Effects of Water Temperature vs. Time in Humidifying Documents for Electrostatic Detection Apparatus Examination

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Forensic Document Examiners (FDE) use different time intervals and water temperatures when humidifying documents before examining them with the Electrostatic Detection Apparatus (ESDA). The purpose of this study was to determine the optimal conditions when humidifying documents for an ESDA examination, for a laboratory that does not utilize a temperature and humidity controlled ESDA room, by using the variables of water temperature and time. The study was conducted using the conditions set forth in the ESDA instruction manual by Foster and Freeman except for changes noted in this paper. The best conditions varied depending on the type of writing instrument and the paper layer examined. Overall, the ideal water temperature and time combination was 55° F for ten minutes.

Introduction

Forensic Document Examiners (FDE) use different time intervals and water temperatures when humidifying documents before examining them with an ESDA. When an FDE relocates to a different laboratory, environmental conditions may change, thereby influencing ESDA results. This study was undertaken to determine if there was an optimal water and time combination for a dry, high altitude climate, such as that found in Colorado where this research was conducted.

A literature search was conducted to locate any prior studies about the variables of water temperature and time. The literature shows many studies on the ESDA (Baier, 1983; Foster and Morantz, 1979; Giles, 1993; Gupta, 1989; Hart and Hart, 1989; Jasuja and Singla, 1991; Jasuja and Singla, 1995; Kelly and Hull, 1993; Lewis, 1981; Riebeling and Kobus, 1994; Strach and others, 1995) and the room environment (D'Andrea and others, 1996; Giles, 1988; Noblett and James, 1983) but no studies were found regarding the two specific elements of this study.

Method and Materials

It is suspected that there is a correlation between humidity and the electrostatic charge created by the corona wand. A brief theory and operation of the corona wand can be found in the literature (Oglesby and Nichols, 1978; Rose and Wood, 1966).

Before the corona wand is used, the paper is humidified because it is easier to obtain an electrostatic charge due to the conductivity of water. The corona wire creates a cascade of electrons that in turn bombard other molecules, such as oxygen, nitrogen and water, thereby creating a negative ion charge (Figure 1). When a document is dry (~50% relative humidity) the corona wire has difficulty creating a charged field on the document.

As the distance between the corona wire and the document increases, it becomes more difficult to achieve a charged field because the electrical potential of the corona wire drops drastically with distance (Oglesby and Nichols, 1978). Rose and Wood (1966) comment on the phenomenon that a negative corona wire develops a charge like beads across the wire. Conversely, a positive corona wire develops a charge along the entire length of the wire (Figure 2).

An examination was conducted to determine the optimal conditions to humidify a document for an ESDA examination, in a dry, high altitude climate, using the variables of water temperature and time.

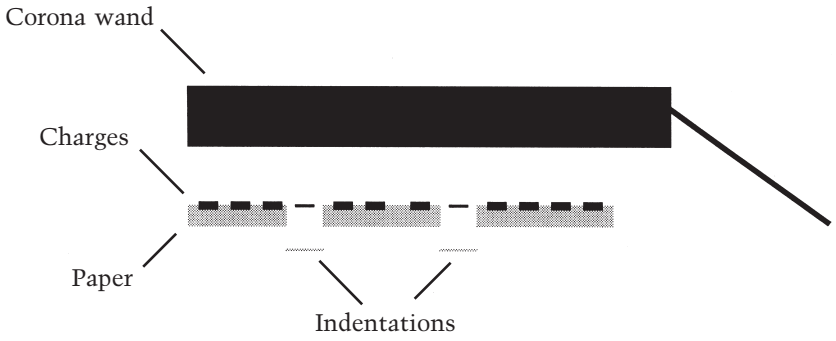

Figure 1. Depiction of corona charges on the indented impressions. The bold "▬ " denotes a stronger negative charge than the regular "— " in the indentation area.

Figure 2. Depiction of corona charges across the wire.

