An Experiment on the Effects of Humidity on Screen-Process Stencils

Thomas R. Bresadola

Follow this and additional works at: https://openprairie.sdstate.edu/etd

Recommended Citation
https://openprairie.sdstate.edu/etd/3765
AN EXPERIMENT ON THE EFFECTS
OF HUMIDITY ON SCREEN-PROCESS STENCILS

BY

THOMAS R. BRESADOLA

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Printing Management, South Dakota
State University

1970

SOUTH DAKOTA STATE UNIVERSITY LIBRARY
AN EXPERIMENT ON THE EFFECTS
OF HUMIDITY ON SCREEN-PROCESS STENCILS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser / Date

Head, Department of Journalism and Mass Communication Date
ACKNOWLEDGEMENTS

The writer would like to express his sincere appreciation to Mr. Joseph Fortwengler, of Ulano Inc., who provided the writer with most of the equipment necessary to complete the experiment. Mr. Fortwengler also spent many hours explaining various products and processes necessary to insure an accurate report.

A sincere thanks also goes to Charlene Schumacher, for her typing, proofreading, and the encouragement necessary to the completion of this study.

Finally, the writer would like to express his deep and sincere appreciation to his family. Not only for their tolerating my adjusting the temperature and humidity of two rooms in the house, for extended periods of time, but also for their encouragement and the moral support so very necessary to the completion of this study.

To those men in the industry who aided my study with their recommendations, a very sincere thanks.

TRB
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Reasons for undertaking the study</td>
<td>1</td>
</tr>
<tr>
<td>Prior Research</td>
<td>4</td>
</tr>
<tr>
<td>Objectives of the Study</td>
<td>5</td>
</tr>
<tr>
<td>History</td>
<td>6</td>
</tr>
<tr>
<td>II. METHODOLOGY OF THE STUDY</td>
<td>12</td>
</tr>
<tr>
<td>Stencils Chosen</td>
<td>12</td>
</tr>
<tr>
<td>Controlled Variable</td>
<td>14</td>
</tr>
<tr>
<td>Constant Factors</td>
<td>14</td>
</tr>
<tr>
<td>Stencils</td>
<td>14</td>
</tr>
<tr>
<td>Screen</td>
<td>15</td>
</tr>
<tr>
<td>Ink</td>
<td>15</td>
</tr>
<tr>
<td>Stock</td>
<td>15</td>
</tr>
<tr>
<td>Temperature</td>
<td>15</td>
</tr>
<tr>
<td>Frame</td>
<td>15</td>
</tr>
<tr>
<td>Tightness of Screen</td>
<td>16</td>
</tr>
<tr>
<td>Time</td>
<td>16</td>
</tr>
<tr>
<td>Procedure</td>
<td>16</td>
</tr>
<tr>
<td>Chapter</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>III</td>
<td>18</td>
</tr>
<tr>
<td>FINDINGS</td>
<td>18</td>
</tr>
<tr>
<td>Results of the Humidity Changes</td>
<td>19</td>
</tr>
<tr>
<td>IV</td>
<td>26</td>
</tr>
<tr>
<td>SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY</td>
<td>26</td>
</tr>
<tr>
<td>Summary</td>
<td>26</td>
</tr>
<tr>
<td>Conclusion</td>
<td>27</td>
</tr>
<tr>
<td>Recommendations for Further Study</td>
<td>29</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>30</td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>36</td>
</tr>
<tr>
<td>APPENDIX C</td>
<td>42</td>
</tr>
<tr>
<td>APPENDIX D</td>
<td>49</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>50</td>
</tr>
</tbody>
</table>
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Temperature-humidity table</td>
<td>3</td>
</tr>
<tr>
<td>2. Humidity scale</td>
<td>14</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Aquafilm graph</td>
<td>19</td>
</tr>
<tr>
<td>2. Blue-Poly 2 graph</td>
<td>21</td>
</tr>
<tr>
<td>3. Direct-Emulsion graph</td>
<td>24</td>
</tr>
</tbody>
</table>
 CHAPTER I

INTRODUCTION

Reasons for undertaking the study

Screen-process printing is a personal favorite of the writer's. Its wide range of adaptability and color makes it a more interesting and challenging field than the routine "black ink on white paper" types of printing.

