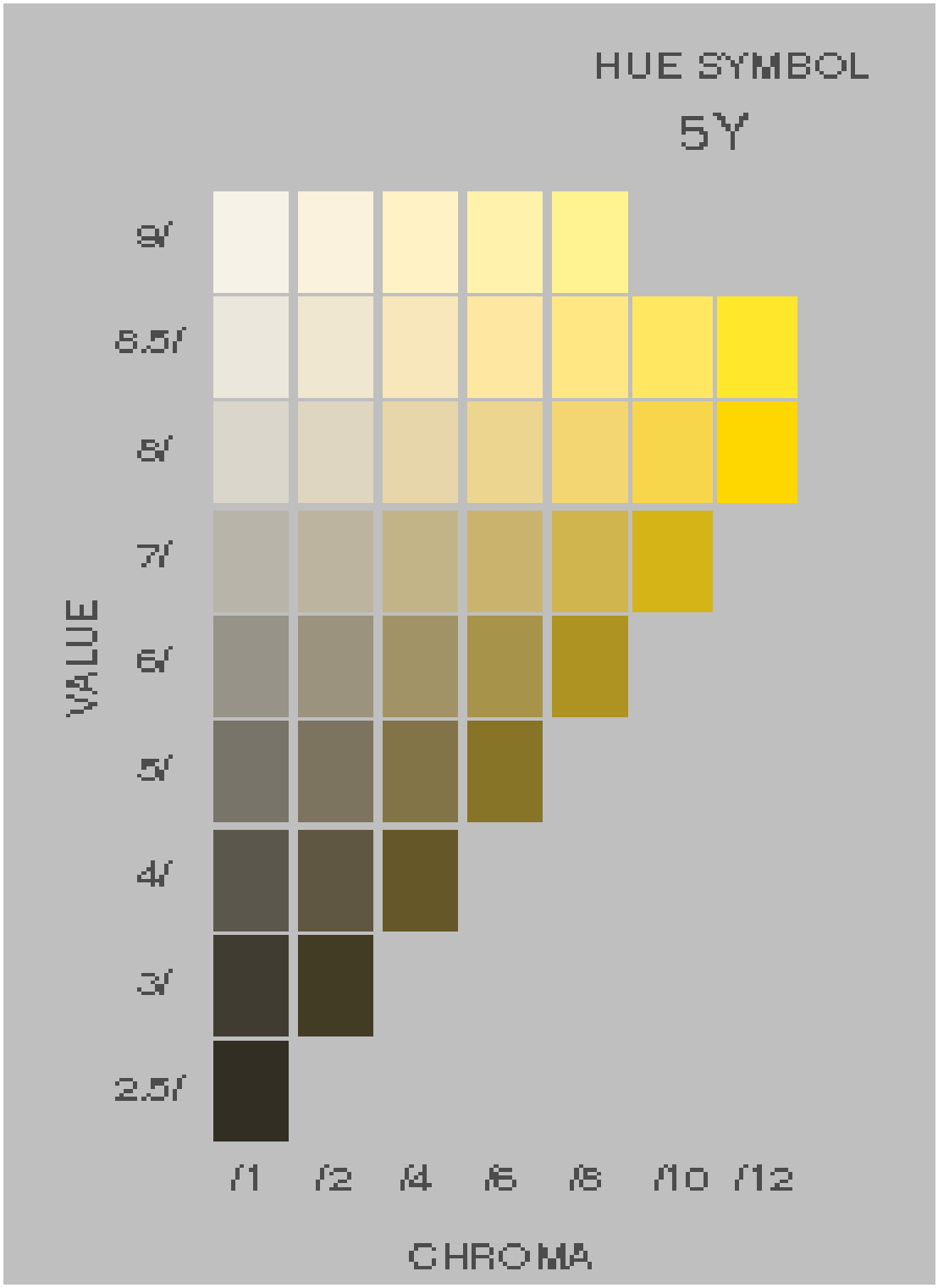

Figure 1 - *Munsell Color Chart (5Y Scale)*
(Institute for Theoretical Physics. Colorimetry: seeing, measuring, and rendering colours.)

2.2 Reaction

A reaction is defined as a process of changing the chemical properties of a substance through the interaction between different molecules (Mosby's, 2005). In this project, a reaction is demonstrated when the iodine from the Counterfeit Detection Pen is applied directly to the surface of paper and produces a visible result. This visible reaction represented by a color change will be the result of the iodine reacting with the presence of starch on the surface of the paper. A lack of color change or no visible reaction will demonstrate no visible chemical change.

2.3 False Positive and False Negative Reaction

A false positive occurs from an erroneously positive reaction to a test. A false negative occurs from an erroneously negative reaction to a test (Saunders, 2007). In this project, a false positive reaction is formed when the iodine from the Pen reacts with the coating created by the product applied to the surface of the genuine currency paper thus producing a color reaction that incorrectly identifies the paper as counterfeit currency. A false negative reaction occurs when iodine reacts with the coating created by the product applied to the surface of the paper and produces a color reaction that incorrectly identifies the paper as genuine currency.

2.4 Starch-Iodine Test

A common starch-iodine test will be used in this experiment. Similar to J.G.A. Lugiol's solution made in 1829, this solution is used as an indicator test for the presence of starches in organic compounds, which reacts by turning a dark-blue/black color. If

starch Amylase is not present then the color will remain orange or yellow (Ophardt, 2003). Interestingly, not all chemical forms of starch will react with the iodine from the Counterfeit Detection Pen. Instead, the iodine from the Pen will only react with Amylase which is only one form of starch (J. Stephens, personal communication, October 21, 2011). The structure of Amylase consists of long polymer chains of glucose units connected by an alpha acetal linkage. As a result of the bond angles in the alpha acetal linkage, Amylase actually forms a spiral much like a coiled spring. Once the iodine molecule slips inside of the Amylase coil a color reaction occurs (Ophardt, 2003). In other words, when the presence of iodine from the Counterfeit Detection Pen comes in to contact with the presence of starch on any paper, a dark brown/black color reaction will form. Therefore, as it is known that genuine currency does not contain any starch, no dark brown/black reaction should occur. Additionally, as it is known that most of today's papers contain starch as a sizing agent or contain the presence of starch from wood pulp a dark brown/black color reaction should occur on those papers.

CHAPTER THREE – GOALS AND OBJECTIVES

The goal of this research is to gain a detailed understanding of the Counterfeit Detection Pen through analysis of concrete laboratory results. These results will determine exactly how the Counterfeit Detection Pen works, whether the consistencies of material making up the paper react differently to the Pen, and what substances can cause the Pen to produce a false positive or a false negative reaction thereby limiting its accuracy. In order to ascertain this information laboratory research will be conducted.

In order to draw accurate conclusions from this testing, genuine and non-currency paper (counterfeit) standards will be created. "Many common document investigations require comparison of the disputed material with specimens from known sources" (Lindblom & Kelly, 2006, pg. 10). Therefore, the results from the known sources will become the standards. The importance of these standards will be used for comparison of the expected response against the actual outcome of the Counterfeit Detection Pen. These standards will consist of one genuine standard which will show the expected response of the Pen to the currency paper and one counterfeit standard for every sample of non-currency paper (for a total of ten standards).

Once these standards are created testing will commence on what type of paper causes a confirmatory reaction to the Counterfeit Detection Pen identifying a note to be counterfeit. Since it is known that the iodine in the Pen responds to the detection of

starch in paper, analysis of different types of papers made up of different consistencies will be conducted (Walden's Paper Handbook, 1995). Each sample of paper tested represents those similar to what a counterfeiter might use to produce counterfeit currency. Several of the paper specimens tested are manufactured from Southworth Paper Company due to the fact that several known counterfeiters have been using Southworth's paper to make counterfeit currency. According to U.S. Secret Service Counterfeit Specialist Tyra McConnell, approximately 90% of the counterfeit currency that contains commercial watermarks that is received by the Treasury Obligation Section for examination has a Southworth watermark (personal communication, October 21, 2011). She believes that Southworth paper is often used due to its texture and similar thickness to genuine currency. Amazingly, even Southworth Paper Company's paper packaging states that the addition of pure cotton linters in their papers that contain 25% cotton offer a substantial feeling of crispness like a new dollar bill (2002). Interestingly, often, when a counterfeiter uses Southworth's paper, their counterfeit currency retains the original watermark from Southworth. Figure 2 shows the watermark from Southworth's Fine Linen paper (which contains 25% cotton) when viewed through transmitted light. Once the counterfeit image has been printed over the paper the watermark is still visible. Figure 3 shows a counterfeit $20 note image printed on a sheet of Southworth paper with the original Southworth watermark still visible viewed through transmitted light.

Figure 2 - *Southworth paper watermark (Courtesy U.S. Secret Service)*

Figure 3 - *Uncut sheet of counterfeit $20 image on Southworth watermarked paper (Courtesy U.S. Secret Service)*

All paper samples tested represent a vast range of material consisting of 25% and 100% cotton and 30% and 100% recycled paper. All of Southworth's papers consisting of less than 100% cotton contain multiple fillers including #1 Sulphite which is the best processed wood pulp grade available (Southworth Paper Company, 2011). In theory, since each of these papers are made of different consistencies of cotton, linen, and wood pulp products and contain different amounts of starch from the wood pulp and the sizing then each paper should react differently to the Pen thereby producing noticeable visible differences in the reactions (Kreitl, 2000). It will be interesting to determine which paper will produce the strongest reaction to the Counterfeit Detection Pen. It will also be intriguing to note how different material consistencies in each paper cause different color reactions to the Pen.

After both genuine and counterfeit standards have been created examination will be conducted to determine what causes a false positive reaction on genuine currency demonstrating one of the limitations of the Counterfeit Detection Pen. The U.S. Secret

Service speculates that certain items can create a false positive reaction from the Pen thereby making a genuine note appear to be counterfeit (S. Kolb, personal communication, October 17, 2011). The following items will be tested to see if they produce a false positive reaction when they come in to contact with genuine currency: laundry starch, French fry grease, and laundry detergent. One of the objectives of this laboratory research is to determine whether these specific items can produce a false positive reaction from the Pen and establish whether a difference in the application of the amount of these items produces different visible color reactions.