Equipment Used

1. Electrostatic Detection Apparatus (ESDA) manufactured by Foster & Freeman Ltd., England
2. Fisher Scientific 11-661-14 Hygrometer/Temperature Pen
3. Georgia-Pacific Xerox paper, bond, 8½ X 11 inch, 75g/m
4. Fisher Space ball-point pen
5. Pilot precise rolling ball pen, V5, extra fine
6. Pentel sign felt pen
7. Eastman #2 COM pencil
8. Pentel 0.5 mm, P205, #2 mechanical pencil
9. Heating plate
10. Metal rod with clamp (to maintain constant writing pressure)
11. Magnetic stirring rod
12. Humidity Chamber, consisting of:
    - 4 Qt, 15 X 10 X 2 inch glass Pyrex container
    - °F Thermometer
    - EKCO 15¼ X 10¼ X ¾ inch cookie sheet (used as the lid)
    - Coated wire rack (to place the document on)

The ambient room temperature and humidity were noted at the start and at the end of the day to obtain an average temperature and relative humidity. The paper was arranged into fifteen stacks consisting of eleven sheets each. Each sheet was marked with the length of time the paper was humidified, the water temperature, the trial number, and the number of the paper layer. For example, on the right side of Figure 3, the notation "2-70-2-1" indicates the time "2" in minutes, the temperature "70" in degrees Fahrenheit, the trial number "2," and the paper layer "1." Paper layers are numbered starting with the sheet under the top sheet. Each writing instru-

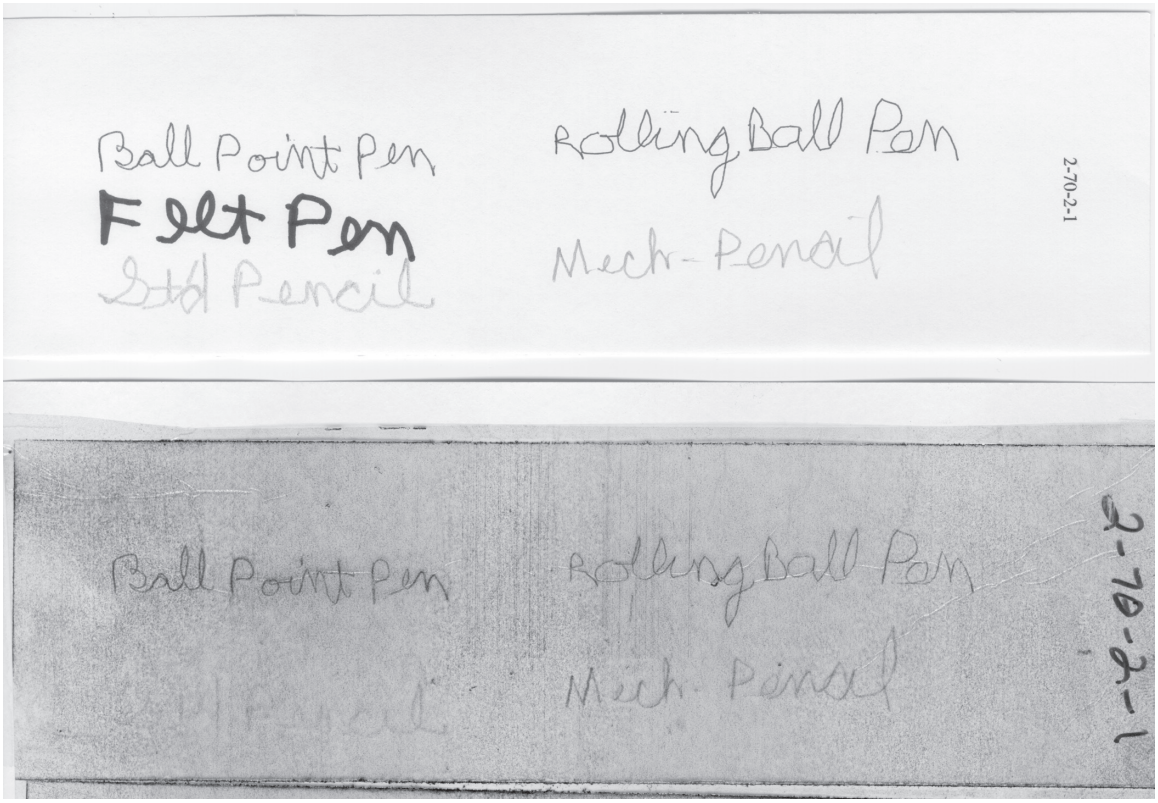

Figure 3. Top sheet and first layer of a stack. This photograph depicts writing produced by the different instruments on the top page and the impressions restored on the first underlying sheet of paper. The inscriptions in the right margin of both sheets represent the time, temperature, trial number and paper layer.

ment was then used to prepare source writing on the top sheet of each stack.

To help maintain constant writing pressure, a clamp attached to a metal rod (~12" long) was used to hold the writing instrument. The writer held the opposite end of the rod from the clamp and, without adding downward pressure, wrote on the top sheet of each stack of papers. Each stack was then cut widthwise to produce five separate trials consisting of eleven sheets for a total of 75 trials.

