

ESDA Effects in Light of Current Discussions

Gary Licht and Ercole Murano

Iowa DCI Crime Laboratory, SLAB, 920 Morgan St., Suite G, Des Moines, Iowa 50319

Unknown parameters abound in the collection, preservation and interpretation of indented writings. One very useful method for visualizing these indented writings is through the use of electrostatic detection devices (EDD). In this paper, the instrument discussed is the Electrostatic Detection Apparatus (ESDA). The purpose of this work is two-fold. First, to develop an efficient and safe way to collect and develop impression evidence with little to no loss of reasonable and resolvable detail. Second, to provide some theoretical explanations as to the “why” of the results. Research presented here shows the effects of external factors that cause varying amounts of friction with a document, and how these effects are detrimental to the ability of the ESDA to detect handwriting impression. Some information is developed about why impressions may or may not be visualized with the ESDA whether they are visible with oblique lighting or not. A current theory of what makes writing impressions that are suitable for visualization is reviewed in light of empirical data from experiments and field observations in casework. Recent discussions of the effects of environmental factors, for instance gloves, are fit into the framework of the theory.

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Introduction

Forensic document examiners (FDEs) begin the examinations of potential handwriting impressions with many unknowns. These unknowns start with the manufacturing of the papers, continue with the environment and actions occurring at the creation of the potential evidence, the collection of the evidence, the later handling of the papers, and the laboratory conditions surrounding the processing of the papers. Some information is developed and presented in this paper about why impressions may or may not be visualized with the ESDA, whether they are visible with oblique lighting or not. The testing involved friction, storage, and chemical contact.

The great unknown environment of the questioned piece of paper processed for indented writings can greatly affect the imaging results. In the end, the result is either readable or not.

When the document examiner wants to explain the results, he or she has a few items of common knowledge to work with. These known factors are: 1) the image is created by some type of paper fiber disturbances, 2) paper to paper action is the typical method of disturbance, typically caused by the act of writing or drawing, 3) inked writing impressions do not respond directly to electrostatic detection imaging, 4) humidity, 5) glove rubbing may deteriorate the image, 6) plastic as one part of the impression process interferes with creating images that are detectable by electrostatic imaging, and 7) liquid water contact with the paper, erasure rubbing, and fingerprint powder dusting adversely affects the ability to detect impressions. These items are addressed in the references listed at the end of this paper.

This research is conducted to expand the knowledge of what affects the production and detection of handwriting impressions.

Methods and Materials

All electrostatic detection visualization was conducted on an Electrostatic Detection

Apparatus (ESDA) produced by Foster and Freeman, Ltd., Evesham, U.K. This instrument was purchased in 1979. The mylar sheet and toner was supplied by Foster and Freeman, and the clear plastic adhesive overlay was purchased from Grafix Plastics. The ESDA was operated (using the cascade method) in a room with the relative humidity set to be maintained at 65 percent, with actual humidity ranging from 62 to 66 percent. The temperature varied from 72 to 80 degrees Fahrenheit. Test papers were of two types – lined notebook paper and white 20 pound copy paper. Each type of paper was placed in sets of two or twelve sheets, depending on the test conducted. Most of the test writing was done with a medium point ballpoint pen, and some test writing was done with a dry fountain pen. The wiping materials were; thin fabric white cotton gloves, nylon fabric gloves, latex examination gloves, nitrile examination gloves, a quarter-inch paint brush, 9 inch by 12 inch manila envelopes, "Kaydry" EX-L paper wipers by the Kimberly Clark Corporation, polypropylene sheet-protectors, copy paper, notebook paper, "Kimwipe" delicate wiper, paper towel, a rubber eraser, and a dry finger.

Each test conducted was relatively simple in design. Therefore, many different tests were able to be completed. This allowed for many variables to be separately studied. Each variable is described in separate short paragraphs. To both create impressions and to study the variables of handwriting pressure, handwriting was done by two writers with pressures judged personally as heavy, medium, and light. No exact equivalent masses can be assigned to these pressures. The heavy pressure left detectable impressions on up to five underlying sheets.

To study the effect of sliding a piece of paper with writing impressions into and out of a manila envelope, test sheets two and four from one packet were placed in 9-inch by 12-inch manila envelopes. They were withdrawn from one to sixteen times, and processed on the ESDA. Then, to test the effect of increased friction, two flexible magnetic strips (measuring 1 inch by 18 inches by 1/16 inch) were affixed across the ends of the envelope near the open ends. Sheet two and sheet four were drawn out with the magnetic force of the two strips causing the envelope to paper friction as the test sheets were forcefully pulled out of the envelopes. The test sheets were pulled out from one to four times, processed on the ESDA, and then sheet two was pulled out of the envelope 25 times and processed.

A group of three tests evaluated the effect of storing a document in a clear plastic sheet protector. In the first test, a test sheet was stored in a clear plastic polypropylene sheet protector for seven days, then carefully removed and processed, stored until day twenty-four, and carefully removed and reprocessed. Then the sheet was placed in a polypropylene sheet protector and withdrawn one to four times, with no additional pressure but with the friction of the weight of the plastic. Another set of test sheets were placed in clear plastic sheet protectors and withdrawn one to four times with additional hand pressure on the sheet protectors.

A critical set of tests was conducted to test the effect of rubbing a cotton glove across the test sheets. The test sheet was rubbed in the direction of the writing with hand pressure administered one, two, or three times. No attempt was made to measure the mass of the hand, the downward force, or any other vector quantities of the rubbing process. In one set of tests, the test sheet was removed from the test pack of papers before rubbing. In a second test, the test sheet was rubbed while still in contact with the underlying sheets of the test pack. The rubbing was as if to simulate flattening out a folded piece of paper or brushing off debris.

Extensions of the previous test were conducted using many different items found in the laboratory as rubbing agents to test and summarize the effects of various sources of friction on paper that is later processed with the ESDA. These tests were conducted to simulate in a controlled method the friction that may be created when collecting questioned documents, or packaging, unpackaging, and processing them in an investigative process. The various friction materials were: cotton gloves, latex gloves, nylon gloves, nitrile gloves, a natural bristle brush, notebook paper, white copy paper, colored copy paper, manila paper, dry finger, Kimwipe delicate wiper, antistatic paper, paper towel, polypropylene sheet protector, and rubber eraser. Each of these items was rubbed across test impressions one, two, three, and sometimes four times.

To test the effect of using a rubber roller to flatten a piece of paper, an ink roller was used to press heavily and roll multiple times across the test sheet.

Some preliminary work was done using additional substrates as writing surfaces. The purpose was to investigate the friction effects of

writing surfaces. The backs of questioned documents can yield critical evidence when processed for handwriting impressions. Since writing surfaces vary, these tests were performed to answer questions about effects seen in casework. Two test sheets were placed on numerous surfaces and written on. The second sheet was processed front and back. The test surfaces were: plastic, man-made laminate table top, cardboard, heavy paper, hardboard (composite material), unfinished wood, varnished wood, latex painted wall, nitrile glove, latex glove, cotton glove, and nylon glove.