Screen-process printing is still in the cradle stage when compared to letterpress, offset, or gravure. The printing industry stresses speed and volume production, and screen printing does not readily lend itself to either of these. Screen-process printing is much more diversified than any other type of printing, hence its adaptability to automation is impaired. However, it is in this diversification that the screen printing industry realizes its greatest growth potential.

Because the screen printing industry is still relatively young, it is faced with some basic problems that have not yet been solved.

Humidity is one of the main problems of screen printers in Chicago, according to information received by interviewing executives of screen-process plants, technical managers and trouble shooters of
graphic arts supply houses, and men on the job working with stencils.

The main problem stems from preparing the stencils on one day, and printing them on another day. Often, a change in the weather may cause the stencils to stick together. If they have been mounted on a screen, chipping and small cracks may appear. These problems make planning difficult and often result in duplication of work and wasting of materials.

The writer has also spoken with instructors of screen printing, in Chicago, and has again found humidity to be causing problems. Many times in a teaching situation, stencils are prepared and stored for longer than usual periods of time. When it is time to print, the stencils are out of register, making instruction difficult. Several instructors have expressed the need for installing temperature and humidity controls in their laboratories, but to no avail. They feel that a study of this problem would aid them in obtaining their request.

Humidity is the amount of water vapor that air can hold, and is almost entirely dependent upon air temperature. Warm air is able to contain much more water vapor than cold air. Also, the maximum amount of water vapor that a given volume of air can hold at a given temperature rises at an increasing rate as the temperature rises. The table on the following page demonstrates this.
TABLE I

Maximum Water-Vapor Capacity of 1 Cubic Foot of Air\(^1\) at Varying Temperatures

<table>
<thead>
<tr>
<th>Temperature, degrees fahrenheit</th>
<th>Water Vapor, grains</th>
<th>Difference between successive 10° intervals, grains</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>2.9</td>
<td>1.2</td>
</tr>
<tr>
<td>50</td>
<td>4.1</td>
<td>1.6</td>
</tr>
<tr>
<td>60</td>
<td>5.7</td>
<td>2.3</td>
</tr>
<tr>
<td>70</td>
<td>8.0</td>
<td>2.9</td>
</tr>
<tr>
<td>80</td>
<td>10.9</td>
<td>3.8</td>
</tr>
<tr>
<td>90</td>
<td>14.7</td>
<td>5.0</td>
</tr>
<tr>
<td>100</td>
<td>19.7</td>
<td></td>
</tr>
</tbody>
</table>


Thus, if the temperature of one cubic foot of air is increased by 10° F., from 30° to 40°, the moisture capacity is advanced only one grain, whereas a similar 10° increase from 90° to 100° increases the capacity five grains.

Relative humidity refers to the amount of water vapor in the air compared with the greatest amount that the air could contain at the same temperature.
A possible solution to the screen printing industry's humidity problem would be temperature-controlled and humidity-controlled plants. However, this solution has many drawbacks. Most commercial printing plants use forced-air ovens for drying prints. These ovens give off vast amounts of heat, making air conditioning difficult. Also, shipping and receiving doors lead directly into the plant to aid the materials-handling flow pattern. The constant opening and closing of these doors increases the problem of controlling temperature and humidity.

A final problem should be mentioned. In any business operation, the ultimate objective is to make a profit. The high cost of installing and maintaining temperature and humidity controls often causes management to be reluctant to reduce profits by installing such controls.

Prior Research

Several books have been written on screen printing, most of them on the "how-to-do-it" phase of the process.2


The emphasis of current research is on development of better synthetic screens. The electronics industry is interested in a high quality, uniform thread diameter screen for use in printing micro circuits. The prints from these screens must be capable of great reduction without distortion or blocking out. This industry is printing circuits with metallic inks, designed for use as conductors of electricity. These must be uniform in size so as not to affect the resistance of a circuit.

Research is also being conducted in the field of automated equipment. Attempts are being made to eliminate the squeegee, by using a suction technique of forcing the ink through the screen.

In the field of stencils, experiments are being conducted in an attempt to extend the shelf life of the stencil. Also, plastic backings have been placed on the stencil films and have solved the humidity problem to a degree. However, once the backing sheet has been removed, the problem of humidity returns.

Objectives of the Study

Quality control is management, it is a way of thinking. To function properly, it cannot be isolated in one section of the plant, but rather it must permeate the entire climate of the plant.

Management is control through decision making. Decision making requires accurate and complete information, if errors are to be avoided. The quality of the information on which decisions are
based determines the quality of the decisions themselves.

