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Application of Experimental Variables to the Use of the Electrostatic Detection Apparatus

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ABSTRACT: The article discusses the theory of the electrostatic detection process and its application to the investigation of questioned documents. A special device for this purpose was developed and introduced to the market in 1978. An experimental design offers a system to determine the quality of the detection process as a function of different technical and environmental factors. Working hypotheses were tested under empirical conditions and gave satisfying results.

KEYWORDS: questioned documents, electrostatic detection apparatus, impressions

The investigation and analysis of indented impressions are difficult and require painstaking care on the part of a document examiner. Moreover, conventional techniques are often inefficient or not sufficiently sensitive. For example, analysis by oblique lighting is time-consuming and presents severe difficulties in achieving a total image of the specimen so that it can be photographed. Chemical methods such as iodine fumes cannot always be used, especially if the document examiner must not damage the questioned document.

Foster and Freeman Co. developed a technical device that overcomes most of the disadvantages of conventional methods in the investigation and analysis of indented impressions on paper surfaces. A thorough check of the unit's possibilities leads to the statement that this electrostatic detection apparatus (ESDA) can, under certain circumstances, substitute for any conventional technique in this field.

The electrostatic detection method was first introduced in 1968 by Morantz et al [*1-3*] (Fig. 1). Up to that time it had been evident that under certain experimental conditions any indented impressions on paper surfaces produced a so-called capacitive arrangement in which the document acts as an insulator (a dielectric) when it is placed between plates that constitute a condenser. The questioned document is placed on a sintered brass plate and is covered by a thin polymer film. The "sandwich" is charged up to a potential of several kilovolts. The differences between two spots produced by the charge on the polymer film correspond to variations in the surface texture of the specimen under test; such variations may be caused by fingerprints, indentations, or other means [*4*].

The ESDA uses this effect and a special powder to make indented impressions visible. The toner adheres to the indentations on the object (document) and therefore represents a higher potential in the sense of a higher capacitance because of the decreased distance between the "condenser plates."

The ESDA method is detailed in Refs *4* to *9*; for convenience, a brief description is given

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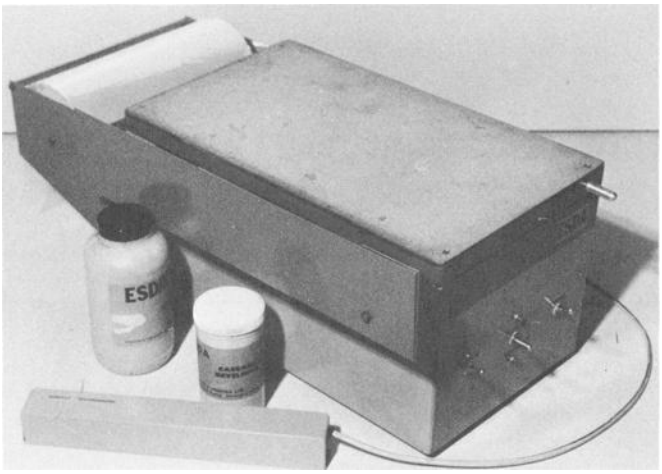

FIG. 1—*Electrostatic surface analyzer (ESDA).*

here. The document is placed on a grounded sintered brass plate and is covered by a thin taut polymer film. This "sandwich" is held in close contact by means of suction through the brass plate. At this stage, extensive care must be taken to avoid warping the paper or the film. An electrostatic charge is applied with a special Corona charging unit containing a thin wire at a potential of about 8 kV. The unit must be moved over the surface of the polymer film several times at a specified distance to make sure that the overall potential is evenly built up. The polymer film is in close contact with the document and therefore follows the irregularities of the paper surface. Variations on the surface of the document cause correspondent fluctuations of the potential on the polymer film.

The user can choose one of two ways to make the indented impressions visible:

(1) a fine spray of powder applied with an injection nozzle housed in a small Plexiglass® cabinet that has to be placed over the polymer film covering the document or

(2) a system known as the cascade developer method: the hinged brass plate should be set at an angle up to about 30°. Very small pellets (approximately 0.5 mm in diameter) coated with toner are rolled over film.