Another area of testing studied the effects of inks and common laboratory solvents on the handwriting impressions. The following liquids were applied in small drops to the test sheets: 70 percent isopropyl alcohol, water, methanol, petroleum ether, acetone, Shandon Xylene Substitute, ballpoint pen ink, and Quink fountain pen ink. In one test, the drops were applied only to one side of the test zones. In a second test, the drops were applied to both sides of the paper in the test zones.

Results were recorded in one of four categories: 1) unaffected, 2) affected, readable, 3) affected, very faint, and 4) affected, none. Category 4 refers to there being no partially readable original image, although there may be fiber disturbances imaged. Categories 1 and 2 are readable, and categories 3 and 4 are unreadable. Categories 2, 3, and 4 were all considered to have some detrimental effect on the ESDA detected images. The use of these categories avoids using any sort of contrast scale or numerical scale.

The research reported here is constrained to a limited number of paper types and conceivable test conditions. Further, only the ESDA results from the second and fourth pages of the test stacks were recorded here. Page one is the sheet with the original writing. The second sheets retained visual impressions of the test writing, and the fourth sheets retained very little visual impressions of the test writing. Also, the size of the writing of the two writers involved was usually limited to the space allowed in single lines of notepad paper, that being about 11/32s of an inch, or about 8.5 millimeters. Larger writing

Test No. 15
Page No. 2

	No. of wiper	Writing Pressure	ESDA result before test	Readable		Unreadable	
				Unaffected	Affected but readable	Very Light	Nothing
WIPERS	1	Heavy	R			X	
		Medium	R				X
		Light	R				X
	2	Heavy	R				X
		Medium	R				X
		Light	R				X
	3	Heavy	R				X
		Medium	R				X
		Light	R				X
Same paper (Note book)	1	Heavy	R		X		
		Medium	R		X		
		Light	R		X		
	2	Heavy	R		X		
		Medium	R		X		
		Light	R		X		
	3	Heavy	R		X		
		Medium	R			X	
		Light	R			X	
Skin (no gloves)	1	Heavy	R		X		
		Medium	R		X		
		Light	R		X		
	2	Heavy	R		X		
		Medium	R		X		
		Light	R		X		
	3	Heavy	R		X		
		Medium	R		X		
		Light	R		X		
Paint Brush	1	Heavy	R		X		
		Medium	R		X		
		Light	R		X		
	2	Heavy	R		X		
		Medium	R		X		
		Light	R		X		
	3	Heavy	R		X		
		Medium	R			X	
		Light	R			X	

Test No. 15
Page No. 4

	No. of wiper	Writing Pressure	ESDA result before test	Readable		Unreadable	
				Unaffected	Affected but readable	Very Light	Nothing
WIPERS	1	Heavy	R				X
		Medium	BR				X
		Light	U				X
	2	Heavy	R				X
		Medium	BR				X
		Light	U				X
	3	Heavy	R				X
		Medium	BR				X
		Light	U				X
Same paper (Note book)	1	Heavy	R		X		
		Medium	BR			X	
		Light	U				X
	2	Heavy	R		X		
		Medium	BR			X	
		Light	U				X
	3	Heavy	R		X		
		Medium	BR				X
		Light	U				X
Skin (no gloves)	1	Heavy	R		X		
		Medium	BR			X	
		Light	U				X
	2	Heavy	R		X		
		Medium	BR			X	
		Light	U				X
	3	Heavy	R		X		
		Medium	BR			X	
		Light	U				X
Paint Brush	1	Heavy	R			X	
		Medium	BR			X	
		Light	U				X
	2	Heavy	R			X	
		Medium	BR			X	
		Light	U				X
	3	Heavy	R			X	
		Medium	BR				X
		Light	U				X

Figure 1. Example of two data pages showing the results from the testing of sheets two and four for one group of tests. R = readable, BR = barely readable, and U = unreadable.

could affect the results descriptions of readable versus unreadable. Also, each type of test could conceivably vary with different combinations of paper types and depths of impressions.

Results

A total of 625 different tests are reported here. This number considers combinations of the many

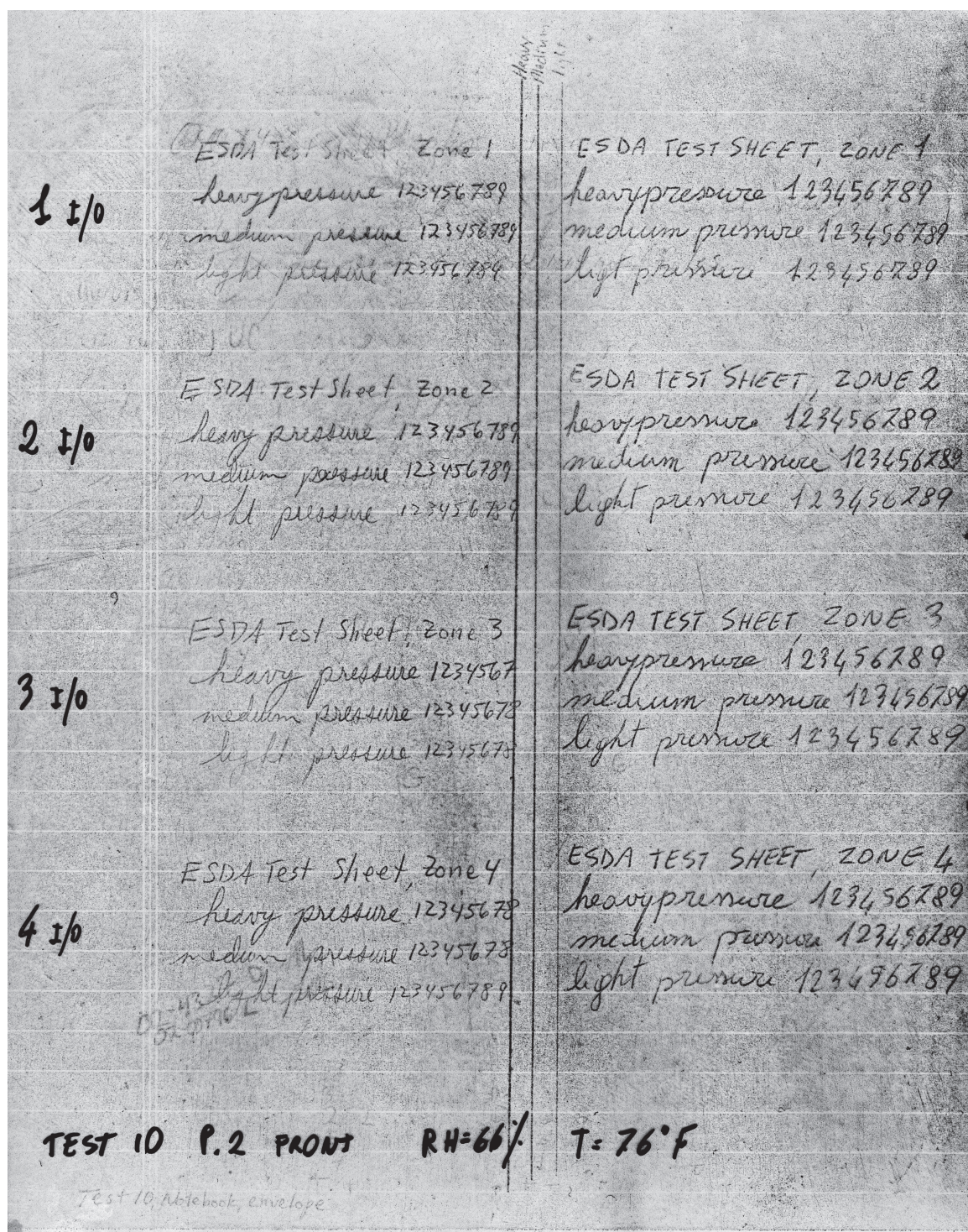


Figure 2: This ESDA lift shows the effect of removing a sheet with test impressions from a manila envelope one to four times with additional pressure from magnetic strips. There is writing from two writers in four test zones. Each test zone was treated differently. "P.2" refers to the sheet under the written page.

variables, such as the heavy, medium, and light pressure writing of two writers, control tests, multiple runs for reproducibility, and summary tests. This is still a limited number of potential variables. The results are presented as summaries in the subsections.