Lastly, further limitations of the Counterfeit Detection Pen will be tested to determine what creates a false negative reaction demonstrating another limitation of the Pen. A nail polish coating, pump and aerosol hairsprays, oven cleaner, deodorant, and stain removing gel products will be applied to each of the ten different non-currency paper specimens to determine what the U.S. Secret Service believes are current counterfeiters' attempts to circumvent the Pen (S. Kolb, personal communication, October 17, 2011). These methods have been found to be used by counterfeiters as they appear to provide a coating to the paper that prevents the starch-iodine reaction from occurring. The objectives are to determine whether these specific products can produce a false negative reaction from the Pen, establish whether a difference in the application of the amount of these products produces different visible color reactions, and establish whether differences in paper consistencies affect the color reactions of the Pen.

CHAPTER FOUR – CREATION OF STANDARDS

4.1 Creation of Standards

The creation of standards is of upmost importance when conducting laboratory research. Standards are essential as the building blocks from which the research stands. Before any testing can begin, it must be known what the normal or typical response would be outside of any variables introduced. Once those standards are created, true comparisons can be made between questioned samples and the known standards.

In this experiment, a genuine standard is used as a reference point to see the "true positive" (normal) reaction the Counterfeit Detection Pen produces upon the genuine currency paper. Genuine currency paper contains 75% cotton and 25% linen and is absent of any wood pulp (Bureau of Engraving and Printing, 2011). Therefore, any reaction produced on the paper from the Counterfeit Detection Pen should appear as a yellow hue identifying the paper as genuine (Kreitl, 2000).

The counterfeit standards produced in this experiment are also used as reference points to see the "true negative" (normal) reaction the Pen produces upon the non-currency papers. These papers are processed and produced from a variety of different sources and materials and contain different consistencies of cotton, linen, or wood pulp. Therefore, the combination of starch from the paper and iodine from the Pen create a characteristic deep purple/black color identifying the paper as non-currency (Kreitl,

2000). Due to a large majority of counterfeiters using Southworth paper for their counterfeit currency, half of the papers tested are from this one source (T. McConnell, personal communication, October 21, 2011).

4.2 Documentation

All testing conducted in this project was accomplished in the U.S. Secret Service Treasury Obligation Section laboratory. All reactions produced were immediately compared against their expected or known standard response and classified accordingly on the Munsell Color Chart. All reactions were documented and scanned using an Epson Perfection 4870 Photo Scanner and time measurements were recorded on a Fischer Scientific Timer. A Video Spectral Comparator (VSC) 6000 which is an instrument used for high magnification viewing, image capturing, and viewing using alternate light sources was used to attain a genuine currency image that was difficult to capture with the photo scanner.

The Counterfeit Detection Pen was purchased new from a supply store and was sealed prior to opening.

Any variables that were applied to tested papers were placed directly in the center of the paper. Reactions to the Counterfeit Detection Pen were demonstrated by a large "X" approximately 2 inches by 2 inches directly in the center of the paper (Figure 4 and Figure 5).

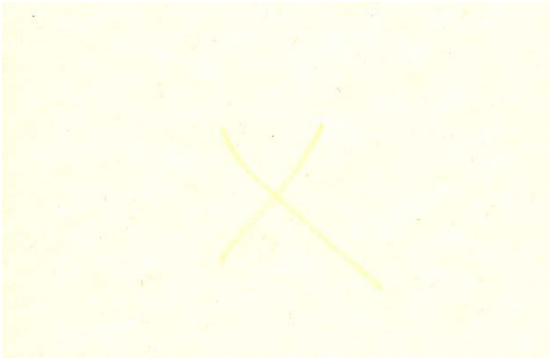

Figure 4 – *A "true positive" (negative color) reaction demonstrated by an "X" on genuine currency.*

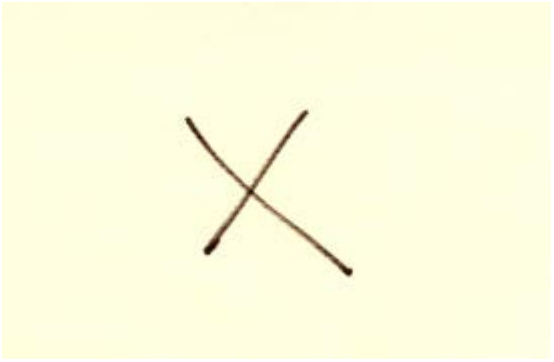

Figure 5 – *A "true negative" (positive color) reaction demonstrated by an "X" on non-non-currency paper.*

Light, heavy, and saturated categories were used to determine the amount of product applied to the surface of the paper. Each category began with a light application and the additional heavy and saturated categories were added only if the previous application was not sufficient in producing a false positive or false negative reaction.

4.3 Genuine Standard

Before initial testing could begin, creations of genuine and counterfeit standards were produced. For the genuine standard, genuine currency paper consisting of 75% linen and 25% cotton was used (Table 1). This paper was retrieved from a supply that was sent specifically from the Crane Paper Making Company to the United States Secret Service and has been sealed in their laboratory vault to keep it free from contaminates. Once retrieved, this paper was laid flat on a table and the Counterfeit Detection Pen was used to test for a reaction.

Table 1 - *Genuine currency paper tested for genuine standard.*

PAPER	COTTON	LINEN	PAPER COLOR
Genuine Currency	25%	75%	Cream

4.3.1 Results

The Counterfeit Detection Pen produced a true positive initial iodine reaction on the paper and the resulting reaction was classified on the Munsell Color Chart with a value of 9 and a chroma of 8 (Table 2).

Table 2 - *Standard reaction on genuine currency.*

PAPER	COLOR REACTION	MUNSELL VALUE	MUNSELL CHROMA	MUNSELL COLOR
Genuine Currency	X	9	8	

"X" = reaction (In all tables)

4.4 Counterfeit Standards

The counterfeit standards were ten different papers made up from different consistencies of cotton, linen, and wood pulp that were retrieved from the United States Secret Service laboratory paper collection found in their vault. These papers were pulled from individually labeled boxes identifying exactly what they were. Once retrieved, these papers were individually laid flat on a table and the Counterfeit Detection Pen was used to test for a reaction (Table 3).

Table 3 - *Specific papers tested for counterfeit standards.*

PAPER	COTTON	OTHER	PAPER COLOR	ITEM #
Southworth Antique Laid	25%	Not Stated	Ivory	464C
Southworth Fine Business	25%	Not Stated	Natural	404NC
Southworth Fine Linen White	25%	Not Stated	White	554C
Southworth Exceptional Business Ivory	100%	Not Stated	Ivory	JD181C
Southworth Resume Paper	100%	Not Stated	White	R141CF
Eaton Gray Granite Paper	25%	Not Stated	Granite	37-835-30
Xerox Business Paper	0%	Recycled Chlorine Free Process, Acid free 75g/m2	White	Not Stated
Great White Heavy Weight Inkjet	0%	30% Recycled Fiber Weight	White	Not Stated
Boise Cascade Laser Paper	25%	100% Recycled, Acid Free	Natural	Not Stated
Eureka Georgia-Pacific Recycled Copier	0%	50% Post-Consumer Content	White	Not Stated

4.4.1 Results

The Counterfeit Detection Pen produced a true negative starch-iodine reaction on the papers and the resulting reactions were classified on the Munsell Color Chart (Table 4).

Table 4 - *Standard reactions on tested papers.*

PAPER	COLOR REACTION	MUNSELL VALUE	MUNSELL CHROMA	MUNSELL COLOR
Southworth Antique Laid	X	2.5	1	
Southworth Fine Business	X	2.5	1	
Southworth Fine Linen White	X	2.5	1	
Southworth Exceptional Business Ivory	X	2.5	1	
Southworth Resume Paper	X	2.5	1	
Eaton Gray Granite Paper	X	3	1	
Xerox Business Paper	X	2.5	1	
Great White Heavy Weight Inkjet	X	2.5	1	
Boise Cascade Laser Paper	X	4	2	
Eureka Georgia-Pacific Recycled Copier	X	2.5	1	

4.5 Discussion

Both the genuine and counterfeit standards displayed the typical response expected by the Counterfeit Detection Pen on genuine and counterfeit paper. The

genuine paper produced a yellow color reaction as no presence of starch was found. The counterfeit papers produced dark color reactions as the iodine from the Pen detected and reacted with the presence of starch found in the paper. Varying paper consistencies appeared to have relatively little differences among each other.

CHAPTER FIVE – FALSE POSITIVE REACTIONS

False positive reactions are the absolute demonstration of the most significant limitation of the Counterfeit Detection Pen. Therefore, determining what creates a false positive reaction is of upmost importance to understanding this limitation. If the Pen is unable to accurately detect genuine currency then the entire premise for which the Pen is based on becomes faulty. Currency often becomes contaminated in daily use and dirty currency can often contaminate clean currency. The transfer of contaminants from one note to another can occur in banks from cash processing or counting machines or through general use by the public (Luzardo, Almeida, Zumbado, & Boada, 2011). These contaminated notes are then spread throughout the banking system and back in to the hands of the general public (Luzardo, et al, 2011). In this manner, notes become contaminated with all sorts of things. In this segment, items that contain starch will be tested to see whether any presence of starch transferred from these items on to genuine currency will create a false positive reaction to the Pen. These items are chosen because the U.S. Secret Service suspects that any currency that might come in to contact with products that contain starch could potentially transfer the starch on to the genuine currency paper thus causing the Pen to detect that starch and produce a false positive reaction (S. Kolb, personal communication, October 17, 2011). The starch from these products could also very easily and unintentionally be transferred to currency without the

owner knowing. Currency is often accidently washed and dried in the pocket of clothing. Concentrations of laundry spray starch or laundry detergent transferred to these notes during the wash and dry cycles might then affect the results of the Pen. Clothes are also often sent to a dry cleaner for cleaning and could easily come in to contact with starch there. The transfer of starch from French fries, which is also another common starch, may also easily be transferred to currency through the passing of change in a fast food establishment. These items and brands are also chosen because they are common brands and easily accessible to the general public.

The following variables were tested on genuine currency paper in an attempt to produce a false positive reaction to the Counterfeit Detection Pen (Table 5).

