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A study on the relationship of the moisture content of paper and the setoff rate of drying oil lithographic ink and its application to thermographic printing

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A Study on the Relationship of the Moisture Content of Paper and the Setoff Rate of Drying Oil Lithographic Ink and Its Application to Thermographic Printing

By

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Certificate of Approval

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

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with a major in Printing Technology
has been approved by the thesis committee as satisfactory for the thesis requirement for the Master of Science degree at the convocation of

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The focus of this study was to determine the specific moisture content of several different papers that were exposed to four different relative humidity environments at approximately 30 degrees centigrade. This was done in order to see if the amount of water present in a sheet of paper affects the drying rate of drying oil inks. This in turn was done so that we would be able to determine if the rate at which this ink dries and its corresponding increase in viscosity affected the tack or "stickiness" which is vital to thermographic printing applications.

The addition of moisture to paper as it is printed lithographically is known to retard the complete drying of drying oil inks. However, in this study, the concern was centered on the role of moisture hygroscopically trapped within the fibers of paper before it enters the lithographic press and its effect on the initial phases of ink drying where the applied ink film is at its tackiest.

The relationship of the drying rate of drying oil ink to thermographic printing is rooted in the application of a finely ground plastic resin to a freshly printed ink film. Tack is usually an important consideration on the press due to the nature of the lithographic system and the principles of ink splitting and trapping. Here, however, the tack of the printed ink surface is of concern due to reception and required retention of plastic resin as is the procedure in thermographic printing.

The goal of this endeavor was to more fully understand the influence paper moisture has on the tack of drying oil ink and to make conclusions on the conditions that prove to be preferable for maximum ink tack results.

CHAPTER I

INTRODUCTION

The problem being addressed is the variability in the length of the induction period of drying oil inks and its effect on the viscosity of the printed ink film. Immediately after a layer of ink is printed, there exists a period of time that has been termed the induction period. During this period there is no absorption of oxygen and no corresponding increase in ink viscosity. Generally speaking, drying oil ink is composed of three components: the varnish vehicle, the pigment, and the drier which is a metal based salt that aids in the absorption and transferral of oxygen to the varnish base. During this induction period there is no absorption of oxygen and no increase in ink viscosity. This occurs because the drier is thought to be reacting with natural antioxidants in the varnish vehicle.

At the end of the induction period, the ink begins to absorb oxygen from the air, and the viscosity of the ink increases. The addition of oxygen promotes a type of polymerization called cross-linking. During this reaction, drying oil molecules hook together, thereby causing a rapid increase in the viscosity of the ink film. It is this course of events upon which lithography that employs drying oil ink depends for its drying mechanism.

In the complete cycle of drying oil ink drying, the printed film goes on to stages of gel formation and the final step of film deterioration where complete hardening of the ink film takes place. However, here the concern is with the aforementioned preliminary aspect

of drying oil inks--the induction period.

Optimum ink viscosity is preferred in thermography because the resin applied to the image area must resist the pull of the vacuum that is present to remove unwanted resin from the non-image areas of the sheet. A short induction period for drying oil ink is needed so that the ink quickly begins to absorb oxygen from the air and displays an increase in viscosity or surface "thickness." The speed at which the ink completes its induction period is directly related to how quickly the ink begins to experience an increase in viscosity and tack.

The problem is really rooted in the effect of the moisture content of paper as influenced by the atmospheric relative humidity on the drying rate of the ink. While it has been acknowledged that moisture is picked up by the sheet of paper as it passes through the blanket/impression nip, it is also prudent to determine the extent of influence moisture contained by the paper before it is printed will have on the final printed press sheet. The concept of the moisture content of paper is usually important in discussions on dimensional stability of the sheet and complete ink drying rates. Here the concern is determining the effect moisture present in the paper before it is printed has on the early stages of drying oil ink setting and drying.

This problem ties into thermographic printing in the following manner. In thermography or "raised printing," a freshly printed sheet of paper is dusted with a finely ground powder of plastic resin. The sheet is then subjected to a vacuum in order to remove the powder from the non-image area. The tack of the ink on the image area must be sufficient to resist this vacuum, because the resin retained on the

printed area will fuse and rise after the sheet is heated to approximately 200 degrees Fahrenheit from coils above and below the conveyor upon which the sheet travels. For a more detailed discussion on the principles and practices of thermographic printing applications, see the following section.