Paper to Paper Friction

When additional friction was created between a test sheet and another paper source, some detrimental effect was noticed, particularly with impressions created by medium to light pressure writing. When a manila envelope was used as the other paper source, and the additional pressure was created with the magnetic strips, there was not as much adverse effect as might be expected. Usually the test impressions were still readable on the ESDA lifts. The main detrimental effect was the addition of striations. This type of testing applies friction to both sides of a test sheet. This effect varied with the type of paper used, and using hand pressure on the envelope with a thinner type of test paper resulted in the loss of the light to moderate depth impression images. When notebook paper bearing test impressions was removed from a manila envelope one to four times without additional friction, no deterioration of the ESDA images resulted. Figure 2 shows the ESDA lift of page two of the test result from removal from the manila envelope, and also shows the general test routine of having two writers varying their writing pressure in each of four test zones. The manila envelope with additional friction test results stood out in contrast to the effect produced by friction from hand rubbing other paper sources across the test sheets. The copy paper and the "same" paper when rubbed across the test impressions produced deterioration of the resultant ESDA lifts from the faces of the test sheets. Figure 3 is a composite test, showing the general results of many other tests. Heavy impressions survived very well, moderate to light impressions did not.

When a manila envelope was used as a storage container for seven days, with no additional pressure, no deterioration of the image was observed. In the tests involving paper to paper rubbing friction on only the face of the document, the ESDA image was still detectable on the back of the document. These were tests with underlying leaves of paper.

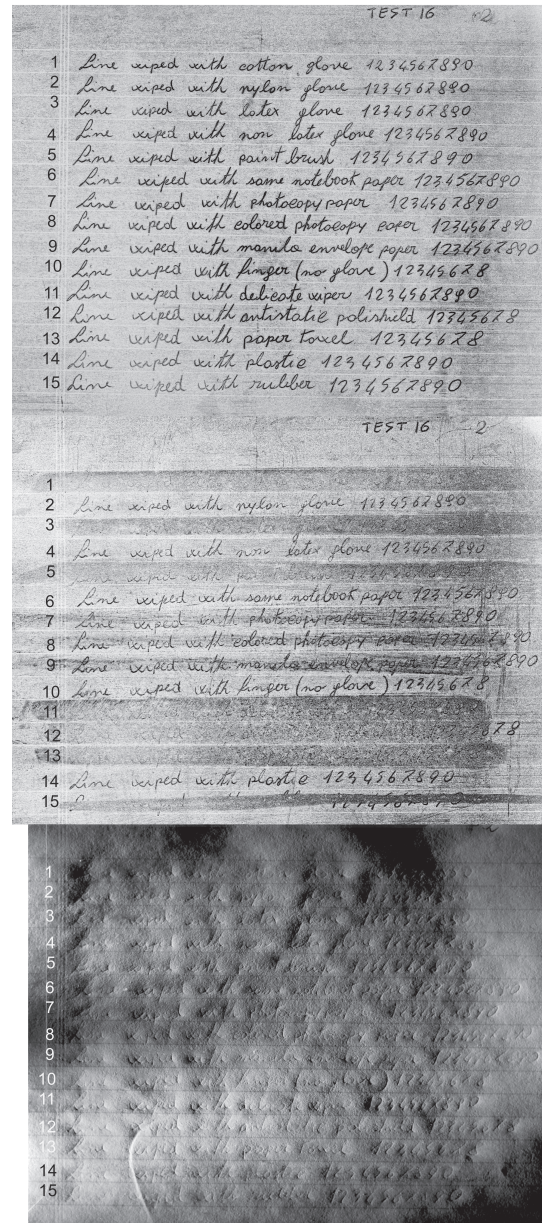


Figure 3. A summary test showing general results of multiple test types. This is page two, before rubbing test (top), after (middle), and the oblique light image of the deep impressions (bottom). On page four the effects are greater, with areas affected by paper rubbing becoming unreadable. The lines read respectively: "Line wiped with..." 1) cotton glove, 2) nylon glove, 3) latex glove, 4) non-latex glove, 5) paint brush, 6) notebook paper, 7) photocopy paper, 8) colored photocopy paper, 9) manila envelope paper, 10) finger, 11) delicate wiper, 12) antistatic polishshield, 13) paper towel, 14) plastic, and 15) rubber.

Plastic to Paper Friction

No deterioration of the ESDA lifts occurred when a plastic sheet protector was the storage device, whether or not additional friction was applied.

Additional Friction Tests

When a dry fountain pen was used to create impressions on a test sheet that was placed on a man-made polymer desktop, an ESDA-detectable impression was created