Quality may be defined by stating what is acceptable, and what is not acceptable. Quality used in this sense varies greatly from plant to plant. The company printing slogans on sweat shirts is not as concerned about quality as is the company printing four-color process work on enamel paper.

To determine what is acceptable and what is not acceptable, management must have some guidelines upon which to base their decisions. This thesis is intended to be one of those guidelines. The objective of this thesis is to show how changes in humidity can affect the quality of screen printed matter.

History

Screen printing dates back to 1851, when Japanese hair stencils were first being produced. However, stenciling, the forerunner of screen printing, goes back to the time of prehistoric man. Stenciling is properly known as the predecessor of screen printing, because both techniques imply printing "through" a plate, rather than printing "from" a plate.

The earliest examples of stenciling are prehistoric cave decorations found on several cave walls in Gargas, France. These decorations, discovered by the Abbe Breuil, were described by him as "stenciled hands."³ They were created by blowing very finely

³ Carr, p. 15.
ground colored earth around actual hands.

Except for these discoveries in France, most traces of early stenciling are found in the Far East, as in the Tun Huang caves of the "Thousand Buddhas" in China. These first stencils are approximately 30,000 years old.\(^4\)

Stenciling is evident in more recent periods of history as well. Roman children were taught to write by tracing letters through perforated tablets. Emperors Theodoric, Justinian, and Charlemagne are believed to have used stencil plates for their signatures. The word "pattern" originates from this time, deriving from "patron," the material through which the color was applied, and "stencil" is derived from the "scintillating" metal powder stencilled on cloth, walls, wood and other forms of stock.\(^5\)

The actual beginning of screen printing as it is known today is described by Frances Carr.

A silk screen for stenciling is supposed to have been seen for the first time in England during the Great Exhibition of 1851, when Japanese hair stencils were shown. Their invention is attributed to a dyer Some-Ya-Yu-Zen, toward the end of the seventeenth century. The stencil was cut through two sheets of tough waterproofed paper; then strands of human hair or silk were stretched tight and glued to the edges of one sheet and it was rejoined accurately to its pair. This pair system held fine detail in position. When the hair stencil was fastened to a wooden frame or placed over a sieve for additional support, the "silk screen" was born.\(^6\)

\(^5\) Carr, p. 15.
\(^6\) Carr, p. 13.
Screen process printing still employs this same basic idea, but much progress has been made since the days of Some-Ya-Yu-Zen.

In 1870, experimental work was being done in Germany and France, using finely woven silk as a screen. Experiments were also being conducted in England, and in 1907, the first silk screen patent was issued to Samuel Simon of Manchester. The patent covered the use of a screen as a plate, but did not mention the squeegee. Simon employed a bristle brush to force the ink through the screen.

The first commercial screen printing company was started in 1911. The company was called Selectasine, meaning "select a sign," and produced advertisements to be placed on jitney buses, which were then making their appearance in America.

In 1914, John Pilsworth, one of the founders of the Selectasine Company, perfected a multicolor screen process, which he aptly titled the Selectasine Process. This process was patented in 1918 by a man named Owens, who was also a founder of the Selectasine Company.

The process consisted of gradually blocking out the screen, starting with the biggest area of color. Reference to early copies of the historic documents which cover the American patents leaves no doubt that the whole industry based its early activities on the principles which were laid down in the Selectasine Process.7

---

7 Biegeleisen, p. 3.
Silk screen at this time still produced prints much inferior to those made by other printing processes, such as letterpress and offset. Screen prints had ragged and blurred edges. Often, the paints used required excessive drying times, and occasionally they did not dry at all.

The first automatic screen press was patented in 1925. The press produced faster work and greater volume. However, the prints were of no better quality, and drying times continued to bottleneck the industry.

Real progress in screen printing occurred in 1929, when Louis F. D'Autremont of Dayton, Ohio, developed a stencil-film tissue. This film tissue eliminated the ragged and blurred edges hitherto characteristic of screen prints. The film, called Profilm, was patented by A. S. Daneman, an associate of D'Autremont.

Several years later, another type of stencil film was developed by Joseph Ulano of New York. This film, called Nufilm, was a great improvement over Profilm, and was accepted as the standard. With these improvements in the industry, paint manufacturers began catering to the needs of the screen printer. Paints with fast drying times were developed for use on all screening jobs, including paper, ceramics, textiles and other printing surfaces. Fast drying time resparked the press manufacturers, and automatic presses were again on the market.