Table 5 - *Variables tested on genuine currency paper in an attempt to create a false positive reaction.*

VARIABLE	LABEL	BRAND
Laundry Starch	Easy On	Yes Speed Starch
French Fries	McDonalds French Fries	McDonald's Restaurant
Laundry Detergent	Oxi-Active Stainlifter	All

5.1 Laundry Starch

5.1.1 Experimental Design

In the light category 1 spray of laundry starch was applied to the center of the note. In the heavy category, 3 sprays were applied to the center of a separate note. Both

sprays were applied from a 12 inch height measured with a ruler directly above the paper. Samples were allowed to dry for 2 hours before being tested.

5.1.2 Results

The application of laundry starch on genuine currency paper has a significant effect upon the starch iodine reaction produced by the Counterfeit Detection Pen. An immediate reaction occurs when the coating of starch added to the paper comes in to contact with the iodine from the Pen. This reaction is consistent with the brown color reaction that would be expected from the Pen on counterfeit currency and is in stark contrast to the yellow color reaction produced on the genuine standard. Differences in the concentration between the light and heavy category on the reaction were slight and still fell within the same hue on the Munsell Color Chart. Only a very slight reduction in the strength of the color reaction from the heavy to light category was noticeable. Comparisons between the color reactions on the genuine standard and the light and heavy concentrations of laundry starch on genuine paper are recorded in Table 6.

Table 6 - *A false positive attempt using a laundry starch coating.*

VARIABLE	STANDARD	LIGHT – 1 SPRAY	HEAVY – 3 SPRAYS
Laundry Starch	Value – 9 Chroma – 8	Value – 3 Chroma – 1	Value – 3 Chroma – 1

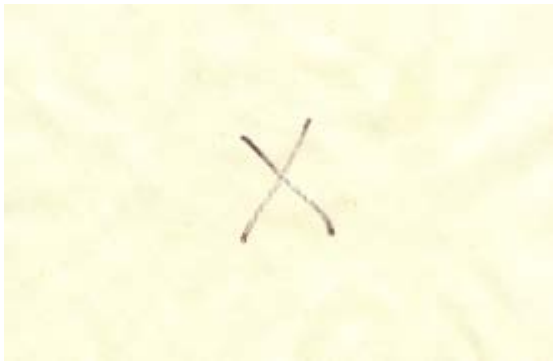

Figure 6 – *Brown reaction visible through heavy category of laundry starch.*

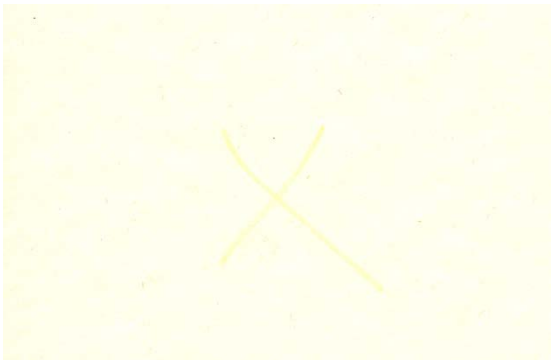

Figure 7 – *Yellow reaction visible on genuine standard currency paper.*

5.1.3 Discussion

Contact of genuine currency with laundry starch is a viable explanation for the generation of a false positive reaction produced from the Counterfeit Detection Pen. Even if genuine currency only briefly comes in to contact with laundry starch as demonstrated in the light category, there is sufficient starch present to react to the iodine from the Pen thus producing the brown color reaction identifying the currency as counterfeit. Therefore, although this experiment proves that the Counterfeit Detection Pen works as intended in detecting papers containing starch, it also proves that the Pen is limited in its identification of counterfeit and genuine currency and the starch-iodine reactions are easily altered.

5.2 French Fries

5.2.1 Experimental Design

A box of French fries was purchased from a local area McDonalds and applied to genuine currency. The fries were given 15 minutes to cool before laying them flat and laterally rubbing them across the center of the note. A new French fry was used every time in between each category. Layers of coating were created by rubbing the French fry laterally back and forth across the surface of the paper. Each change in rubbing direction represented a new coating. In the light category 10 coatings of French fry grease were applied to the center of the note. In the heavy category, 25 coatings were applied and in the saturated category 50 coatings were applied. All coatings were applied directly on top of each other. Samples were allowed to dry for 1 hour before being tested.

5.2.2 Results

Application of French fries to genuine currency produced minimal significant visible results in the production of a false positive under the light category. The resulting color reaction from the Pen indicated no significant change in the hue from standard genuine currency. A slight decrease in the intensity of the hue was observed from a value of 9 and chroma of 8 to a value of 9 and a chroma of 6 in the lightest application of saturation. Significant results were only reached under the heavy and saturated categories were a slight brown color reaction was visible.

Table 7 - *A false positive attempt using a French fry.*

VARIABLE	STANDARD	LIGHT – 10 COATINGS	HEAVY – 25 COATINGS	SATURATED – 50 COATINGS
French Fries	Value – 9 Chroma – 8	Value – 9 Chroma – 6	Value – 6 Chroma – 1	Value – 8 Chroma – 2

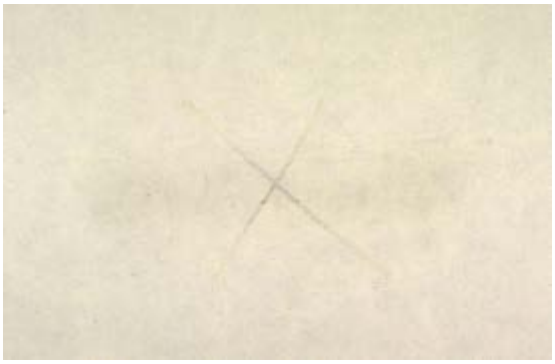

Figure 8 – *Brown reaction visible through 25 coats of French fry grease. (Image taken with a VSC 6000)*

5.2.3 Discussion

The transfer of French fry starch to genuine currency paper appeared to create a slight false positive reaction to the Pen. This false positive reaction however was only visible under the heaviest concentrations of French fry starch. Concentrations in the light category appeared to have minimal significant effects upon genuine currency and therefore did not circumvent the Pen's starch-iodine reaction. Increases in the color change of the brown reaction in the heavy and saturated categories may be due to the supplementary amount of starch added to the paper from the extra coatings.

Additionally, as the exterior surface of the French fry began to break apart under constant pressure and friction from application of the coatings, the starch from inside the French fry was added to that from the outside of the fry thus contributing more starch. Surprisingly, application in the heavy category produced a darker brown reaction than the increased application of coatings in the saturated category. This may be due to variance in the amount of starch or grease concentrated in the different French fries used in each category. However, even with the heaviest concentration of French fry starch in both categories and the creation of a slight false positive, the resulting color reaction may not be enough to cause a consumer using the Pen to be suspicious. Additionally, there are very few instances where currency paper might be exposed to such an extreme amount of French fry starch, especially without the owner's knowledge.

5.3 Laundry Detergent

5.3.1 Experimental Design

This experiment was conducted in a home setting. In the light category 1 coating of laundry detergent was applied to currency paper. In the heavy category 5 coatings of laundry detergent were applied to currency paper. In the saturated category 10 coatings of laundry detergent were applied to currency paper. Each category of coatings was applied to separate currency papers and with separate Q-tips. In the heavy and saturated categories the Q-tip was re-dipped each time between applications and immediately applied on top of the previous coating which was still wet. Samples were allowed to dry for 168 hours before being tested.

5.3.2 Results

Application of three different concentrations of laundry detergent on genuine currency paper had negligible visible results on the Pen's reaction. Despite any additional layer of detergent coating added to the paper the hue produced by the reaction remained the same. The hue between the standard and all three categories of light, heavy, and saturated remained consistent at a value of 9 and a chroma of 8 on the Munsell Color Chart as seen in Table 8.

Table 8 - *A false positive attempt using laundry detergent.*

VARIABLE	STANDARD	LIGHT – 1 COATING	HEAVY – 5 COATINGS	SATURATED - 10 COATINGS
Laundry Detergent	Value – 9 Chroma – 8	Value – 9 Chroma – 8	Value – 9 Chroma – 8	Value – 9 Chroma – 8

Figure 9 – *Yellow reaction visible through saturated category of laundry detergent.*

5.3.3 Discussion

The application of laundry detergent on genuine currency paper does not appear to have any false visible effect on the Counterfeit Detection Pen. A false positive reaction was not formed as originally suspected. Therefore, if genuine currency paper does not produce a false positive reaction under this intense concentration of laundry detergent when applied directly to the currency paper then any genuine currency passed through a washing machine at a lower concentration of detergent would not have a different outcome. Possible explanations for this lack of false positive reactions may demonstrate that laundry detergent does not contain the appropriate Amylase version of starch. Additionally, perhaps the only scenario where a false positive reaction would occur would be from the transfer of laundry spray starch from a shirt that has been included in the wash cycle on to genuine currency.

CHAPTER SIX – FALSE NEGATIVE REACTIONS

False negative reactions are yet another significant demonstration of the Counterfeit Detection Pen's limitation. In fact, it is these false negative reactions that counterfeiters rely upon when creating and passing their own counterfeit currency. If the Pen is unable to identify the paper as counterfeit, and a merchant is using the Pen as their sole source of counterfeit detection, then the counterfeiter has won. Therefore, it is of vital importance to understand exactly what the counterfeiters are doing to circumvent the Pen.

This segment will test whether any of the below products, in varying amounts, are able to provide a sufficient barrier to the Pen thereby preventing the starch-iodine reaction from occurring and producing a false negative result. According to U.S. Secret Service Agent Sam Kolb, U.S. Secret Service agents have found at counterfeit currency manufacturing locations that products that can be used to stiffen notes or repel the Pen have been used by some counterfeiters. These products include anything that can provide a coating to the note such as hairsprays, oven cleaner, nail polish, and laundry stain remover, among many others (personal communication, October 17, 2011). The products used in this testing simulate the items that have been found at counterfeit manufacturing locations as well as suspected products and methods that other counterfeiters may be using to circumvent the Pen. Products to be tested were chosen because they are

common brands that are easily accessible to the public. Both aerosol and pump applied hairspray products are used to determine whether the application of the hairspray on to a note will make a difference in the reaction of the Pen.