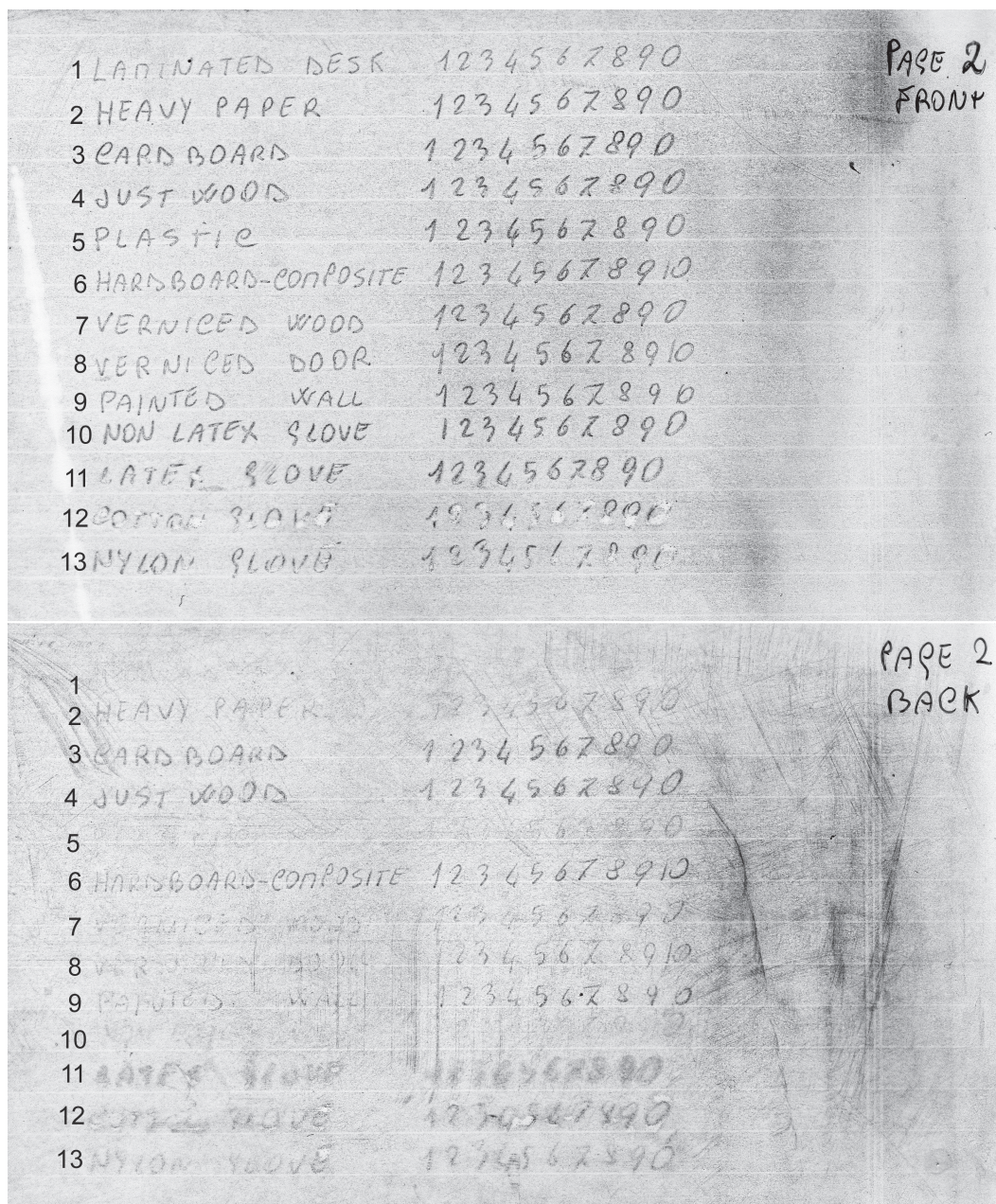


Figure 4: Face and back ESDA lifts of page two. This test was a two-sheet packet that was placed on different writing surfaces. Those surfaces that provide stable contact and some amount of friction allow ESDA detectable images to be formed. The lines read: 1) laminated desk, 2) heavy paper, 3) cardboard, 4) just wood, 5) plastic, 6) hardboard-composite, 7) varnished wood, 8) varnished door, 9) painted wall, 10) nonlatex glove, 11) latex glove, 12) cotton glove, and 13) nylon glove.

on the face of the test sheet, but not on the back.

When two test sheets were used and ballpoint-pen handwriting was done using other writing surfaces (or backing substrates), ESDA-detectable impressions were created on the back of the second sheet of paper when the backing substrate was cardboard, heavy paper, hardboard, and unfinished wood. Some limited readable impressions were created when the backing was cotton glove, latex glove, nylon

glove, latex painted wall, and varnished wood. No readable impressions were created when the backing was plastic or a nitrile glove (Figure 4).

Glove Friction

The rubbing of cotton and latex gloves across the surface of the test sheets resulted in the deterioration of the ESDA images. The ESDA image was still detected on the backs of these test pages (Figures 5a, 5b, 5c). The rubbing with

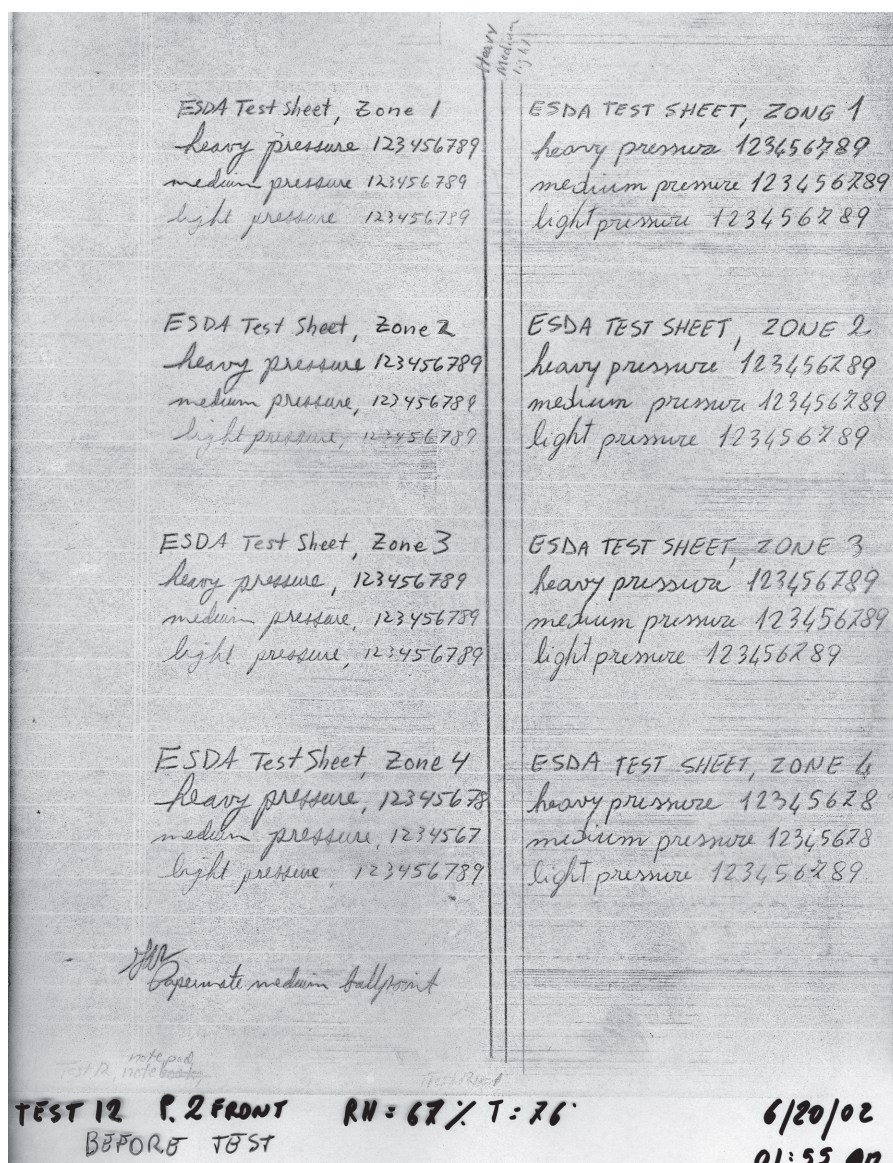


Figure 5a. Sheet two, before glove test.

nylon and nitrile gloves had limited detrimental effects, and the images were still readable. These results can best be summarized in Figure 3. No effect of the rubbing was found on the back of the test page, or on the face of the underlying page when the test sheet was rubbed with the cotton or latex glove while still in the notebook. Therefore, the glove rubbing

affected only the contacted surface. In these tests, the pieces of paper were held together so that no rubbing occurred between them.