The study was conducted using the operating procedures set forth in the ESDA instruction manual by Foster and Freeman except for the following changes:

- A Pyrex container was substituted for the Foster & Freeman humidifying chamber so the container could be placed on a hot plate to maintain constant water temperature,
- The corona wand was passed over the surface for fifteen seconds as opposed to the recommended 2-3 passes[1] and,
- Trials were conducted using both the cascade and aerosol methods of toner application without re-humidifying the documents.

When the water reached the desired temperature in the humidifying chamber, the first five layers under the top sheet were placed on the support screen along with the hygrometer.[2] Each paper layer was humidified for its respective time interval of 2, 5, 10, 15 or 20 minutes. After the allotted time, the lid was removed and the chamber's air temperature and humidity were recorded (Table 1).[3]

The sheets were then placed on the ESDA plate and developed by cascade and aerosol toner applications. For the aerosol method, four bursts of

Score for Ball Point Pen							
Temperature 70° F							
Method: Cascade							
Chamber T (°F)	Chamber % Hum.	Time (min)	Paper Position				
			1	2	3	4	5
70.4	57	2	5	4	1	0	0
70.3	54	2	5	4	3	0	0
71.2	68	2	5	5	3	0	0
70.7	46	5	5	4	1	0	0
71.9	65	5	5	4	1	1	0
71.4	65	5	5	4	1	0	0
72.1	73	10	5	4	1	0	0
72.3	71	10	5	4	2	0	0
71.7	54	10	5	4	2	0	0
72.0	78	15	5	5	1	0	0
73.6	84	15	5	3	0	0	0
73.4	84	15	5	3	0	0	0
72.9	82	20	5	3	0	0	0
73.2	78	20	5	4	0	0	0
72.8	44	20	5	4	1	1	0

Table 1

Score for Ball Point Pen							
Temperature 70 F							
Method: Cascade							
Chamber T	Chamber % Hum.	Time (min)	Paper Position				
			1	2	3	4	5
70.4	57	2	5	4	1	0	0
70.3	54	2	5	4	3	0	0
71.2	68	2	5	5	3	0	0
70.7	46	5	5	4	1	0	0
71.9	65	5	5	4	1	1	0
71.4	65	5	5	4	1	0	0
72.1	73	10	5	4	1	0	0
72.3	71	10	5	4	2	0	0
71.7	54	10	5	4	2	0	0
72.0	78	15	5	5	1	0	0
73.6	84	15	5	3	0	0	0
73.4	84	15	5	3	0	0	0
72.9	82	20	5	3	0	0	0
73.2	78	20	5	4	0	0	0
72.8	44	20	5	4	1	1	0

Table 2

toner from the nozzle were used with a pause between bursts to let the toner cloud settle. After the document was processed, adhesive sheets were placed on top of the film to preserve the results. The date, toner application method, humidifying time, temperature, trial number and paper layer number were recorded. A score from 0 to 5 was assigned to denote the quality of the indentations developed (Table 2). Indented impressions were not observed on the fifth paper layer, so the trials for layers six through ten were not conducted.

Results

Three trials were conducted for each temperature (55°, 70°, 85°, 100° and 115° F) and time (2, 5, 10, 15 and 20 minutes) combination. The scores of the three trials were averaged to obtain one value for each of the twenty-five temperature and time combinations. After the average values were plotted on twenty-seven graphs, the results were studied to ascertain if a specific temperature and time combination yielded a better quality of developed indentations.

The best combination of temperature and time was prepared from the graphs for the following categories:

1. Writing instrument and paper layer were known by the FDE.

2. Writing instrument was known but paper layer was not known by the FDE.

3. Paper layer was known but writing instrument was not known by the FDE.

4. Both writing instrument and paper layer were not known by the FDE.

Category 1: Writing instrument and paper layer were known

Ball Point Pen Cascade Toner Application

First paper layer:
- All temperature and time combinations were optimal, except:
  - 115° F humidified for 20 minutes
  - Chamber relative humidity ranged from 38% to 100%

Second paper layer:
- 55° F humidified for 10 minutes
- 100° F humidified for 2 minutes
- Chamber relative humidity was 70% and 80% consecutively

Third paper layer:
- 55° F humidified for 15 or 20 minutes
- Chamber relative humidity was 75% and 78% consecutively