The following variables were tested on counterfeit currency paper in an attempt to produce a false negative reaction to the Counterfeit Detection Pen (Table 9).

Table 9 - *Variables tested on counterfeit paper in an attempt to create a false negative reaction.*

VARIABLE	NAME	DESCRIPTION
Nail Polish Hardener	Hard As Nails	Clear
Pump Hairspray	White Rain	Extra Hold
Oven Cleaner	Homelife	Heavy Duty
Aerosol Hairspray	Bumble and Bumble	Classic
Deodorant	Lady Speed Stick	Invisible Dry
Laundry Stain Remover	Shout	Ultra Gel

6.1 Nail Polish Hardener

6.1.1 Experimental Design

All ten non-currency papers were tested under each category. In the light category 1 coating of nail polish was applied to each separate paper. In the heavy category 5 coatings of nail polish were applied to separate papers. In the saturated category 10 coatings of nail polish were applied to separate papers. In each category of coatings, additional layers were applied through a brush that was re-dipped each time. Each coating was applied directly on top of the previous coating while the coating was

still wet. Samples in the light and heavy category were allowed to dry for 1 hour before tested. Samples in the saturated category were allowed to dry for 3 hours before tested.

6.1.2 Results

In the light category, the application of the nail polish coating on the tested papers appeared to provide an effective block to the Counterfeit Detection Pen. In the light category, application of just one coating of nail polish to three different test papers effectively prevented the Pen from reaching the surface of the paper thereby blocking the starch iodine reaction from occurring. These papers were Southworth's Antique Laid, Fine Business, and Fine Linen. The papers that showed the most color reaction were Southworth's Exceptional Business and Resume paper as well as Eaton Gray's Granite paper. In these samples the full outline of where the color reaction went through the coating was visible. In all other samples, although no outline was visible, heavy spotting was present.

In the heavy category, application of five coatings of nail polish further reinforced the Pen's limitation this time creating an even thicker barrier that prevented even less of the Pen's iodine from reaching the paper. Therefore, even fewer color reaction spots were visible through these additional coating layers in comparison to the application of only one coating in the light category. As in the light category, papers from Southworth's Antique Laid, Fine Business, and Fine Linen completely prevented the reaction from occurring. Additionally, reactions on papers from Boise Cascade and Eaton Gray were also effectively blocked. All blocked reactions were on papers consisting of material made from 25% cotton. The first visible reaction to the Pen appears on recycled papers

made with no cotton or linen produced by Xerox, Eureka, and Great White. Lastly, the Southworth Exceptional Business and Resume papers made 100% from cotton showed the most reaction to the Pen allowing a near visible outline of the Pen's marking and a few larger spots to be seen.

In the saturated category where the heaviest application of ten coatings was applied to different papers the starch iodine reaction from the Pen was completely blocked on every tested paper.

On all paper samples tested, an initial color reaction to the Pen appeared however completely disappeared within 5 seconds of application. Additionally, on tested papers that did produce a visible reaction, due to limited and incredibly small reaction spots the colors from the reactions were not able to be classified on the Munsell Color Chart. However, the color of the small reaction spots that was visible appeared to match the expected hue of those produced on each paper's standard. Results from this experiment are recorded below in Table 10.

Table 10 - *A false negative reaction attempted through nail polish coatings.*

PAPER	LIGHT - 1 COATING	HEAVY - 5 COATINGS	SATURATED – 10 COATINGS
Southworth Antique Laid	-	-	-
Southworth Fine Business	-	-	-
Southworth Fine Linen White	-	-	-
Southworth Exceptional Business Ivory	X	X	-
Southworth Resume Paper	X	X	-
Eaton Gray Granite Paper	X	-	-
Xerox Business Paper	X	X	-
Great White Heavy Weight Inkjet	X	X	-
Boise Cascade Laser Paper	X	-	-
Eureka Georgia-Pacific Recycled Copier	X	X	-

"-" = No Reaction (In all tables)

**On all paper samples tested, an initial color reaction to the Pen appeared however completely disappeared within 5 seconds of application. Additionally, on tested papers that did produce a visible reaction, due to limited and incredibly small reaction spots the colors from the reactions were not able to be classified on the Munsell Color Chart. However, color reactions did not appear to deviate from reactions produced on the standards.*

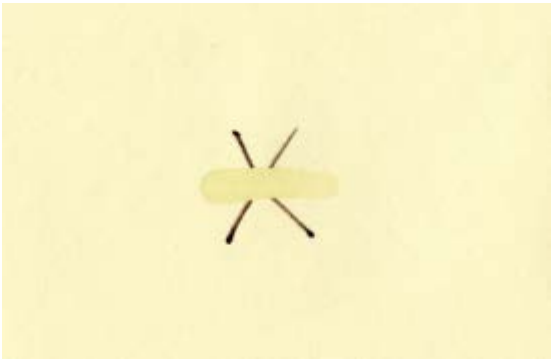

Figure 10 – *Sample of Antique Laid Paper in the lightest category of nail polish coating.*

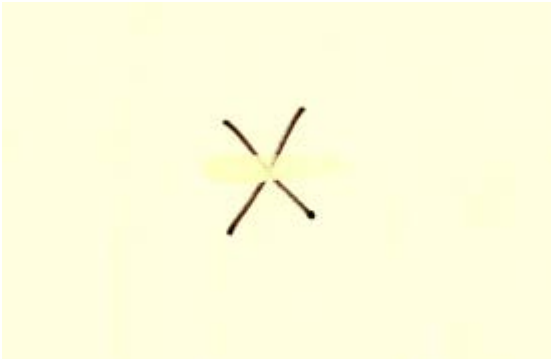

Figure 11 – *Sample of Exceptional Paper in the lightest category of nail polish coating.*

6.1.3 Discussion

Application of the nail polish to the surface of the paper was a relatively easy process and on some papers required only one coating to thwart the Pen and render its counterfeit detection ability useless. Additionally, even the five and ten layers of nail polish did not cause the paper to feel much thicker or more unusual than might be expected of genuine currency. Varying paper consistencies between those produced with no cotton or those that contained 25% or 100% cotton appeared to produce slight differences in the results of the light and heavy categories. It appeared as though papers consisting of 25% cotton required fewer layers of nail polish followed closely by those consisting of recycled pulp, and lastly papers made from 100% cotton. However, with the application of sufficient layers of nail polish, overall differences in the paper consistency made no difference in the Pen's reaction as the Pen was unable to identify any of the papers as counterfeit. Reasons for these differences might be accounted for due to the fact that papers made from cotton are more absorbent than papers made from

linen and recycled pulp. Therefore, more of a coating would be necessary to provide a full barrier between the surface of cotton papers and the Pen.

6.2 Pump Hairspray

6.2.1 Experimental Design

All ten non-currency papers were tested in the light, heavy, and saturated categories. In each category, samples were sprayed toward the center of the paper from a measured 12 inch height directly above. Under the light category, 1 spray of hairspray was applied. In the heavy category 3 sprays of hairspray were applied. In the saturated category 15 sprays were applied. One hour dry time was allotted in each category before testing.

6.2.2 Results

In the light and heavy category the application of pump hairspray to different consistencies of paper appeared to have a negligible reaction in its ability to block the Counterfeit Detection Pen. The only marked difference in the reaction to the Pen once the paper was coated in hairspray was a slight color decrease from the normal hue intensity reaction produced on the standard to a slightly lesser hue between each of the light, heavy, and saturated categories. This change in hue is reflected in the lowering of value and chroma on the Munsell Color Chart (Table 11). This lessening in the color intensity was only noticeable when the standard was compared directly against paper coated with heavy or saturated amounts of hairspray. Further, hues remained consistent

throughout six of the ten tested papers within each category demonstrating that a heavier concentration of hairspray does not necessarily alter the results.

Since it is known that counterfeiters have used hairspray to thwart the Pen's effectiveness (S. Kolb, personal communication, October 17, 2011), an additional portion of testing was conducted in a third category where each paper was fully saturated with the hairspray in an attempt to simulate counterfeiter's known results. This additional saturated category demonstrated that although fully saturating different papers in hairspray the Pen was still able to detect the presence of starch and produce a reaction. Although this reaction was lessened and both the value and chroma reflected larger hue changes compared to that found in the light and heavy category of testing the starch iodine reaction was still fully visible and the Pen's identification of the counterfeit paper successful. Xerox, Great White, and Boise Cascade papers reflected the largest change in hue reaction with Boise Cascade producing the closest reaction to what would be expected on a genuine standard. Differences in the color reactions between the standards and tested papers are recorded in Table 11.

Table 11 - *A false negative reaction attempted through pump hairspray.*

PAPER	STANDARD	LIGHT - 1 SPRAY	HEAVY - 3 SPRAYS	SATURATED - 15 SPRAYS
Southworth Antique Laid	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1
Southworth Fine Business	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1
Southworth Fine Linen	Value – 2.5 Chroma – 1	Value – 4 Chroma – 1	Value – 4 Chroma – 1	Value – 3 Chroma – 2
Southworth Exceptional Business	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1
Southworth Resume	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1
Eaton Gray Granite	Value – 3 Chroma – 1	Value – 4 Chroma – 1	Value – 5 Chroma – 1	Value – 5 Chroma – 1
Xerox Business	Value – 2.5 Chroma – 1	Value – 4 Chroma – 1	Value – 4 Chroma – 1	Value – 5 Chroma – 1
Great White Heavy Weight Inkjet	Value – 2.5 Chroma – 1	Value – 5 Chroma – 2	Value – 5 Chroma – 2	Value – 5 Chroma – 2
Boise Cascade	Value – 4 Chroma – 2	Value – 5 Chroma – 2	Value – 5 Chroma – 2	Value – 6 Chroma – 4
Eureka Georgia Pacific Recycled Copier	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1

Figure 12 – *Sample of Boise Cascade Paper in the saturated category of pump hairspray.*

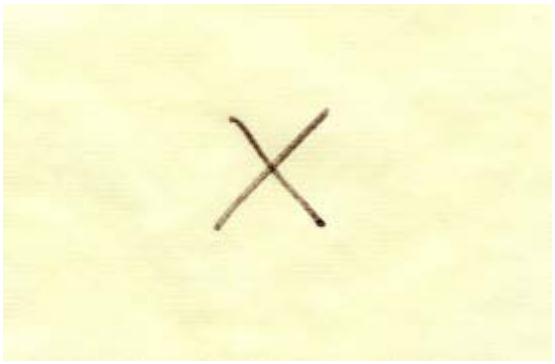

Figure 13 – *Sample of Antique Laid Paper in the saturated category of pump hairspray.*

6.2.3 Discussion

The application of both a light and heavy concentration of pump hairspray to different consistencies of paper appeared to be an insufficient manner of blocking the Counterfeit Detection Pen. Although in each category the reactions of the Pen to the different papers underwent a gradual degree of lightening this slight difference in color is practically undetectable to the naked eye. It was only when the paper was fully saturated that any significant difference was discernible on three of the papers. Therefore, the use of pump hairspray applied to different consistencies of paper used to circumvent the Pen appears to be largely insignificant and of little use to a counterfeiter. In the book based off the true story "The Art of Making Money: The Story of a Master Counterfeiter", counterfeiter Art Williams describes using hairspray on his counterfeit notes to thwart the Pen (Kerston, 2009). Although it is known that counterfeiters such as Art Williams and others like him have used the application of hairspray on their counterfeit notes it is unknown whether differences in the brand they use or other variables such the manner in

which they applied the hairspray could make any difference to the results reached in this experiment.