A test sheet with areas affected by cotton and latex glove rubbing was processed three days, one month, and two months later. No improvement in the ESDA images was observed.

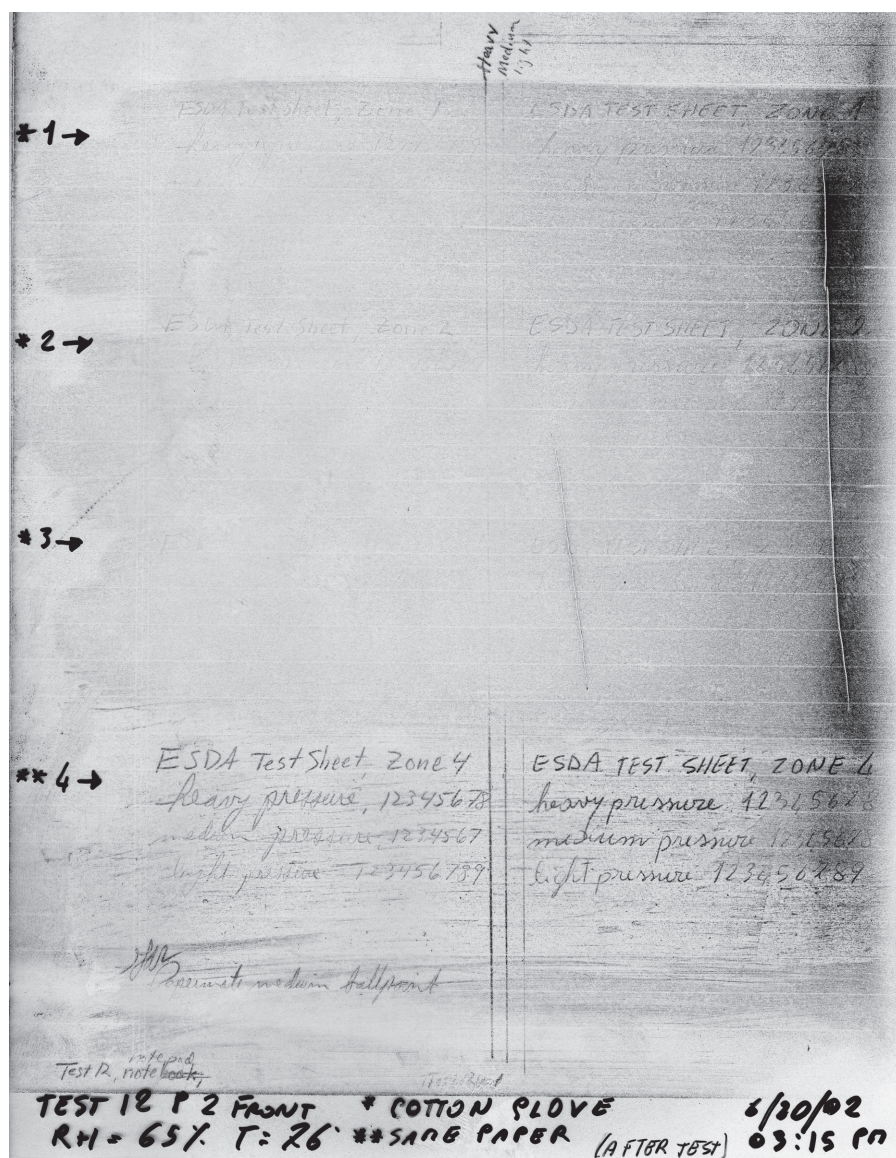


Figure 5b: ESDA lift of face of sheet two after rubbing one, two, and three times with a cotton glove, and four times with a sheet of the same paper.

Roller pressure

Heavy rolling from a hard rubber ink roller had no effect on the ESDA detected impressions.

Solvent testing

Solvent testing was divided into two categories. The first was to apply drops of solvents or inks to one side of a test impression sheet. The

second was to apply drops to both sides of a test impression sheet. The drops applied to one side only were with the test sheet lying on top of ten more leaves of paper. This allowed the solvents and inks to be wicked around the paper fibers. The drops applied to one side were detrimental to the ESDA imaging for water, isopropanol, Quink, ballpoint pen ink, methanol, petroleum ether, acetone, and Shandon Xylene Substitute. However, readable

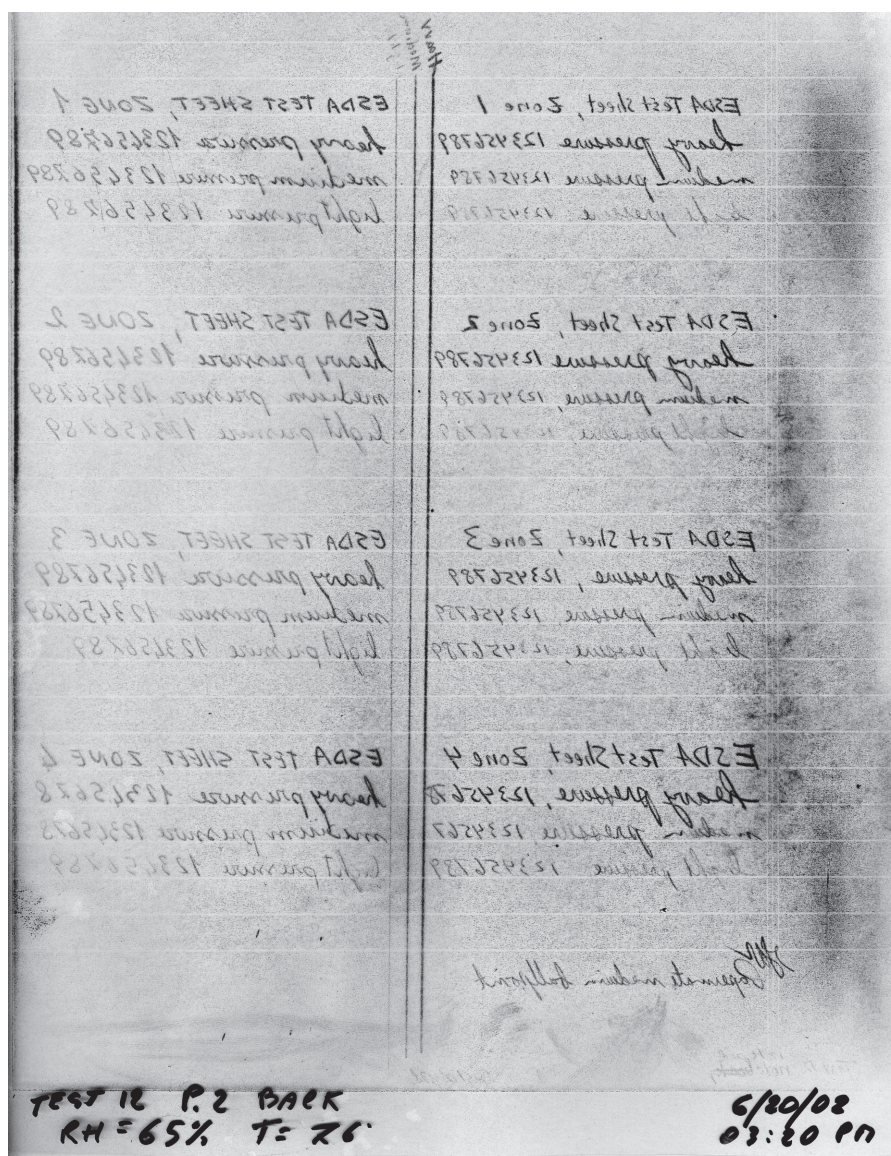


Figure 5c: Back side up ESDA lift of sheet two after testing with the cotton glove and sheet of same paper.