Both methods lead to covering (coating) of the polymer film with toner. The distribution of toner corresponds to the indentations on the document: the deeper the indentation, the more toner adheres to the spot. Deep and strong indentations give a more or less clear black on white reading. For several reasons, the document examiner will notice some deviations from this general rule when confronted with typewritten indentations.

The developed image can be fixed with an adhesive film. Because this process in general doesn't affect the document at all, the investigation may be repeated several times.

Application and Limits

The application of the ESDA seems especially useful for the following areas of investigation:

1. On many anonymous/pseudonymous documents the document examiner will search for indented impressions the writer of the document overlooked. For example, a certain writer used the sheet of paper under investigation as a support for a normal letter written in his regular handwriting.

2. If chemical abrasives were used on the document, it is possible to make the erasures visible.
3. Fingerprints can be detected.

The ESDA certainly has many advantages over conventional methods, as evident in the following points:

1. The method is simple and straightforward. The financial cost is low, no special knowledge is required, the process is standardized, and the procedure guarantees stability in terms of reproduction quality.
2. The investigation and analysis do not affect the document under test. Possible variations in the overall results stemming from the preparation of the document under special conditions (such as treatment in a climatic chamber under high humidity) are negligible.
3. The ESDA is more sensitive than conventional methods. Under conditions that will be detailed later in the paper, impressions were discovered on the fifth sheet of a sheaf of papers used to support the original sheet of handwriting. All the conventional techniques had failed in that instance.

Experimental Design

No detailed description of the physical process of electrostatic detection is available to the general user. Under normal circumstances it seems to be impossible to control the numerous chemical/physical conditions of the detection procedure without a detailed schedule. For this reason, the author developed an experimental design incorporating nearly all of the relevant constituents of the electrostatic detection process in order to maintain systematic control over the different variables.

The electrostatic detection process is definitely more sensitive to the differences in potential on the surface of the polymer film than to the absolute value of the electrostatic charge over a range of several kilovolts. The document examiner may be confronted with some factors that cannot be immediately identified and controlled. Some of these factors were varied systematically to isolate their effects on the results in terms of the quality of the detected image. Of course, this design had to undergo certain limitations for practical and economical reasons.

Figures 2 and 3 show the factors that were manipulated. The experiment itself was carried out on the basis of a crossover procedure between all the steps of Variables A through F. The result was a sum of 864 cells.

Critical factors besides the experimental design were held constant; for example, no variation of the time or mode of use of the Corona charging unit was investigated. The author used two or three movements over the entire film at a distance of approximately 2 cm. The charging process seems not to be critical, according to Foster and Morantz [*4*]; the absolute charge density plays a minor role in the procedure.

In later experiments it proved to be necessary to extend the charging process if the injection nozzle (powder method) was used to develop the image. The length of the charging process if not too critical if the cascade developer system is to be used.

In general, factors such as storage, humidity, exposure to light sources of any kind, support of the samples produced in the laboratory, and comparable influences were held constant.

Results were rated by scaling the quality (legibility) from 0 to 4 points. The better the legibility, the higher the rating number. Two advanced students rated the samples over the range of 864 cells (see Fig. 4). Each cell contained two samples, and the arithmetic means over the four ratings per cell were expressed in round numbers. Other factors not included the crossover schedule were differentiated as shown in Fig. 3.