---

8 Biegeleisen, p. 4.
The growth of the industry demanded organization, and so the Screen Process Printing Association International was formed on October 22, 1948. The Association received its charter on November 12, 1948, from the state of Illinois. Its membership includes processors and associate members (suppliers and manufacturers) from every part of the United States, Canada, Mexico, South America, Central America, Europe, Asia, Africa and Australia.9

There are thirty-four chapters in major cities of the United States, Europe, South Africa, Canada and Australia, with an international chapter covering members in other parts of the world.

At the annual international convention, educational and technical sessions are held; an art exhibition is arranged; and suppliers and manufacturers maintain exhibition space to allow the processor members to see what is new in the way of equipment and supplies for the industry.

The Association has many active committees working constantly for the good of the industry. Two industry committees, one for decal manufacturers and the other for point-of-purchase manufacturers, were formed in recent years under the auspices of the Association.

It is interesting to note that although the United States was one of the last countries to enter into the screen printing industry, it has now taken the lead in this field. Today, prints can be run on presses at speeds between 2,000 and 3,000 impressions an hour. These

9 Carr, p. 17.
same prints can be force-dried in a matter of seconds. The United States has turned a crude hand craft into a major industry, with a volume of more than $300,000,000 a year.
CHAPTER II

METHODOLOGY OF THE STUDY

Stencils Chosen

There are three basic types of stencils commonly used by the screen printing industry. They are: 1. hand-cut transfer stencils, 2. photo-sensitive transfer stencils, and 3. photo-sensitive direct-emulsion stencils.

The hand-cut transfer stencil is a sheet of gelatin adhered to a plastic backing. The stencil is placed over the artwork, and cut by hand using a scalpel-sharp cutting tool. The sections of the stencil to be printed are then peeled away from the plastic backing sheet. The stencil is then adhered to a screen, using a mild solution of alcohol and vinegar. When the stencil has dried, the plastic backing is peeled away from the screen. The result is a gelatin film cemented to the screen, and ready for printing. The term "transfer" comes from first preparing the stencil, and then transferring it to the screen.

The photo-sensitive transfer stencil is also a gelatin adhered to a plastic backing sheet. However, in this case, the gelatin is photo-sensitive. The art work must be in the form of a photographic negative. The art work is placed over the stencil, in a vacuum frame. The film is then exposed to a strong light for a short time, usually a
few minutes, and then placed in a developing solution which dissolves the undesired parts of the gelatin. The film is then washed off with warm water, and adhered, wet, to the screen. When dry, the backing sheet is peeled away. The result is a gelatin film adhered to a screen, ready for printing. This stencil, when photographed through a screen, is often used for printing half-tones.

The photo-sensitive direct-emulsion stencil starts in liquid form. The liquid is applied to the screen and allowed to dry. The artwork, in photographic negative form, is placed on top of the stencil and exposed to a strong light. The stencil is then placed in a developer, washed off with warm water, and when dry, is ready for printing.

There are several variations of these three basic types of screens. However, those stencils chosen are the most commonly used by the screen-printing industry in Chicago. The first two respectively are: 1. aquafilm -- hand-cut transfer, and 2. blue poly 2 -- photo-sensitive transfer. Both are produced by Ulano Inc. The third stencil, direct-emulsion, is produced by ADVANCE process supply company.

The null hypothesis for this experiment was that increases in humidity will not affect these stencils. The working hypothesis for this experiment was that increases in humidity will affect these stencils.
Controlled Variable

The only controlled variable throughout the study was the humidity factor. The following humidity scale was used:

40%, 50%, 60%, 70%, 80%

Constant Factors

1. Stencils:

A. Aquafilm, a water-soluble hand-cut stencil. This is a poly-vinyl material, having a chemical formula similar to that of latex. The finished stencil is transferred to the screen.

B. Blue-poly 2, a water-soluble photo stencil. This is an animal-gelatin film containing a plasticizer to keep it flexible. A dye content is added. It is also a transfer-type stencil.

C. Direct-emulsion stencil. This stencil material is in liquid form, and is applied to the screen. It is a sensitized, photographically active gelatinous solution. Once the screen has been coated with this emulsion, the artwork is photographed on the stencil. The stencil is then developed, washed out, and when dry is ready for printing.