ESDA lifts were obtained from the face of the test sheet in the areas treated with the acetone, methanol, and Shandon Xylene Substitute. When the sheet was processed with the back up, readable results were obtained in the areas treated with each solvent or ink, although the

water, isopropanol, Quink, and ballpoint pen ink were very detrimental (Figures 6a and 6b). The drops applied to both sides had a greater detrimental effect on the electrostatic imaging of the impressions, although the visual impressions remained (Figures 7a and 7b).

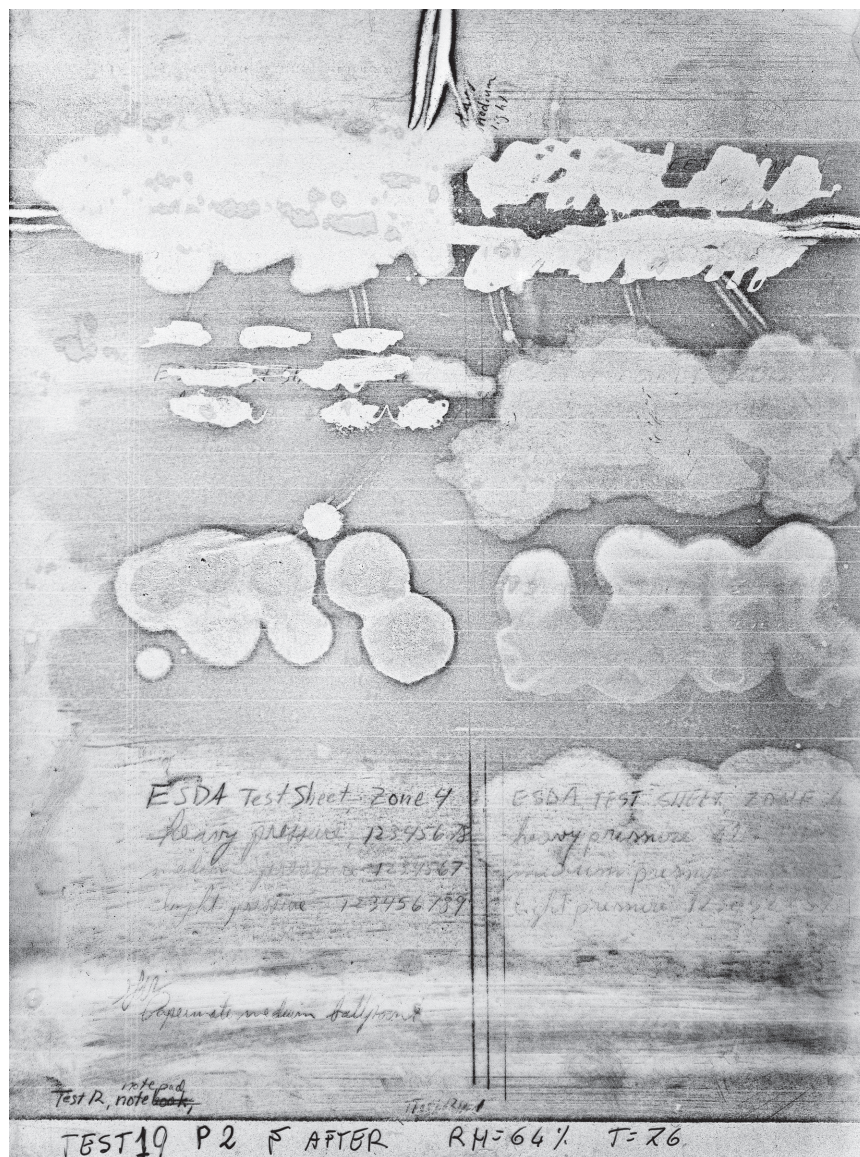


Figure 6a: ESDA lift of face of sheet two after the following chemical drops and water were applied to this side while the sheet was on the notepad: isopropanol, Quink, Ballpoint ink, SXS, methanol, Pet-ether, and acetone.

Permanency

A question had been raised in discussions about the permanency of the glove brushing effects. Some of the test sheets were processed again, approximately four months after the initial

tests. No changes in the ESDA images were found. The brush marks that were observed did not diminish with time, and the original handwriting impressions did not reappear or improve in contrast. This corroborates the permanency of ESDA impressions, with