6.3 Oven Cleaner

6.3.1 Experimental Design

All ten non-currency papers were tested with oven cleaner in both the light and heavy categories. In the light category 3 sprays of oven cleaner were sprayed on the paper. In the heavy category 5 sprays of oven cleaner were sprayed on the paper. No additional saturated category was used as after 5 sprays the paper was fully covered and soaked making the need for additional sprays unnecessary. Each additional spray was laid immediately following the previous spray while still wet. In both categories the spray was aimed toward the center of the paper and sprayed from a measured 12 inch height directly above the paper. A three hour dry time was allotted before testing.

6.3.2 Results

Application of oven cleaner on tested papers in the light and heavy category did not appear to provide an effective block against the Counterfeit Detection Pen. However, there were discernible differences between the standard reactions produced on the normal papers when compared against those reactions produced on papers that had contact with oven cleaner. These differences were reflected in both the intensity and the hue of the color reactions. The most significant differences occurred between the standard and the papers sprayed with the heaviest concentration of oven cleaner. The papers that showed the most dramatic differences were Southworth's Fine Business, Eaton Gray, Xerox, and

Eureka papers. Paper that demonstrated the least amount of difference was Southworth's Exceptional Business paper. With the addition in concentration of oven cleaner between the standard, light, and heavy category the hue of the reaction gradually decreased in intensity (Table 12). Additionally, reactions that were produced were spotty and contained what appeared to be many small pockets of color instead of a uniform layer of color. This was due to the variable and unequal distribution of the oven cleaner as the spray was laid down in dots over the surface of the paper.

Table 12 - *A false negative attempt using oven cleaner.*

PAPER	STANDARD	LIGHT - 3 SPRAYS	HEAVY - 5 SPRAYS
Southworth Antique Laid	Value – 2.5 Chroma – 1	Value – 4 Chroma – 1	Value – 4 Chroma – 1
Southworth Fine Business	Value – 2.5 Chroma – 1	Value – 5 Chroma – 1	Value – 6 Chroma – 1
Southworth Fine Linen	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 5 Chroma – 1
Southworth Exceptional Business	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1
Southworth Resume	Value – 2.5 Chroma – 1	Value – 5 Chroma – 1	Value – 4 Chroma – 1
Eaton Gray Granite	Value – 3 Chroma – 1	Value – 3 Chroma – 1	Value – 6 Chroma – 1
Xerox Business	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 6 Chroma – 1
Great White Heavy Weight Inkjet	Value – 2.5 Chroma – 1	Value – 4 Chroma – 1	Value – 5 Chroma – 1
Boise Cascade	Value – 4 Chroma – 2	Value – 6 Chroma – 2	Value – 6 Chroma – 4
Eureka Georgia Pacific Recycled Copier	Value – 2.5 Chroma – 1	Value - 6 Chroma – 1	Value - 6 Chroma – 1

Figure 14 – *Sample of Boise Cascade Paper in the heavy category of oven cleaner.*

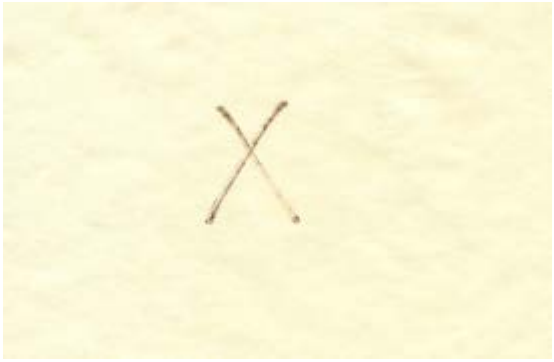

Figure 15 – *Sample of Fine Linen Paper in the heavy category of oven cleaner.*

6.3.3 Discussion

Although the application of oven cleaner on different test papers appeared to slightly alter the intensity and hue of the color reaction produced by the Counterfeit Detection Pen on the paper, overall, the Pen was able to function as intended and produced a close enough reaction to the expected standard color reaction. The results demonstrate that tested papers made primarily of wood pulp and that have no cotton seem to have the greatest difference between the standard reaction and that produced with the heavy concentration. Further, papers consisting of 100% cotton seemed to reflect the least amount of difference. As mentioned earlier, this may be due to the higher absorbency of cotton papers to those made from linen and recycled pulp. Therefore, a thicker coating would be necessary to provide a full barrier between the surface of cotton papers and the Pen. In this segment, application of oven cleaner does not produce a sufficient false negative reaction nor provide a sufficient coating in blocking the paper's starch from the iodine of the Pen.

6.4 Aerosol Hairspray

6.4.1 Experimental Design

Aerosol hairspray was applied to sample papers in both the light and heavy category. In both categories the hairspray was applied to the center of the paper from a measured 12 inch height directly above the paper. In the light category 1 spray was applied to paper. In the heavy category 3 sprays were applied to the paper. Each spray was applied immediately following the previous spray. A saturated category was not included as under the heavy category the paper was already fully coated and soaked thus making the need for another category unnecessary. A one hour dry time was allotted before testing.

6.4.2 Results

Application of aerosol hairspray to tested papers in the light and heavy category appears to alter the starch iodine reaction occurring between the Pen and the papers although it does not fully block the reaction from the Counterfeit Detection Pen. Significant differences in color reactions are seen as the hues progressively decrease from the high intensity hue of the standard, down to the lesser intensity hues of the light and heavy category. Respectively, intensity level differences were most significant between the standard and the heavy category hues. Additionally, hue changes between the different concentrations were more difficult to distinguish on papers that were white colored such as Xerox, Great White, and Eureka followed closely by papers that were ivory colored such as Southworth's Fine Linen and Exceptional Business Paper. Changes

in hues were most easily discernible on the Boise Cascade and Eaton Gray Granite Paper and also reflected the greatest change in intensity (Table 13).

Table 13 - *A false negative reaction attempted through aerosol hairspray.*

PAPER	STANDARD	LIGHT - 1 SECOND	HEAVY - 3 SECONDS
Southworth Antique Laid	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 5 Chroma – 1
Southworth Fine Business	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 2
Southworth Fine Linen	Value – 2.5 Chroma – 1	Value – 4 Chroma – 1	Value – 4 Chroma – 4
Southworth Exceptional Business	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 4 Chroma – 1
Southworth Resume	Value – 2.5 Chroma – 1	Value – 2.5 Chroma – 1	Value – 3 Chroma – 2
Eaton Gray Granite	Value – 3 Chroma – 1	Value – 4 Chroma – 1	Value – 5 Chroma – 6
Xerox Business	Value – 2.5 Chroma – 1	Value – 4 Chroma – 1	Value – 4 Chroma – 1
Great White Heavy Weight Inkjet	Value – 2.5 Chroma – 1	Value – 3 Chroma – 1	Value – 3 Chroma – 1
Boise Cascade	Value – 4 Chroma – 2	Value – 6 Chroma – 4	Value – 7 Chroma – 4
Eureka Georgia Pacific Recycled Copier	Value – 2.5 Chroma – 1	Value – 3 Chroma – 2	Value – 3 Chroma – 1

Figure 16 – *Sample of Antique Laid Paper in the lightest category of aerosol hairspray.*

Figure 17 – *Sample of Exceptional Paper in the lightest category of aerosol hairspray.*

6.4.3 Discussion

The application of aerosol hairspray in different amounts and on different paper consistencies demonstrated noticeable differences in the color reactions. Changes in the value and chroma of the hues when varying the concentration of aerosol hairspray were significant enough to be observed and recorded however did little to alter the Pen's intended reaction beyond allowing for the changes in hue's intensity to lessen.

Despite complete saturation of the paper the aerosol hairspray method did not provide a sufficient barrier against the Counterfeit Detection Pen and could not prevent the starch iodine reaction from occurring. Therefore, although the differences in color reactions are clearly visible when comparing the standard to any paper fully saturated in aerosol hairspray, it is uncertain whether that difference will be strong enough to sway a merchant from receiving the paper as genuine currency after being tested with the Pen. Only with the Boise Cascade paper would the alteration in hue be significant enough to possibly be mistaken as genuine currency with a heavy coating of aerosol hairspray.

6.5 Deodorant

6.5.1 Experimental Design

Application of deodorant to tested papers only occurred in the light category as only one coating of deodorant was needed to block the Counterfeit Detection Pen. The light category was conducted first and when only one coating proved to provide a sufficient barrier on all papers no additional categories were added. In this sequence, a new deodorant stick was purchased to avoid previous contamination. The deodorant was applied directly from the stick to the center of the paper. Twenty hours of dry time were allotted before testing.