The exact contents of the stencils cannot be given, because they are trade secrets of the manufacturer.
2. Screen:

The screen used for all experiments was monofilament nylon. The nylon selected had a mesh count of 260 strands per linear inch, an aperture size of .0023 of an inch, and 36.0 percent of open area. Nylon was chosen because it is not affected by humidity, it produces a sharp print, and it is the most commonly used screen in the commercial screen printing industry.

3. Ink:

Both inks were mineral-spirit poster inks. These inks have a fast drying time, and are recommended for use on enameled papers.

4. Stock:

All stock used was 80-lb. offset enamel, coated on both sides. Even though the paper was exposed to the increased humidity condition only while it was being printed, a heavy enamel paper is the least affected by humidity.

5. Temperature:

72° (This is the average indoor temperature, according to the Chicago Tribune weather department.)

6. Frame:

Both frames were varnished wood. They were small enough so as not to be affected by humidity.
7. Tightness of screen:

All screens were mounted on the frame by mechanical means, thereby insuring uniformity. This was done by the factory providing the frames.

8. Time:

After the humidity had been effectively increased, the stencil was exposed for one hour.

Procedure

Three of the most commonly used stencils were tested, with a total of six stencils prepared for the experiment. Each print was a two-color design and used two stencils, of the same material, one stencil for each color.

All six stencils were prepared at the same time and under the same conditions. Three prints were made immediately at 40 per cent humidity to produce a standard. All materials used, except the stencils, remained in a room with a constant temperature of 72° and a constant humidity of 40 per cent.

The stencils were placed in a room which also had a constant temperature of 72°. However, the humidity was increased 10 per cent. The stencils were exposed to this increased humidity condition for one hour, after which time a second print was made. This procedure was repeated until all humidity changes had been tested.
Register was guided by using the two-cross-mark system common to the industry.

All prints were checked with a micrometer under a magnifying glass to determine any amount of change which had occurred.
CHAPTER III

FINDINGS

Results of the Humidity Changes

The first stencil tested was aquafilm. The stencil was prepared at a temperature of 72° F. and humidity of 40 per cent. It was placed over the artwork and trace-cut. The printing parts of the stencil were then stripped away from the plastic backing sheet. Register marks were also cut in and stripped at this time. The stencil was then adhered to the screen using a solution of 1/3 alcohol, and 2/3 vinegar. When dry, the plastic backing sheet was peeled away. The stencil was then allowed to "season" in the temperature/humidity-controlled room for a period of one hour. The experiment started after the hour had elapsed.

The aquafilm showed the greatest amount of change, having a total expansion of .026 inch. (See Fig. 1) The expansion was caused by the film absorbing the humidity in the air.

Printing difficulties began to occur at a relative humidity of 70 per cent. The stencil was becoming tacky, and small bubbles appeared, indicating a partial loss of adhesion.

At a relative humidity of 80 per cent, extreme printing difficulties were encountered. The stencil was excessively tacky, and was beginning to come away from the screen upon removal of the stock. After
Expansion readings

Least squares

Formula for prediction:  \( Y = a + bX \)
\( \begin{align*}  
a &= -8 \\
b &= .82 
\end{align*} \)

Standard Error of the Estimate: 2.29
nine prints had been made, the stencil could no longer be used.

The second stencil tested was blue-poly 2. The artwork, in photographic negative form, was placed over the film. The film and artwork were placed in a vacuum frame in a way that would expose the film through the polyester backing sheet. The film was then exposed to a 3,000 candle power carbon arc light for a period of 2-1/2 minutes. The light was 64 inches from the film.

The film was then developed in a special developer (contents not known) for a period of 1-1/2 minutes. The film was then washed out with 100°F. aerated water, until clean. The film was then rinsed with cold water, and adhered to the screen.

When dry, the stencil was stripped, and placed in a room with a constant temperature of 72°F. and 40 per cent humidity for a period of one hour. At this point, the experiment began.

Blue-poly 2 proved to be more stable than did the aquafilm, having a total expansion of .013 inch. (See Fig. 2) However, some expansion was occurring in the film with the first humidity increase. The first printing problems began to occur at a humidity of 70 per cent. The film was getting tacky, but no loss of adhesion was evident. The stock was sticking slightly to the stencil upon removal after printing.