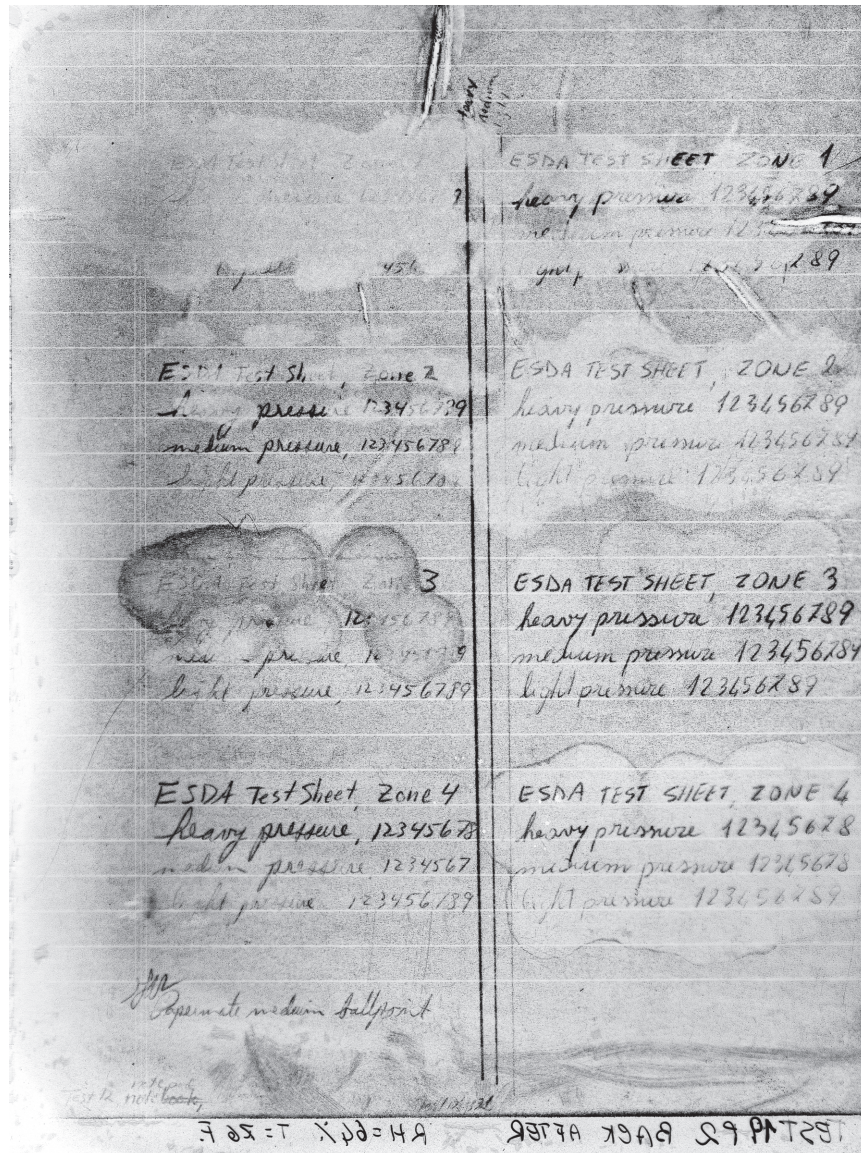


Figure 6b: ESDA lift of back of sheet two, flipped to be right-reading, after the following chemical drops and water were applied to the face of the document: isopropanol, Quink, Ballpoint ink, SXS, methanol, Pet-ether, and acetone.

casework examples of handwriting impressions being recovered from documents secured in evidence for as long as 24 years yielding readable ESDA images. It is reasonable that the detrimental effects of glove and paper friction would also be just as permanent.

Discussion

From a purely practical and empirical standpoint, documents processed in the laboratory were routinely run on the ESDA more than once, often with the back yielding good results.

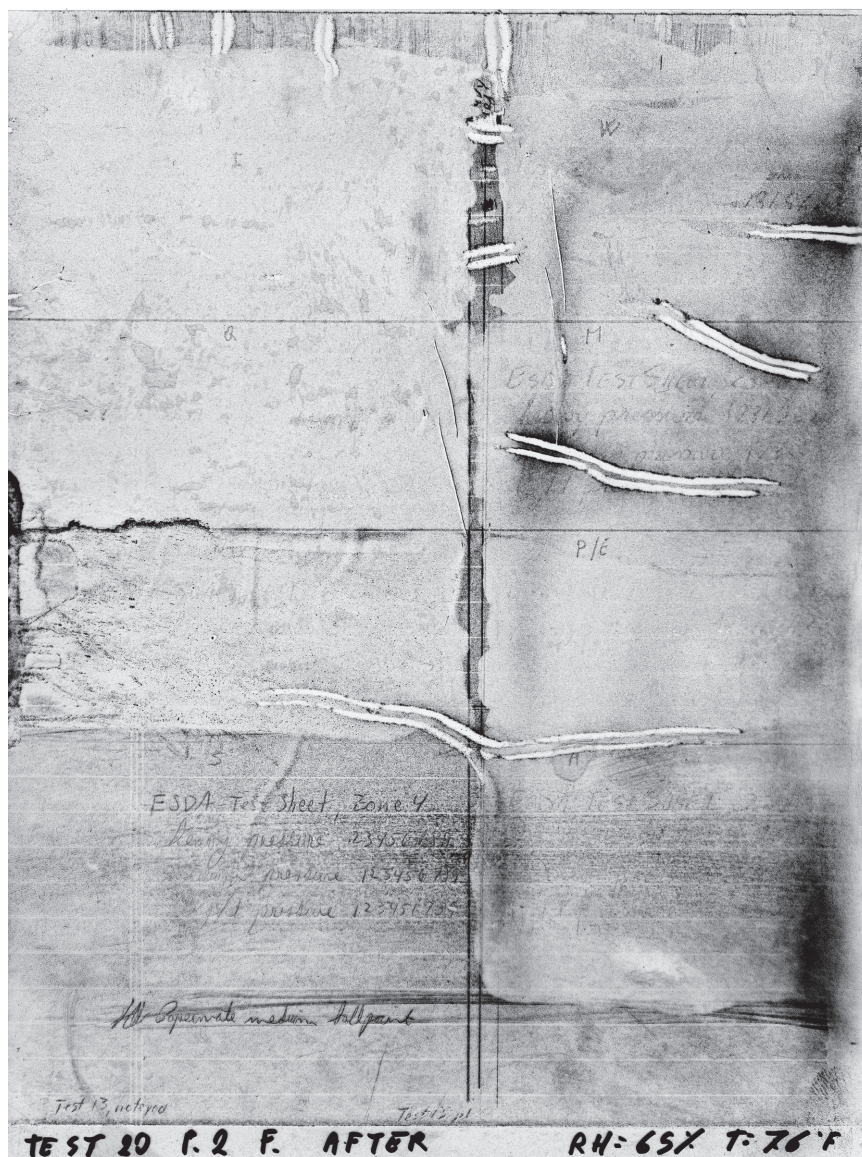


Figure 7a: ESDA lift of face of sheet two after the following chemical drops and water were applied to both sides of the sheet: isopropanol, Quink, Ballpoint ink, SXS, methanol, Pet-ether, and acetone.

The reason for this was based on observations that if an area of a document yielded poor resultant images of handwriting impressions, then a change in conditions may yield better images. Low humidity did not appear to be the only detrimental factor. Other unknown factors were probably affecting the results. A paper

by Ellen (1982) mentioned processing both the front and the back of a document, and that dusting or rubbing may be detrimental to the image. The ESDA operating instructions (Foster and Freeman, 1979) mentioned turning a questioned document over and processing the back.