6.5.2 Results

Application of just one layer of deodorant represented in the light category provided a sufficient layer of coating preventing the iodine from the Counterfeit Detection Pen from reaching the starch in the tested papers. Absolutely no visible reaction was produced through the deodorant when the Pen came in to contact with any of the papers of different consistencies. Additionally, as the Pen passed across the coated portions of deodorant, pieces of the deodorant flaked off and transferred on to the tip of the Pen. Once the contaminated Pen was then applied to a separate area of the same paper that had not been coated in deodorant, the transferred deodorant from the tip of the Pen still had a difficult time detecting the starch in the paper and continued to block the Pen from working properly (Table 14).

Table 14 - *A false negative reaction attempted through deodorant.*

PAPER	COLOR REACTION: LIGHT - 1 COATING
Southworth Antique Laid	-
Southworth Fine Business	-
Southworth Fine Linen White	-
Southworth Exceptional Business Ivory	-
Southworth Resume Paper	-
Eaton Gray Granite Paper	-
Xerox Business Paper	-
Great White Heavy Weight Inkjet	-
Boise Cascade Laser Paper	-
Eureka Georgia-Pacific	-

Figure 18 – *Sample of Exceptional Paper in the lightest category of deodorant.*

Figure 19 – *Sample of Antique Laid Paper in the lightest category of deodorant.*

6.5.3 Discussion

The application of deodorant to sample papers proves to be an effective block against the Counterfeit Detection Pen and varying paper consistencies appear to have no visible effect on the reaction of the Pen. Although the U.S. Department of Health and Human Services Household Products Database lists many deodorants as containing some starch in them, it would seem as though either the concentration of starch in the deodorant was not strong enough to affect the results of the Pen by producing a starch-iodine reaction or the chemical make-up of the starch was not Amylase which is the form of starch needed to react with iodine (2011). Additionally, "extensively modified starches may not give the color characteristic for unmodified products, and the color observed usually depends on the degree of modification. Modification can be carried so far that no color is produced with iodine" (Brunelle & Reed, 1984, pg. 237). Interestingly, instead of creating a more intense reaction with the addition of the deodorant, the deodorant actually provided an effective block and not only protected that specific coated area of the paper but also provided a barrier against the Pen in other non-coated areas of the paper as well. Although the surface on the paper felt slightly powdery to touch, the invisible color of the deodorant on the paper along with the absence of the starch-iodine color reaction from the Pen would be enough to fool anyone handling currency. Currency is often so worn, dirty, stained, and mutilated that a slight powdery feeling on a note might not raise enough suspicion. This sequence demonstrates that the Counterfeit Detection Pen alone can be faulty or contaminated and can produce altered or variable results on not only the paper that is being tested but also on other samples of

paper that are subsequently tested. That is a lot of faith to place in something that can so easily be altered.

6.6 Laundry Stain Remover

6.6.1 Experimental Design

Application of laundry stain remover to sample papers only occurred in the light category as only three coatings were needed to block the Counterfeit Detection Pen. Experimentation began with three coatings and when it was found to be completely sufficient the additional categories of heavy and saturated applications became unnecessary. The laundry stain remover was applied using a "stain lifting brush" directly to the center of the paper. Each coating was applied immediately following the previous coating and they were placed directly on top of each other. Twenty one hours of dry time were allotted before testing.

6.6.2 Results

Application of just three coatings of laundry stain remover in the light category provided a sufficient barrier against the Counterfeit Detection Pen. Not only was the starch-iodine reaction prevented, but a false negative reaction was produced with a yellow hue. The reactions on Southworth's Antique Laid paper, the Eaton Gray paper, and the Boise Cascade paper all matched the hue that standard genuine currency produces. All other papers produced a nearly similar yellow hue which fall only one step away from the genuine standard hue (Table 15).

Table 15 - *A false negative reaction attempted through laundry stain remover*.

PAPER	STANDARD	LIGHT – 3 COATINGS
Southworth Antique Laid	Value – 2.5 Chroma – 1	Value – 9 Chroma – 8
Southworth Fine Business	Value – 2.5 Chroma – 1	Value – 9 Chroma – 6
Southworth Fine Linen	Value – 2.5 Chroma – 1	Value – 9 Chroma – 6
Southworth Exceptional Business	Value – 2.5 Chroma – 1	Value – 9 Chroma – 6
Southworth Resume	Value – 2.5 Chroma – 1	Value – 9 Chroma – 6
Eaton Gray Granite	Value – 3 Chroma – 1	Value – 9 Chroma – 8
Xerox Business	Value – 2.5 Chroma – 1	Value – 9 Chroma – 6
Great White Heavy Weight Inkjet	Value – 2.5 Chroma – 1	Value – 9 Chroma – 6
Boise Cascade	Value – 4 Chroma – 2	Value – 9 Chroma – 8
Eureka Georgia Pacific Recycled Copier	Value – 2.5 Chroma – 1	Value – 9 Chroma – 6

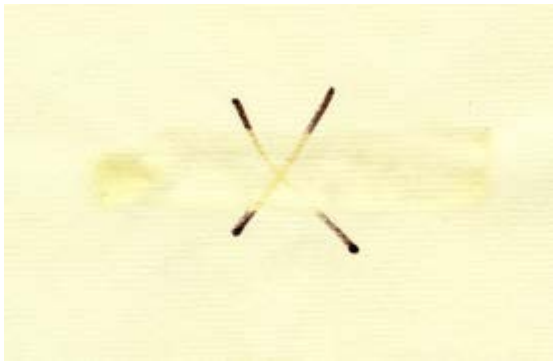

Figure 20 – *Sample of Antique Laid Paper in the lightest category of laundry stain remover.*

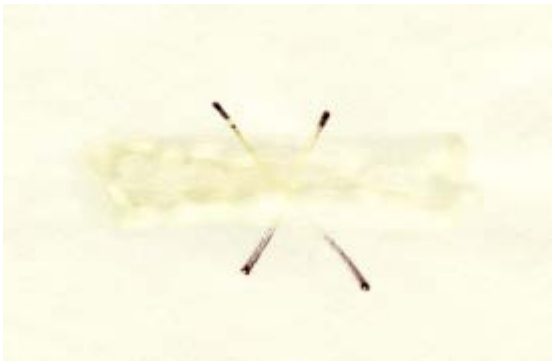

Figure 21 – *Sample of Fine Business Paper in the lightest category of laundry stain remover.*

6.6.3 Discussion

The application of laundry stain remover to paper provides an effective barrier to the Counterfeit Detection Pen. Varying the paper consistencies appear to have no significant impact on the areas coated in starch. A yellow color reaction was produced by the Pen on all papers tested and produced a hue similar to what would be expected of the reaction on genuine currency paper. Therefore, not only does laundry stain remover circumvent the Pen but it also produces a perfect false negative reaction.

CHAPTER SEVEN – OVERALL DISCUSSION

Overall, the results of the laboratory experiments were incredibly helpful in ascertaining the specific limitations of the Counterfeit Detection Pen. As expected, under normal conditions, the Pen works as indicated by the inventor. Both the genuine and counterfeit standards produced the expected results.

7.1 False Positives

The presence of both laundry starch and heavy amounts of French fry grease on genuine currency altered the results of the Pen and created false positive reactions. This transfer of starch to genuine currency paper causes an unfortunate limitation on the Pen as only the slightest amount of laundry starch was easily seen to alter the reaction of the Pen. Further, starch could easily and unintentionally be transferred on to genuine currency in a common setting such as leaving one's currency in clothes that are sent to a dry cleaner establishment for cleaning. Additionally, although a heavy concentration of French fry starch was needed, a false positive reaction was still created. Therefore, despite the great amount needed, the presence of French fry starch is also a limitation of the Pen.

The presence of laundry detergent on genuine currency demonstrates no false positive reaction. Perhaps, the best explanation for why it was suspected to work is that genuine currency that went through a wash and dry cycle might often come in to contact

with clothing that had been sprayed with starch. The transfer of starch from one item of clothing placed in the wash cycle to currency that has been placed in the same wash load might possibly be enough to cause a false positive reaction (Figure 22 and Figure 23).

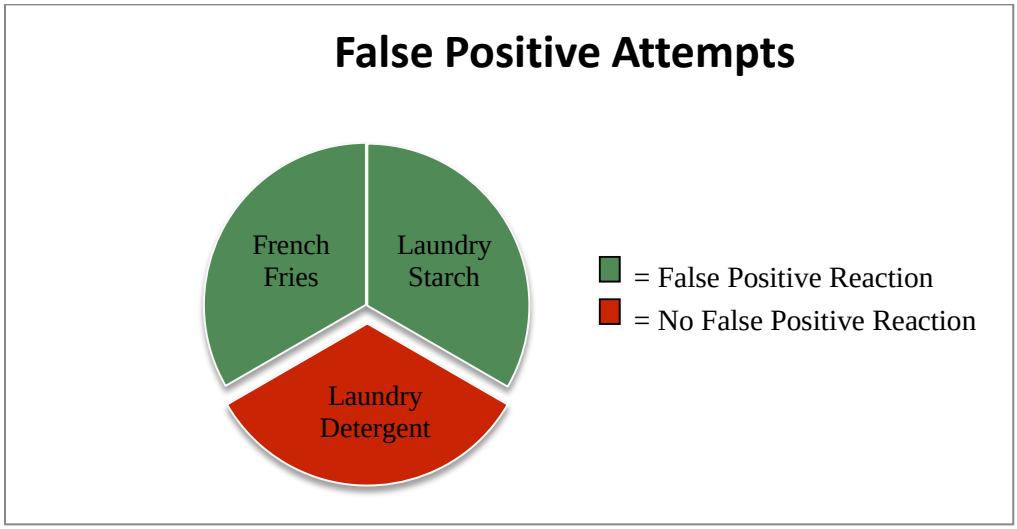

Figure 22 – *Variables and conclusion in the attempt for a false positive reaction achieved in at least one category.*