Fourth paper layer:
- 100° F humidified for 2 minutes
- Chamber relative humidity was 80%

Fifth paper layer:
- No indentations were noted

Ball Point Pen Aerosol Toner Application

First paper layer:
- All temperature and time combinations were optimal, except:
  - 70° F humidified for 5 minutes
- Chamber relative humidity ranged from 38% to 100%

Second paper layer:
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Third paper layer:
- 100° F humidified for 2 minutes
- Chamber relative humidity was 80%

Fourth and fifth paper layers:
- No indentations were noted

Rolling Ball Pen Cascade Toner Application

First paper layer:
- All temperature and time combinations were optimal except:
  - 70° F humidified for 5 minutes
  - 85° F humidified for 15 minutes
  - 100° F humidified for 15 or 20 minutes
  - 115° F humidified for 15 minutes
  - Chamber relative humidity ranged from 38% to 100%

Second paper layer:
- 5° F humidified for 10 or 15 minutes
- 100° F humidified for 2 minutes
- Chamber relative humidity was 70%, 75% and 80% consecutively

Third paper layer:
- 55° F humidified for 5 minutes
- Chamber relative humidity was 63%

Fourth paper layer:
- 100° F humidified for 2 minutes
- Chamber relative humidity was 80%

Fifth paper layer:
- No indentations were noted

Rolling Ball Pen Aerosol Toner Application

First paper layer:
- All temperature and time combinations were optimal, except:
  - 70° F humidified for 2 minutes
  - 100° F humidified for 10, 15 or 20 minutes
  - 115° F humidified for 5 or 15 minutes
  - Chamber relative humidity ranged from 38% to 100%

Second paper layer:
- 70° F humidified for 10 minutes

- Chamber relative humidity was 66%

Third paper layer:
- 55° F humidified for 20 minutes
- 100° F humidified for 2 minutes
- Chamber relative humidity was 78% and 80% consecutively

Fourth and fifth paper layers:
- No indentations were noted

Mechanical Pencil Cascade Toner Application

First paper layer:
- 55° F humidified for 2, 5, 10, 15 or 20 minutes
- 70° F humidified for 10, 15, or 20 minutes
- 85° F humidified for 2 or 10 minutes
- 100° F humidified for 2 or 5 minutes
- 115° F humidified for 2 minutes
- Chamber relative humidity ranged from 38% to 100%

Second paper layer:
- 85° F humidified for 2 minutes
- Chamber relative humidity was 38%

Third paper layer:
- 55° F humidified for 5 or 20 minutes
- Chamber relative humidity was 63% and 78% consecutively

Fourth and fifth paper layers:
- No indentations were noted

Mechanical Pencil Aerosol Toner Application

First paper layer:
- 55° F humidified for 10, 15, or 20 minutes
- 70° F humidified for 15 or 20 minutes
- 85° F humidified for 2, 5 or 20 minutes
- 100° F humidified for 2 minutes
- 115° F humidified for 2 minutes
- Chamber relative humidity ranged from 38% to 100%

Second paper layer:
- 85° F humidified for 2 minutes
- Chamber relative humidity was 38%

Third paper layer:
- 55° F humidified for 20 minutes
- Chamber relative humidity was 78%

Fourth and fifth paper layers:
- No indentations were noted

Standard Pencil Cascade Toner Application

First paper layer:
- 55° F humidified for 2 or 10 minutes
- Chamber relative humidity was 48% and 63% consecutively

Second paper layer:
- 55° F humidified for 20 minutes
- Chamber relative humidity was 78%

Third paper layer:
- 55° F humidified for 15 minutes
- 70° F humidified for 2 minutes
- 100° F humidified for 2 minutes
- Chamber relative humidity was 75%, 60% and 80% consecutively

Fourth and fifth paper layers:
- No indentations were noted

Standard Pencil Aerosol Toner Application

First paper layer:
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Second paper layer:
- 55° F humidified for 10 minutes
- 85° F humidified for 5 minutes
- Chamber relative humidity was 70% and 38% consecutively

Third, fourth and fifth paper layers:
- No indentations were noted

Felt Pen Cascade Toner Application

First paper layer:
- 55° F humidified for 2 minutes
- Chamber relative humidity was 48%

Second, third, fourth and fifth paper layers:
- No indentations were noted

Felt Pen Aerosol Toner Application

First paper layer:
- 55° F humidified for 2 minutes
- Chamber relative humidity was 48%

Second, third, fourth and fifth layers:
- No indentations were noted

Category 2: Writing instrument was known but paper layer was not known

Ball Point Pen

Cascade Method:
- 55° F humidified for 15 minutes
- 100° F humidified for 2 minutes
- Chamber relative humidity was 75% and 80% consecutively

Aerosol Method:
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Comparing the two-toner applications (cascade or aerosol), the cascade method produced more legible impressions than the aerosol method.