At 80 per cent humidity, the film was extremely tacky, making printing difficult. Small cracks were beginning to appear on the stencil. Only seven good prints were made at this humidity. The cracks began to print on the eighth print made, and upon removal of this print,
FIGURE 2

Blue-Poly 2 Linear Regression Graph

Expansion (thousandths of an inch)

Humidity

Expansion readings
- Least squares

Formula for prediction: \( Y = a + bX \)
\[ a = -1 \quad b = .34 \]

Standard Error of the Estimate: 1.4
the film was coming away from the screen, sticking to the paper.
Further printing was impossible due to the breaking up of the stencil.
The stencil was distorted very little during all of the printing.
It printed well at 70 per cent humidity, but broke down almost completely
at 80 per cent humidity.

The third stencil tested was the direct-emulsion type. The
liquid emulsion was first sensitized. The sensitizer was a solution
of four ounces of ammonium bichromate mixed into one quart of 85° F.
temperature water. This sensitizer was then added to the emulsion in
the ratio of one part sensitizer to five parts emulsion.

Coating of the screen was done under yellow lights, so as not
to affect the light-sensitive emulsion. A small portion of the emulsion
was poured onto the screen, and pulled across the screen using a
plastic scraper. When the entire screen was coated, it was placed in
front of a fan and allowed to dry for 20 minutes. The second coat was
then applied in the same manner as the first.

The artwork, in photographic negative form, was placed on the
printing side of the stencil, and held in place in a vacuum frame. The
stencil was exposed to a 3,000 candle power carbon arc light, placed
64 inches from the stencil, for a period of three minutes. After
exposure, the stencil was washed out with 110° F. aerated water until
the design was clean.

When dry, the stencil was seasoned for one hour in a 72° F., 40
per cent humidity controlled room. It was at this point that the
standard was printed, and the experiment was begun.

The direct-emulsion stencil proved to be the most stable of all films tested, having a total distortion of only .005 inch. (See Fig. 3) The first distortion did not occur until the 70 per cent humidity test was made.

Throughout the experiment, the stencil showed no apparent effects of the humidity. It did not become tacky or break up in any way. It was as easy to print at 80 per cent humidity as it was at 40 per cent humidity.

A linear regression graph was plotted for each of these films, because regression is one of the more common methods of statistical analysis used to measure relations between two variables.\(^{10}\) Regression may be called a trend, or a line which shows how many units of change in one variable are associated with one unit of change in another variable.

The regression line was computed using the method of least squares. This regression line, colored red on all figures, is the one which on the average comes nearest to all the points of data. The least squares method of computing the line was used because it gives a more complete and adequate analysis of the data than does a free hand line, or lines through class averages.\(^{11}\)


\(^{11}\) Blair, p. 232.
FIGURE 3

Direct-Emulsion Linear Regression Graph

Expansion (thousandths of an inch)

<table>
<thead>
<tr>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Expansion readings

Least squares

Formula for prediction: $Y = a + bX$

- $a = -2.50$
- $b = .17$

Standard Error of the Estimate: .76
The mathematical formula for a straight line is \( Y = a + bX \), in which \( Y \) and \( X \) represent the measurements of pairs of data.\(^{12}\) The "a" measures how high or low the line is on the graph, and "b" indicates the slope of the line. That is, how many units it changes on \( Y \) for the change of one unit on \( X \). If "b" is positive, the relationship between \( X \) and \( Y \) is positive, and the trend line rises to the right. If "b" is negative, there is a negative relationship between \( X \) and \( Y \), and values of \( Y \) decrease as values of \( X \) increase.

The purpose of the regression equation is to estimate average values for \( Y \) from specific values of \( X \). Since these two values were not identical, the standard error of the estimate was computed to measure that error.

The practical application of this formula will reveal to screen printers how much expansion can be expected in screen process films when humidity increases.

\(^{12}\) Blair, p. 243.
CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

An experiment was conducted to determine the effects of humidity on screen process stencils. There are three basic types of stencils, each type having several variations. The stencils chosen were the most commonly used variation of each of these three basic types.

Two rooms were chosen for the experiment. One of these rooms, room 1, was constantly maintained at a temperature of 72° F. with a relative humidity of 40 per cent. The other room, room 2, was maintained at 72° F. with the humidity adjusted as necessary.

All materials used in the experiment, except the stencils mounted on the screens, were kept in room 1 until needed. The stencils were kept in room 2, which at the outset was maintained at 72° F. with a relative humidity of 40 per cent. After the stencils had remained in room 2 for one hour they were printed, thus producing the standard by which all other prints would be compared.