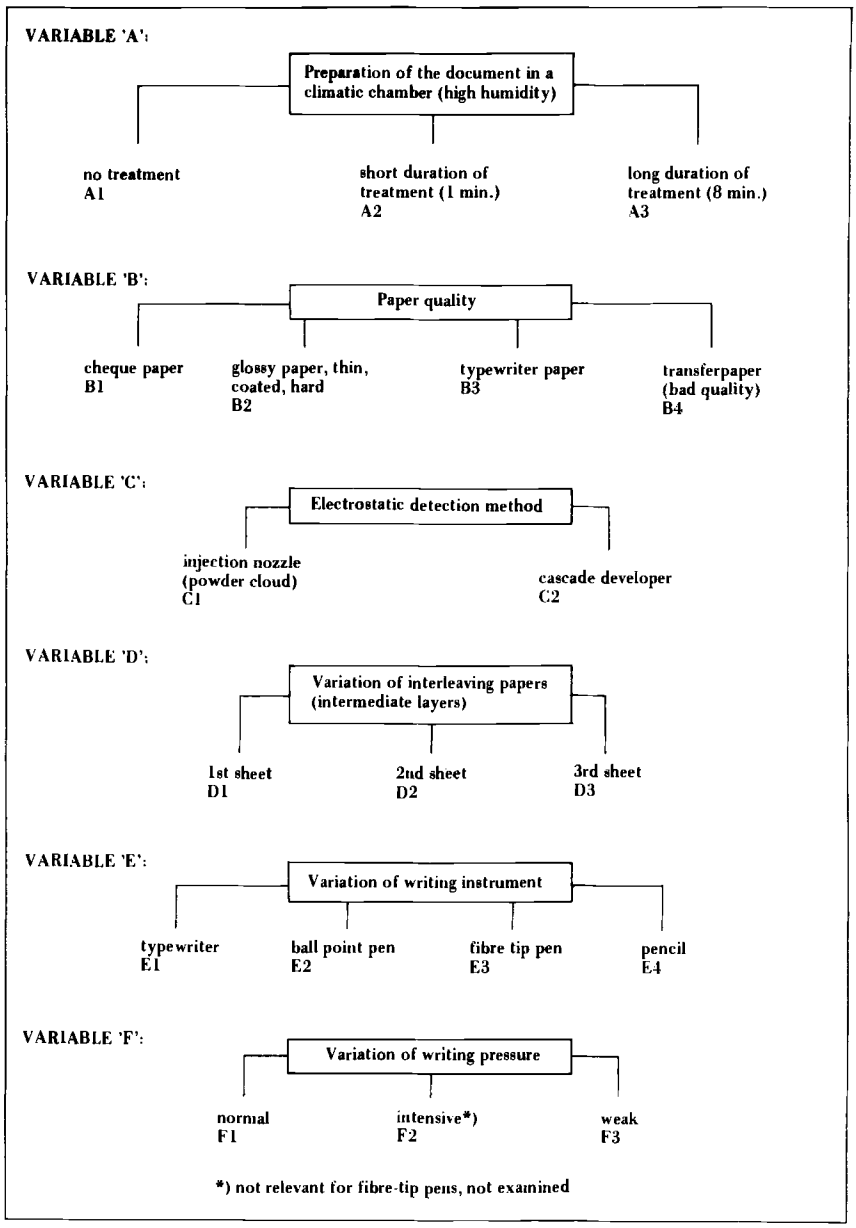

FIG. 2—*Crossed independent variables differentiated in steps.*

Results and Discussion

Figure 5 gives the results of the crossover procedure, excluding Variables E and F. The numbers in the cells of Fig. 5 are related to the factors listed in Fig. 6 as follows. The arithmetic means of the cells (see Fig. 5) were transformed into arithmetic means over the columns and over the lines to provide an interpretation of individual and main effects and of interactions between the variables. Economical considerations preclude a complete presentation and discussion of all the effects observed. The most important findings are discussed.

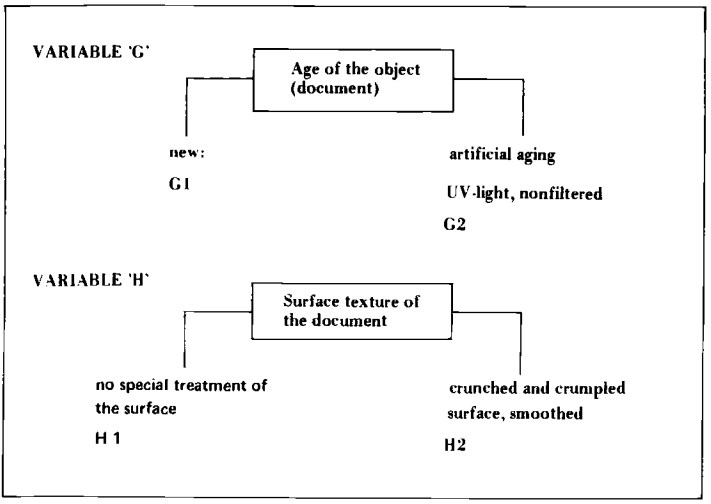

FIG. 3—*Independent variables differentiated in steps.*

Paper

Typewriter paper and checks give the best results. Low quality paper (such as spirit duplicator copy paper), especially intensively glued and coated paper, is not suitable for an ESDA investigation.