Rolling Ball Pen

Cascade Method:
- 55° F humidified for 10 or 15 minutes
- 100° F humidified for 2 minutes
- Chamber relative humidity was 75%, 78% and 80% consecutively

Aerosol Method:
- 70° F humidified for 10 minutes
- Chamber relative humidity was 66%

Comparing the two-toner applications (cascade or aerosol), the cascade method produced more legible impressions than the aerosol method.

Mechanical Pencil

Cascade Method:
- 85° F humidified for 2 minutes
- Chamber relative humidity was 38%

Aerosol Method:
- 85° F humidified for 2 minutes
- Chamber relative humidity was 38%

Comparing the two-toner applications (cascade or aerosol), the cascade method produced more legible impressions than the aerosol method.

Standard Pencil

Cascade Method:
- 55° F humidified for 20 minutes
- Chamber relative humidity was 78%

Aerosol Method:
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Comparing the two-toner applications (cascade or aerosol), the cascade method produced more legible impressions than the aerosol method.

Felt Pen

No optimal temperature and time combination was observed.[4]

Category 3: Paper layer was known but writing instrument was not known

First paper layer

Cascade Method:
- 55° F humidified for 2 or 10 minutes
- Chamber relative humidity was 48% and 70% consecutively

Aerosol Method:
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Comparing the two-toner applications (cascade or aerosol), the cascade method produced more legible impressions than the aerosol method.

Second paper layer

Cascade Method:
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Aerosol Method:
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Comparing the two-toner applications (cascade or aerosol), the cascade method produced more legible impressions than the aerosol method.

Third, fourth and fifth paper layers

No optimal temperature and time combination was observed.

Category 4: Both writing instrument and paper layer were not known

Cascade
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Aerosol
- 55° F humidified for 10 minutes
- Chamber relative humidity was 70%

Comparing the two-toner applications (cascade or aerosol), the cascade method produced more legible impressions than the aerosol method.

Discussion

At the end of the study, three effects were noted. As the temperature and time increased from 85° F to 115° F, the quality of the developed indented impressions generally decreased. This may be the result of higher temperatures over saturating the document, thereby swelling paper fibers and obliterating the indentations.

The second effect was the quality of indentations produced by the different writing instruments. The ballpoint pen's indentations produced clearer impressions on lower paper layers than the other writing instruments. The quality of restored indentations decreased in the following order: 1) ball point pen, 2) rolling ball pen, 3) mechanical pencil, 4) standard pencil, and 5) felt pen.

Finally, when using either the cascade or the aerosol method of toner application, the cascade method was easier to manage and produced clearer impressions. The aerosol method seemed more sensitive to the colder temperatures used to humidify the documents. The duration of time for holding the lever down for the aerosol burst needed to be shortened otherwise too much toner was deposited on the ESDA plate obscuring the indentations.

The purpose of this study was to determine the optimal conditions when humidifying documents for an ESDA examination, for a laboratory that does not utilize a temperature and humidity controlled ESDA room, by using the variables of water temperature and time. Humidifying a document with a water temperature of 55° F, for ten minutes produced the best results for a relatively dry, high altitude climate like Colorado. A more humid climate could impact the quality of the impressions developed. When the results of water temperature and time interval of 55° F for 10 minutes was compared to the manufacturer recommended water temperature/time interval of hot water for a couple of minutes, the 55° F/10 min. interval produced clearer impressions.

Future studies may consider: 1) if the 55° F for 10 minutes would be the best combination for a geographical area with higher humidity and lower elevation, and 2) if there truly was a correlation between the aerosol burst time and the colder water temperatures.

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Endnotes

[1] A "pass" requires an indeterminate amount of time depending on the user. To maintain consistency a period of 15 seconds was used.

[2] Although the maximum humidity reading of the hygrometer was 98%, if moisture was observed the hygrometer was not used due to possible detrimental effects to the hygrometer. When moisture was observed, the relative humidity was estimated to be 100%.

[3] The other numbers under paper position are the scores given to the indentations viewed. See Table 2 for scoring definitions.

[4] All scores were less than a score of 2 (Table 2).