After the standard print was made, all materials, minus the stencils, were returned to room 1. The humidity in room 2 was then raised 10 per cent, to a level of 50 per cent. After the humidity was effectively raised, the stencils remained in this room for one hour.
One hour was recommended as being long enough for the stencils to be affected. At this time, the second print was made. All printing was done in room 2. This process was repeated until all humidity changes had been tested, and the stencil could no longer produce any prints.

When all prints had been made, they were examined with a micrometer, under a magnifying glass, to determine the amount of change that had occurred. Each of the experiments took between 18 to 20 hours to complete. Once an experiment was started, it was not interrupted until all humidity changes had been tested and the stencil was no longer able to print.

**Conclusions**

All stencils tested were affected by humidity, so the null hypothesis is rejected. The transfer stencils were affected more than was the direct-emulsion stencil. Also, the hand-cut stencil was affected more than either of the two photo-sensitive stencils.

The reason for the transfer stencils distorting more than direct-emulsion stencil could be because of the way in which they are adhered to the screen. The transfer stencil and the screen are two distinct parts of the completed printing plate. In a highly magnified cross-sectional view of the printing plate, (see Appendix D) it can be seen that the film is merely stuck to the nylon fibers of the screen. Large portions of the stencil are hanging down from the screen. The stencil receives very little support from the screen.
Because the direct-emulsion film is applied to the screen in liquid form, it becomes an integral part of the screen. For this reason, the film receives maximum support from the screen. Since a nylon screen is not affected by humidity, there was practically no distortion in the direct-emulsion stencil. (See Appendix D) The fact that the film is an integral part of the screen could explain why the direct-emulsion film did not break up under high humidity conditions.

It should be noted that the direct-emulsion film took considerably longer to prepare than did either of the two transfer stencils. Also, the direct-emulsion film did not print as sharp a line as did the photo-sensitive transfer film. This difference in sharpness, however, is not due to changes in humidity.

The reason for the hand-cut film distorting more than the photo-sensitive film could be in the chemical composition of the film itself. The exact chemical composition of the films tested are trade secrets and could not be obtained by the writer. However, it appears that the photo-sensitive films are designed to be more stable than hand-cut films. This would be logical, since many of the photo-sensitive films are used for printing half-tones. Also, photo-sensitive transfer films are used for doing four-color process work, where dimensional stability is a critical factor.

The Pearsonian coefficient of correlation test was used to measure the amount of variation of a film's expansion that is accounted for by variations in humidity. All three films had a positive
correlation. That is to say, that as the humidity was increased, the amount of expansion increased.

The coefficient of correlation for aquafilm was .96, for blue-poly 2 it was .94, and for direct emulsion it was .92. On the basis of this information, the working hypothesis is accepted.

**Recommendations for Further Study**

The author would like to recommend that this same experiment be repeated at different temperatures. The amount of water vapor that air can hold is dependent upon air temperature. At high temperatures, the air can hold more water vapor, and thus the screen process films may be affected to a greater degree. Also, an experiment could be conducted in which both the temperature and the humidity are changed, and their combined effect on the films measured.
APPENDIX A

Aquafilm Prints
Aquafilm
Relative Humidity 40%
Standard
Aquafilm
Relative Humidity 50%
Expansion .001 inch
Aquafilm

Relative Humidity  60%

Expansion  .008 inch
Aquafilm

Relative Humidity 70%

Expansion .014 inch
Aquafilm

Relative Humidity 80%

Expansion .026 inch
APPENDIX B

Blue-Poly 2 Prints
Blue-Poly 2

Relative Humidity 40%

Standard
Blue-Poly 2
Relative Humidity 50%
Expansion .001 inch
Blue-Poly 2

Relative Humidity 60%

Expansion .008 inch
Blue-Poly 2
Relative Humidity 70%
Expansion .009 inch
Blue-Poly 2
Relative Humidity 80%
Expansion .013 inch
APPENDIX C

Direct-Emulsion Prints
Direct-Emulsion

Relative Humidity 40%

Standard
Direct-Emulsion
Relative Humidity  50%
No Expansion
Direct-Emulsion

Relative Humidity  60%

No Expansion
Direct-Emulsion

Relative Humidity  70%

Expansion  .003 inch
Direct-Emulsion
Relative Humidity  80%
Expansion  .005 inch
APPENDIX D
APPENDIX D

Transfer film adhered to screen

Direct-emulsion film adhered to screen
BIBLIOGRAPHY