Method

The differences between the cascade developer and the powder methods are relatively minor. The injection nozzle produces a somewhat more uniform arrangement of toner compared to the rather granulated and grainy distribution pattern achieved by the cascade developer method (compare Fig. 7 with Fig. 8).

The data summed over the cells show that the more uniform distribution of the toner (injection nozzle) consistently gave better results. However, this advantage of the method depends on the quality of the indented impression. Although the first and second sheets in a stack can be identified much better with the powder method, the third paper can be developed much better with the cascade developer method (Fig. 9). It seems to be the rule that, in general, the better the condition of the object, the more suitable the powder method for developing the image. Under bad and worst conditions (such as faint indentations) the cascade developer should be preferred.

Writing Instrument

The influence of the writing instrument could be differentiated in a quite precise way. Indented impressions made by ball-point pens could be identified very clearly, indentations by pencil strokes gave a fair reproduction quality, and printed letters (typewriter) and indentations caused by fiber-tip pens gave bad results (see Fig. 10).

There are numerous reasons for the unsatisfactory results from typed letters. The author suspects the polymer film is not elastic enough to follow the relatively deep grooves of some typed letters. In such cases, it was impossible to develop an image corresponding to the indented impressions on the document, but the indentations did show up as white spots on the polymer film. This effect is most clear with deep-cut grooves typed on a sheet of paper without any backing support.

Scaling: 4 = excellent legibility

Scaling: 3 = good legibility

Scaling: 2 = visible

Scaling: 1 = faintly visible

Scaling: 0 = not visible anymore

FIG. 4—*Examples for determining the reproduction quality of the ESDA results.*

Typewritten indentations give good electrostatic images when they are printed on coated paper with a smooth and glossy surface.

Fiber-tip pens produce very subtle indentations compared with other writing instruments because their soft tips tend to absorb the writing pressure to a certain extent.

Number of Sheets

The experimental data show a linear decrease in the reproduction quality of the image based on the number of copies used as support. It is useful to know that even the first sheet with deep-cut grooves cannot be developed under certain circumstances because of the reasons already mentioned (flexibility of the polymer film). In these cases oblique lighting should be used to detect the image.

A high negative correlation was found between writing pressure and the number of intermediate layers (Fig. 11). The data must be interpreted in conjunction with the effect of another variable, the depth of the indented impressions. Depth has an enormous effect on the

			no treatment			normal treatment			intensive treatment		
			prints:			prints:			prints:		
			1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
	Cheque paper	Nozzle	000	000	000	000	000	000	020	010	000
			443	332	110	443	332	110	333	131	010
			1-1	0-0	0-0	1-0	0-0	0-0	1-0	0-0	0-0
			342	210	000	331	220	000	331	110	000
		Cascade	000	010	000	010	000	000	000	000	100
			343	342	110	443	342	110	443	120	000
			1-2	0-1	0-0	1-2	0-0	0-0	0-0	0-0	0-0
			231	231	010	332	221	000	231	010	000
	Coated paper (hard)	Nozzle	no results			no results			121	120	110
									020	000	010
									0-0	0-0	0-0
									010	000	100
		Cascade	no results			no results			121	120	000
									000	000	100
									0-0	0-0	0-0
									000	010	010
	typewriter-paper	Nozzle	241	140	010	030	010	000	230	010	000
			343	331	220	232	220	010	332	441	120
			3-2	2-1	0-0	0-0	0-0	0-0	1-1	1-1	0-0
			332	331	110	110	010	000	230	220	110
		Cascade	000	010	010	000	000	000	000	000	100
			333	332	231	233	210	220	231	231	010
			2-3	2-3	0-1	2-1	1-1	0-0	1-0	1-0	0-0
			332	342	221	121	110	000	231	221	000
	transfer-paper	Nozzle	no results			no results			000	000	010
									110	010	010
									0-0	0-0	0-0
									010	010	000
		Cascade	no results			no results			000	110	000
									120	020	000
									0-0	0-0	0-0
									120	010	010

FIG. 5—*Results of the crossover procedure.*

quality of the ESDA results. On the other hand, ESDA analysis greatly minimized the influence of other variables.