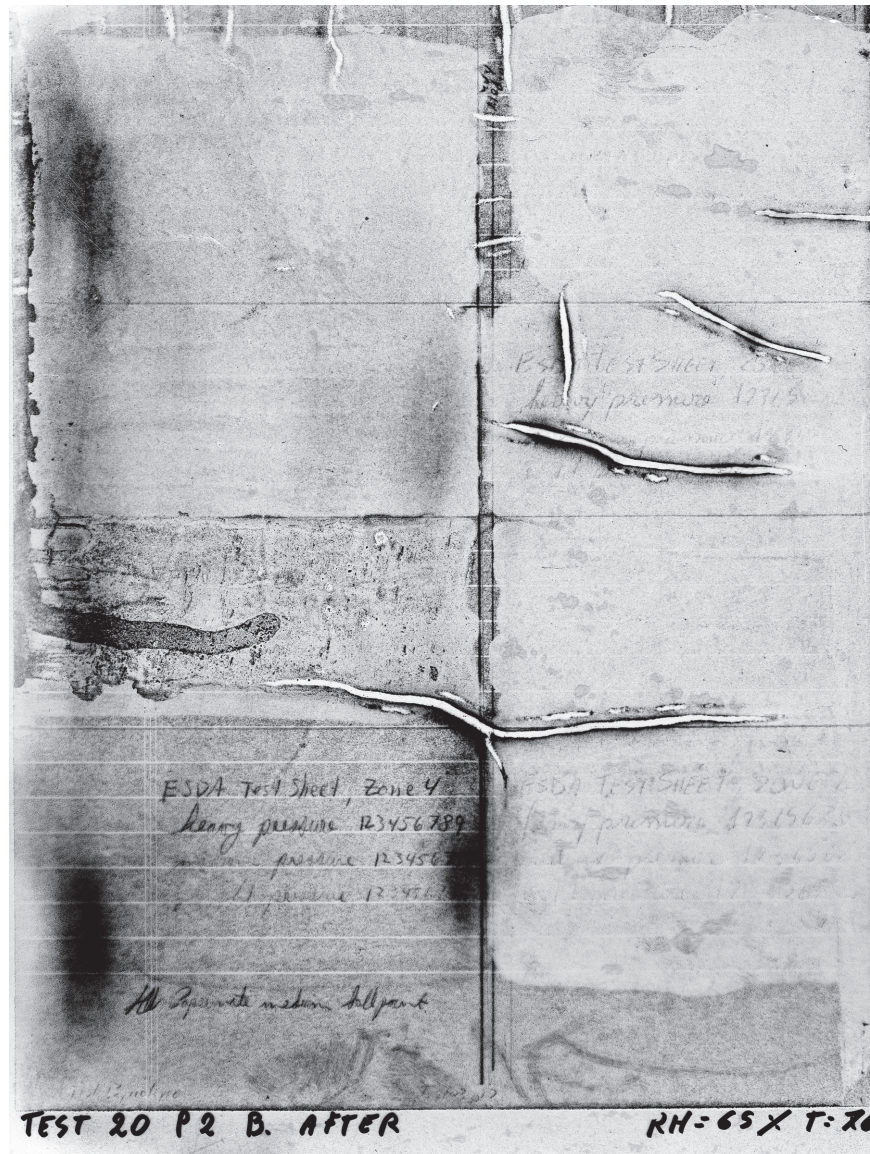


Figure 7b: ESDA lift of back of sheet two after the following chemical drops and water were applied to both sides of sheet: isopropanol, Quink, Ballpoint ink, SXS, methanol, Pet-ether, and acetone. Lift has been flipped to be right-reading.

In criminal casework, crime scene investigators and laboratory personnel typically wear gloves. Many questioned documents are recovered as folded, possibly dirty, requiring unfolding, and often, processing for latent prints. Perhaps the most significant result of this study was that the rubbing of cotton and latex gloves across the surface of the test paper was very detrimental to the recovery of handwriting impressions from that surface. Other detrimental rubbing occurs with brushes and paper, as was also mentioned years ago in an unpublished, unassigned paper titled, "Factors Affecting the Quality of Indented Writing Images Produced by ESDA." The findings in this paper were reaffirmed by Dunkerly and Riley (1997). Equally important is that the back of the paper can still yield the impression evidence, unaffected by the rubbing. The test paper still needs to be lying on another cellulosic surface, such as paper, to get the test impressions to be revealed by using the back side of the paper in the up position on the ESDA.

A second area of importance to the retrieval and storage of questioned documents is that paper-to-paper friction may be detrimental to the electrostatic detection of handwriting impressions. The common method of piling papers in a stack, then ruffling through the stack to find the desired paper, and then sliding that paper out of the stack, should be avoided. This may be a reason for the finding of ESDA "dead" zones on a surface of a piece of paper. The document examiner cannot control what investigators do, but advice can be given about the proper care and handling of important documents.

One area of interest is the question about why some casework related ESDA dead zones on documents do not show wipe marks as were observed in these tests. It is hypothesized that there are other environmental factors involved in some of those "dead zones" such as humidity, oils from hands, and other abrasions that have not yet been studied. Questions have also been raised as to whether plastic sheet protectors are detrimental to visualizing handwriting impressions. The polypropylene sheet protectors used in this study had no effect on the recovery of impressions. This is consistent with a study done by Nelson (1990).

A research paper by George H. Seward (1998) may not have been widely noticed by forensic document examiners. Seward presented the

theory that the friction which occurs between two leaves of paper is what leads to an electrostatic detected image — if not enough friction occurs, no image will be detected. The tests run by Seward to support the friction theory involved using a stainless steel rod to create indentations on a test set of leaves of paper and a mylar plastic layer. Test sheets were scanned with an electrostatic probe to measure a voltage difference known as the perturbation potential. Those indentations and accompanying embossed areas that could be imaged with an ESDA (and showed a perturbation potential) were those that had been subject to paper-to-paper interaction; i.e., the back of one page in contact with the face of the underlying page. The plastic to paper and stainless steel to paper surfaces did not yield images. It was interesting to note that the stainless steel rod to paper contact did not yield an ESDA detectable image due to the rod being polished smooth. The Seward friction theory states that the electrostatic detection of fiber disturbances is due to an electric potential which is a surface charge that results after fiber-to-fiber friction. He further states that it is due to the binding of extrinsic molecules at the perturbed sites within the paper. The model presented in the paper also explains why a higher humidity level allows the electrostatic effect to be increased. There was no identification of the molecules responsible for the surface charges that are the source of the images. Also, Seward did not provide an explanation as to why the friction can be derived from metal, cellulose, rubber, or even rough man-made polymer surfaces.

An ancillary hypothesis is presented here that there are two reasons why inked impressions typically do not yield ESDA images. The first hypothetical reason is that the writing ink acts as a lubricant, and not enough friction is created to allow the electrostatic detection of a writing disturbance. The second reason is that the ink interferes with the electrostatic process. This hypothesis needs further testing. It was found that a dry fountain pen creates impressions or disturbances that are detectable with the ESDA. It was also found that ink applied to detectable impressions negates the electrostatic effect.

The Seward paper reports on a theory and test measurements supporting a model about the Mylar to paper structure that allows images to be formed from fiber disturbances in the test paper. This may not be viewed as a total explanation for what is seen in actual casework.

In addition, the test measurements proposed by Seward may be beyond the capabilities of the typical questioned document laboratory. However, the research reported in this paper supports Seward's friction theory. Unknown factors still exist. There is room for additional research to determine why some papers do not yield good EDD images.

Conclusions

The research reported here reaffirms that friction on the surface of paper is responsible for creating fiber disturbances; e.g., handwriting impressions, that can be visualized with an EDD. Also, friction on the surface of paper can degrade or destroy the electrostatically detected handwriting impressions. Both sides of the paper need to be subjected to friction if both sides are going to yield electrostatic images. Accordingly, detrimental friction to one side of the paper is not detrimental to the other side; therefore, process both sides of the paper if additional information can be gained.

With regards to storage and processing of questioned documents, this research has shown several useful results. The polypropylene sheet protector used in this study had no effect on the electrostatically detected images. Also, storage in manila envelopes or within stacks of paper was not necessarily detrimental. However, when high amounts of friction or repeated friction are applied to the questioned paper, then detrimental effects can be expected. It was also reaffirmed that questioned documents should be studied, imaged, and analyzed before chemical processing. Not all chemical exposures are completely detrimental to electrostatic imaging; however, this should be avoided. Of key interest here is that fact that the rubbing of cotton gloves, latex gloves, brushes, and certain other types of objects can be very detrimental to the recovery of handwriting impressions. There appears to be an advantage to wearing smooth nylon or smooth nitrile gloves.

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