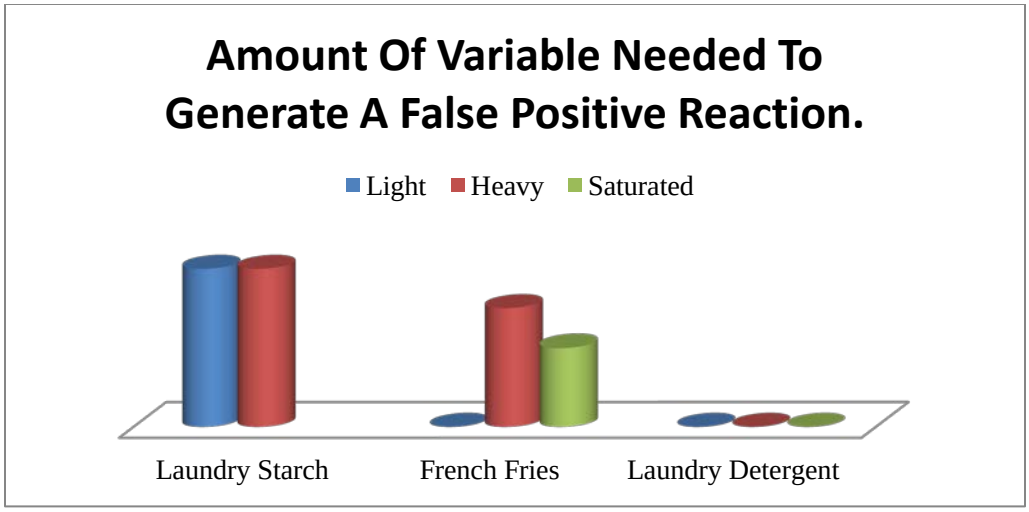

Figure 23 – *Categories of variables that achieved a false positive reaction. (Columns ranked by hue intensity of value and chroma on the Munsell Color Chart. Highest columns had the darkest brown color reaction.)*

7.2 False Negatives

The presence of nail polish, deodorant, and laundry stain remover on counterfeit papers provided an effective barrier against the Counterfeit Detection Pen. This barrier was able to prevent the iodine in the Pen from reaching the starch of the paper. Thus, the starch-iodine reaction was prevented and false negative reactions occurred. The formation of false negative reactions is a great detriment to the Pen and severely limits its ability to identify counterfeit currency. Only the slightest application of nail polish, deodorant, and laundry stain remover to most of the papers was necessary to circumvent the Pen. Further, these coatings did little to alter the feeling or increase the thickness of the paper beyond what normal wear and tear currency might feel like. Additionally, any slight feeling that was altered on the paper due to the presence of these materials only added to the feeling of stiffness which almost made the paper seem more real and less

suspect. These three methods could be easily applied to counterfeit currency and should be considered as the foremost method of limiting the Pen.

The presence of oven cleaner and both pump and aerosol hairspray on paper appeared to have only minimal effects on the reaction from the Counterfeit Detection Pen. These methods were an insufficient manner in preventing the starch-iodine reaction from occurring. Differences in the reactions to these substances were only reflected in the lowering of hue intensity when compared to the standard reaction expected on each paper. Differences in paper consistencies did appear to affect the reactions between light, heavy, and saturated categories but merely reflected that a higher concentration of the substance was needed to affect the reaction in a similar way to other papers. Under all three variables tested, the Boise Cascade paper demonstrated the highest change in hue intensity. On this paper, the color reaction from the Pen appeared as a yellow hue which could pass as a false negative response. However, even though Boise Cascade exhibited the closest response to a false negative reaction, it is also the paper whose standard color classification on the Munsell Color Chart began with the lightest shade of brown reflected by a higher chroma and value than any other paper samples. Of the three variables used, the aerosol hairspray appeared to reflect the greatest change in hues on all papers. In addition to the Boise Cascade paper, the use of aerosol hairspray on Eaton Gray's Granite paper appeared to also reflect a significant enough change in hue which formed a yellow hue reaction which might also pass as a false negative reaction. However, this interpretation of the color reaction can be subjective and largely dependent upon the viewer. Although the application of hairspray and oven cleaner on currency is

known to be used by counterfeiters, the actual brand, method of application, and amount of substance needed to fully circumvent the Pen are unknown (Figure 24 and Figure 25).

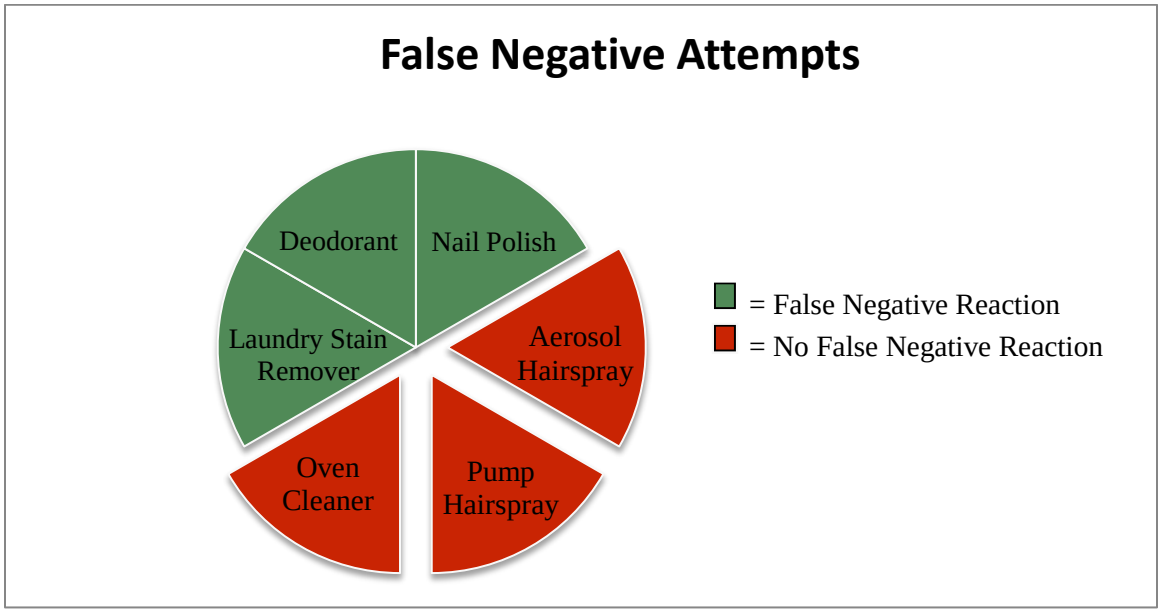

Figure 24 – *Variables and conclusion in the attempt for a false negative reaction achieved in all categories.*

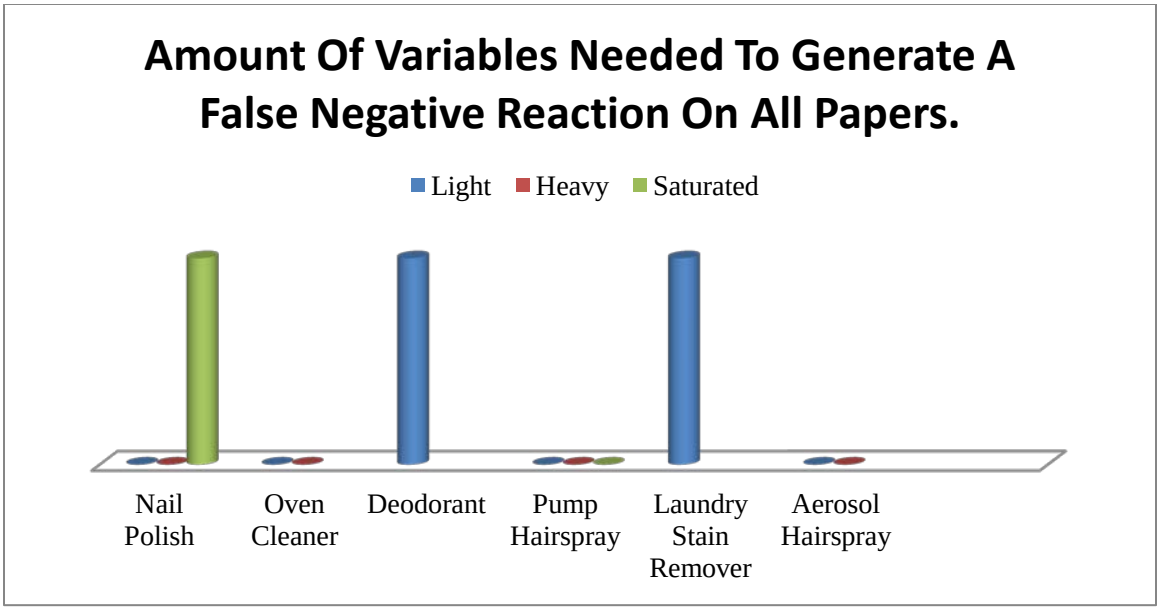

Figure 25 – *Categories of variables that achieved a false negative reaction on all papers.*

The formation of several false positive and false negative reactions were absolutely determined through the use of certain products such as laundry starch, French fry grease, nail polish, deodorant, and laundry stain cleaner while other products such as laundry detergent, hairsprays, and oven cleaner were able to be ruled out as having no significant effect at all on the reaction from the Counterfeit Detection Pen. Differences in paper consistencies were shown to be a variable in the use of certain products.

7.3 Color Interpretation

The perception of color comes from the response the eyes have to the illumination on the retina of relative amounts of red, green, and blue in the light. By mixing these colors two at a time, the secondary colors of magenta, cyan and yellow are formed (Donnelly, Marrero, Cornell, Fowler, and Allison, 2010). In the starch-iodine reaction,

the perception of the resulting hues is determined by these secondary colors. "Color-based presumptive testing relies on the ability to attribute a certain color with a positive or negative result" (Myers & Adkins, 2008, pg. 866). Therefore, colors have been classified using the Munsell Color Chart in order to diminish some of the subjectivity of the viewer in the interpretation of the color reactions. The intensity of the color reactions were based upon the amount or concentration of the product or starch found in the paper. Therefore, reactions that were dark brown with a value of 2.5 and a chroma of 1 or bright yellow with a value of 9 and a chroma of 8 were the easiest to determine. Color reactions that were less intense fell in a range between these values and chromas.

Additionally, material color differences of paper brands tested, although sometimes similar in color, no doubt made a difference in the perception of the color of the starch-iodine reaction. Although most papers tested were ivory, natural, or white in background color, different intensities of the color in the background of the paper most likely affected the color reaction by strengthening or diminishing the resulting hue of the starch-iodine reaction. This may have been demonstrated best by samples tested from Boise Cascade's paper as the results from the above experiments often showed that these samples produced reactions that were most similar or closest to a reaction formed on genuine currency. Boise Cascade's paper's standard hue was the highest value and chroma on the Munsell Color Chart to begin with so any changes or products applied to the paper that lightened the results sometimes had a more noticeable difference than those of other papers. However, although Boise Cascade was a "natural" color, Southworth's Fine Business paper was also a "natural" color and still demonstrated different results.