Artificial Aging

In general it appears to be risky to assume analogous conditions regarding genuinely old documents and documents treated with an aging apparatus (artificial aging). Age itself had

SCHEDULE II: Differentiation of cell numbers related to the steps of factors 'E' and 'F'

		Writing Pressure		
		normal	intensive	weak
Writing instrument	typewriter	0	0	0
	ballpoint-pen	4	4	3
	fibre-tip-pen	1	–	1
	pencil	3	4	2

*) The numerals have been extracted from cell A1, B1, D1 (1st cell)

FIG. 6—*Differentiation of cell numbers related to the steps of Factors E and F.*

FIG. 7—*The ESDA result with an unprepared document treated with the powder spray method. It is rated 3, good legibility, on the arbitrary scale.*

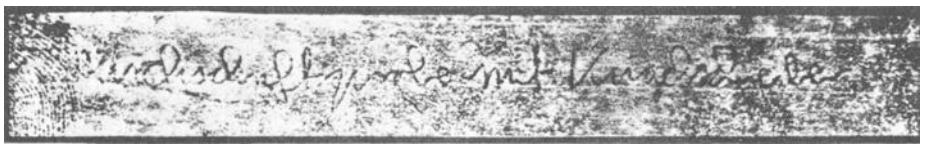

FIG. 8—*The ESDA result with an unprepared document treated with the cascade developer method. It is rated 2, visible, on the arbitrary scale.*

little effect on the reproduction quality of the image. Older documents show a slight degradation in reproduction quality that seems to be tolerable. The quality of the electrostatic image decreases a bit, but still remains legible, with age.

Texture

The texture (surface structure) of the object happened to be one of the most inhibiting factors in achieving good results with ESDA. Crushed and crumpled paper gave the worst results even when it was smoothed and stretched thoroughly before being tested. Any mechanical treatment applied to the surface of the document inevitably leads to a degradation of reproduction quality.

High Humidity

High humidity contributes a high degree of variance to the results of the electrostatic detection process. Although this variance is difficult to control, experimental studies have re-

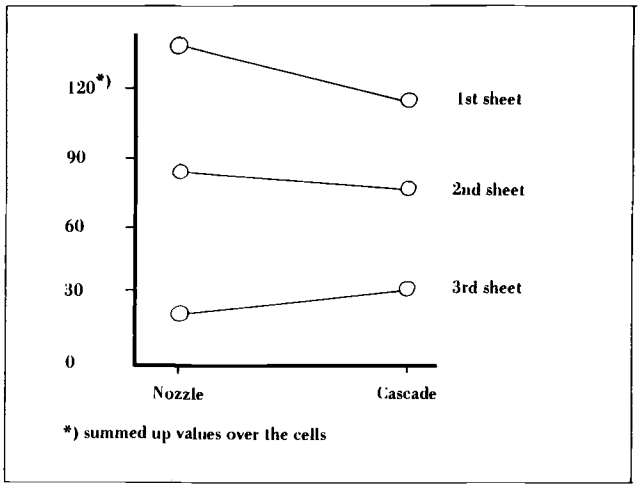

FIG. 9—*Relationship between intermediate layers and the method used to develop the impressions.*

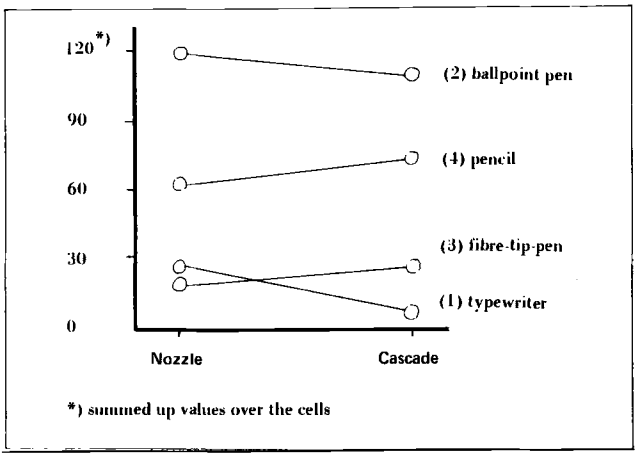

FIG. 10—*Relationship between the writing instrument and the method used to develop the impressions.*

vealed that high humidity does not have any negative effects on the quality of the toner on the polymer film. In most cases the results remain as good as before, but under certain conditions the reproduction quality increases in terms of legibility.

It is important to understand the influence of other, related climatic conditions, such as dry air or low humidity in general, on the ESDA detection procedure. Under conditions of generally low humidity, the preparation treatment with high humidity proved to be essential. Moreover, it is necessary to control the paper quality. Coated and intensively glued paper needs more time in the climatic chamber until saturation has reached the same degree as that for, for example, normal typewriting paper.

The author recommends a preparation of the document in a commercially available high-humidity chamber.

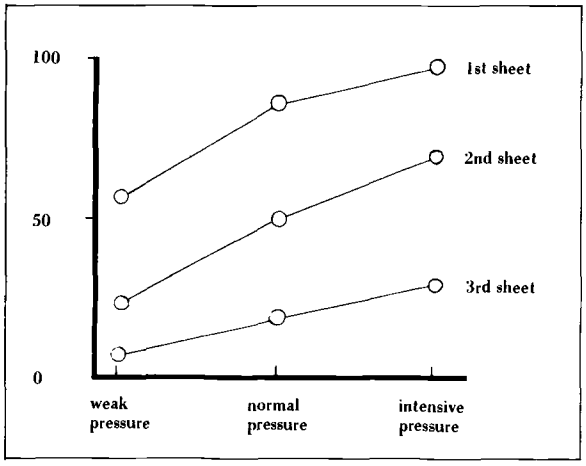

FIG. 11—*Relationship between the writing pressure and the number of intermediate layers.*

References

[1] Morantz, D. J., Foster, D. J., and Ellen, D. M., "An Electrostatic Method for Identifying Indented Impressions," presented at the 8th International Meeting of the Association of Forensic Sciences, Wichita, KS, 1978.

[2] Baier, P. E., Dhom, M., and Lehmann, R., "Bericht über das 8th International Meeting of Forensic Sciences in Wichita, *Mannheimer Hefte fur Schriftvergleichung*, Vol. 4, 1978, pp. 81-95.

[3] Holleyhead, R., "The Use of Electrostatic Imaging in the Detection of Indented Impressions," BKA-Vortragsreihe: Der Sachbeweis im Strafverfahren, Wiesbaden, 1979.

[4] Foster, D. J. and Morantz, D. J., "An Electrostatic Imaging Technique for the Detection of Indented Impressions in Documents," *Forensic Science International*, Vol. 13, 1979, pp. 51-54.

[5] Schima, K., "Neue Wege in der Untersuchung von Prägespuren. Ergebnisse des ESDA-Verfahrens in der Praxis," paper presented at the 6th Mannheimer Symposion für Schriftvergleichung, Mannheim, West Germany, 1981.

[6] Iten, P. X., "Fortschritte in der Kriminaltechnik, Parts I and II," *Kriminalistik*, Vol. 35, 1981, pp. 156-163 and 182-188.

[7] Carney, B. B., "Use of the ESDA in Developing Indented Writing," paper presented at the 39th Annual Conference of the American Society of Questioned Document Examiners, Houston, TX, 1981.

[8] Nemecek, J. and Clift, R. E., "Technical Information on the ESDA," paper presented at the 39th Annual Conference of the American Society of Questioned Document Examiners, Houston, TX, 1981.

[9] Lewis, G. W., "Examining Indented Writings Using the Electrostatic Detection Apparatus," paper presented at the 39th Annual Conference of the American Society of Questioned Document Examiners, Houston, TX, 1981.

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