Differences in the manufacturer's perceptions of the colors ivory, natural, or white are most likely reflected in each particular brand of paper. Therefore, a counterfeiter has to take in to account not only the method and concentration of a product that is applied to the paper and the consistency of the paper materials itself, but also the actual color of the paper when attempting to circumvent the Pen.

CHAPTER EIGHT – IMPACT AND CONCLUSION

According to U.S. Secret Service Supervisory Counterfeit Specialist S. Fortunato, as counterfeiters continue to improve their methods in counterfeiting currency they will continue to devise new and improved ways of circumventing counterfeit currency detection devices (personal communication, October 21, 2011). These circumvention methods will continue to improve and change over time therefore it is the responsibility of the United States Secret Service and the public to understand these methods and the current detection devices being used today.

Understanding the limitations of the Counterfeit Detection Pen in the identification of genuine and counterfeit currency is vital. The results of this research are far reaching and will affect several communities; the forensic science community in the area of questioned document authentication, the law enforcement community where countless local arrests have been made based on the false information provided by the Counterfeit Detection Pen, consumer awareness for businesses who are not aware of the Pen's limitations and base their sole belief in a note's authenticity from the results of the Pen, and the United States Secret Service in currency authentication and training.

Crimes committed with counterfeit documents for financial gain cost the country billions of dollars each year (McGaw, Szymanski, & Smith, 2009). In addition to U.S. currency, social security cards, birth certificates, passports, and checks are counterfeited

for financial gain. Specific and detailed insight in the paper making process and an understanding of the materials that are used to create papers of different consistencies is incredibly significant in all types of paper document examinations. Additionally, in the field of questioned document authentication, this research will provide useful insight in to one of the more widely used methods of counterfeit detection by the public and the limitations behind the Counterfeit Detection Pen. Further, knowledge of the methods that currency counterfeiters are attempting when circumventing the Pen can provide a possible association to similar methods that are used on all paper based security documents that are counterfeited. Associations can be made between similar counterfeiting methods, products used, coatings placed on papers, and the physical and chemical properties of paper used (Sugawara, 2007). Additionally, insight in to how false positive or false negative reactions are formed on U.S. currency might help other countries around the world who face similar problems with counterfeit currency.

One of the biggest influences that this research will have within the law enforcement community is the knowledge they will gain on the limitations of the Pen. According to U.S. Secret Service Special Agent S. Kolb, previous arrests have been made by law enforcement officers where an individual has attempted to pass a genuine note to a merchant that has been perceived to be counterfeit (personal communication, October 19th, 2011). This false identification often leads to the individual's arrest. If this individual happens to be arrested on a Friday afternoon, they are often held in jail over the weekend until Monday morning when the U.S. Secret Service is notified and able to determine that the note is actually genuine. Therefore, with the knowledge of the Pen's

limitations, if this false arrest was caused by the Pen's incorrect identification, law enforcement officers can begin to look at other security features of suspected counterfeit notes instead of relying solely upon the Pen's identification. Increased knowledge and fewer false arrests will save face for not only the law enforcement agency but will also keep an innocent individual from being detained.

As the primary users of the Counterfeit Detection Pen, consumer awareness of the Pen's strengths and limitations is vastly important. Often, the consumers or merchants that are actually using the Pen are not told how the Pen works. Instead, they are merely given the Pen and told to mark the note. If the note reacts strangely to the Pen often they do not know what to do (S. Kolb, personal communication, October 17, 2011). As merchants are usually the first receivers of suspected counterfeit currency it is important that they know what the limitations are, how false positives and false negatives are created, and how to look for other security features in genuine currency beyond sole reliance on the Pen. Merchants are therefore the first line of defense in the detection of counterfeit notes. They are the ones that have the ability to catch suspected counterfeit notes that counterfeiters have altered to circumvent the Pen. Better detection would allow merchants to catch these notes sooner before the counterfeit is placed in to their deposit at a bank. Early detection can lead to investigative leads on the identification of the suspect thus increasing the chances of the suspect being caught. Further, merchants will understand that use of the Pen should not be the final authentication method in genuine currency and that all notes identified as counterfeit by the Pen should be further scrutinized to ensure that the note is truly counterfeit.

The United States Secret Service stands the largest chance of benefiting from the results of this research. According to the Assistant Special Agent in Charge of the Criminal Investigative Division Joe DeSantis, the official Secret Service answer when questioned on the Counterfeit Detection Pen is that the Pen is not endorsed (personal communication, October 20, 2011). Instead, the U.S. Secret Service recommends knowing the security features of genuine U.S. currency and when in doubt, comparing suspected counterfeit notes to genuine notes. Beyond this official answer and the initial knowledge that the Pen has limitations, neither the Secret Service agents nor its Counterfeit Currency Specialists know the specific details as to what affects the Pen's results. Currently, the Secret Service can only speculate on what causes a false positive reaction on genuine currency and what counterfeiters are doing to simulate false negative reactions thereby circumventing the Pen in counterfeit currency. However, since none of these speculations are absolute, the Secret Service is unable to provide any further information. Therefore, not only will this research provide the Secret Service with the necessary details behind the limitations of the Pen through the formation of false positives and false negatives but it will also allow them to provide an informed explanation to the public. Increased public knowledge of the limitations of the Pen would then allow for better detection of counterfeit notes. Further, increased knowledge of the Pen's limitations can be given to the inventor of the Counterfeit Detection Pen and to future inventors of similar detection devices in an effort to create an improved product that might not have these same limitations.

In addition to processing counterfeit currency, the Secret Service Counterfeit Specialists are also tasked with providing official training on counterfeit and genuine currency to include genuine security features and counterfeit detection. This training is provided to federal, state, and local law enforcement agencies, Forensic Science communities such as the American Association of Forensic Document Examiners, foreign law enforcement entities, financial institutions and merchants, and even their own Special Agents in Training. As the Pen's use is widely known, there are countless training seminars given where discussions are held on the use and possible limitations of the Pen. Forensically, the Pen is so unreliable that it would never be considered as a sound scientific technique or hold up under scrutiny in a court of law. Therefore, with knowledge gained through this research, the Secret Service can provide a concrete official explanation to these entities. While training Secret Service Special Agents, the information can even be used to provide agents with the knowledge of the materials that they need to look for when conducting searches and seizures at counterfeit currency manufacturing locations. When encountering a manufacturing site, special agents are trained to seize any printers, papers, scanners, desktops, and products that could be used in counterfeiting (S. Kolb, personal communication, October 17, 2011). The paper can be used to associate prior counterfeit notes printed back to that one source. The amount of paper can also be used to determine the amount of counterfeit that could have been printed and show intention in a court of law (S. Kolb, personal communication, October 17, 2011). Further, forensic links between counterfeit notes based off their paper, coating methods, and their reaction to the Counterfeit Detection Pen can assist Counterfeit

Specialists in linking notes received at different times and from different areas to one individual source.

Further application of this research can be used in the international forensic community as the inventor of the Counterfeit Detection Pen claims that the same Pen that works on United States currency has the ability to detect foreign counterfeit in currencies such as the Bank of England Pound, Swiss Franc, Russian Ruble, Turkish Lira, Japanese Yen, Chinese Yuan, Mexican Peso, Brazilian Real, and European Union Euro ("EuroTester Pen", 2003). However, each country has its own physical characteristics and chemical make-up of their paper currency which may react differently to the Pen than U.S. currency. Separate research in this area will be necessary to see whether the results are similar for both United States currency and currency from other countries.

The results of this research have the ability to greatly influence the field of questioned documents in the area of counterfeit currency research. The answers and applications provided through this research can be used indefinitely and will provide much needed information to a specialized field where there is little concrete information available.

8.1 Future Research

Future research in this area extends in many potential directions. Continued exploration in to the different types of products that could create false positive and false negative reactions would be largely beneficial. The addition and application of other coating products on both genuine currency and non-currency paper could be examined to determine whether other products further limit the Counterfeit Detection Pen.

Further, it would be interesting to see whether alteration from the specific brand names that were used in this project would produce different results. Multiple examinations could be done of the same product testing whether particular brands produced better results over other brands. In particular, assessment of hairspray brands as a method of generating a false negative reaction should be examined. As it is known that counterfeiters have used hairspray to circumvent the Pen, further experiments on the different brands of hairspray and methods of application could be attempted to generate false negative results.

Analysis of the affects of transfer between currency or paper that has become contaminated by products that alter the Pen's reaction, to non-contaminated currency or paper, would be beneficial toward determining the specific amounts of a product needed for the transfer to produce a false positive or false negative reaction. Scenarios of this type of examination would include whether laundry spray starch could be transferred from previously starched clothing on to genuine currency being washed in the pocket of non-starched clothing in a laundry machine and thus produce a false positive reaction. Other examination scenarios would include the transfer of deodorant or laundry stain remover from currency or paper to non-contaminated currency or paper.

Application of this research and any future research should be analyzed by inventors and companies that create security and counterfeit detection devices to allow them to create improved genuine and counterfeit currency detection techniques and instrumentation. With the limitations of the Counterfeit Detection Pen know,

improvements in the Pen could be made which would act as an enhanced detection device eliminating the potential for the generation of false positive and false negative reactions.

At a minimum, limiting or controlling access to who can acquire the Pen may be beneficial so that a vast majority of counterfeiters are unable to test the Pen against the counterfeit notes they produce. Currently, the Pens are sold from multiple stores and to anyone who wants one. Limiting the Pen's access to strictly merchants might slightly help keep the Pen out of the general public's hands. With restricted access to the Pen, the chance of counterfeiters using the Pen to experiment on devising methods of circumvention would greatly decrease.

The ultimate goal in counterfeit detection is to stay one step ahead of counterfeiters. To do this, it is the responsibility of everyone to stay abreast of current research and counterfeiting techniques and continue to evolve.

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CURRICULUM VITAE

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