It has generally been established that as the relative humidity or water content of the air in the pressroom increases, ink drying time increases markedly. However, the goal of this study is to determine the effect, if any, the moisture content of a single sheet of paper has on the initial phases of ink drying. It is theorized that the reason high atmospheric relative humidity lengthens ink drying is because the presence of excess water vapor in the air interferes with the absorption of oxygen by the drier in the ink. In the design parameters delineated here, the question centers not on the problem of excess atmospheric relative humidity and its influence on ultimate ink drying in standard lithographic printing procedures, but rather the answers are to questions unique to thermographic printing.

The problem of lengthy induction periods is being addressed because printed sheets are fed into thermographic units immediately after the completion of the blanket impression and delivery off the lithographic press. Normally, ink drying concerns are associated with the problem of ink blocking and/or bindery operations. Thermographic applications and system requirements, on the other hand, need a printed image area on paper that is as tacky as possible. If the role played by moisture present in the paper before it is printed extends the induction period of the drying oil ink, the oxidation/polymerization process will not occur quickly enough. This can only

contribute to poor thermographic output. Insufficient resin application yields unacceptable and undesirable texture and appearance.

The key questions that lend themselves to the discussion above and the matter at hand are: Does the moisture content of paper (minus the water additive influence of the lithographic printing experience) have a significant bearing or influence on the induction and subsequent drying rate of drying oil lithographic ink? If so, can basic guidelines be established regarding acceptable limits of moisture in paper that can be allowed to be printed in a thermographic situation?

Due to the nature of thermographic printing procedures as described above, a display of favorable ink tack conditions will be designated as a positive environment for good results in the realm of resin adhesion. A tacky image on the printed substrate is solely responsible for the adhesion between the ink surface and the plastic resin particle. Lack thereof will ordinarily signify and also serve as a precursor to potential problems.

It is necessary to determine the relevance of moisture in paper in the matter at hand due to the requirements of lithography. The very tenet of printing by lithographic means involves the inescapable usage of water as an integrated function. In looking into the question of moisture and ink induction period symbiotic circumstance, a more thorough understanding of the benefits of preferred water usage and control will allow for a more purposeful and rational approach to this type of printing.

The uniqueness of this concern toward a much studied phenomenon such as the ink-water relationship that exists in lithography is anchored in the premise of thermographed printed matter itself.

Thermographed products have come to be associated with high quality and above average appearance. No matter how precise and exemplary the image is graphically reproduced by the printing press, the postpress performance of the thermographic unit makes or breaks the finished output. The elevated expectations that come with thermographic materials put heavy system requirements on the process itself. Therefore, it is not only prudent but vital to know how the moisture content of paper being used will affect the conditions of the ink, once it has been imbedded in the fiber walls of such paper.

The design of the experiment undertaken here revolves around the application of a drying oil ink on paper samples in which the basic water content is varied. Interpretation of the results can yield answers to the questions and the significance of the nature and extent of water's influence on a process that needs to be dissected to the limit of practical examination.

CHAPTER II

THERMOGRAPHY

The origins of thermography can be traced back to the beginning of the century. Initially, to achieve the raised effect desired, a sheet printed via letterpress was sprinkled with a ground resin and held above a kerosene flame to melt the resin. This seemingly radical procedure was devised to supplement expensive copperplate engraving used in fine printing, such as formal invitations and representative business stationery. The development and implementation of this process allowed for the adaptation of common printing to higher levels of quality.

In the past 70 years, this secondary printing process has been fine tuned and raised to loftier levels of sophistication. Today, all thermographed printing is associated with lithographic printing. The growth of lithography during the past 50 years that has resulted in its dominance as the most widely used form of printing has lent itself well to the concept of thermography. Moist, freshly printed ink in lithography is sufficient in tack and surface characteristics whereby it acts as the optimum receiver of thermographic powder.

Regarding the types of resins used in thermography, the requirements are a sufficiently low melting point and melting point range, as well as low melt viscosity to allow the material to fuse and level at a temperature that will not burn paper. At one time, shellac was the standard. Other materials such as rosin derivatives have been used and may still have special applications on film and foil. Currently,

almost all of the thermopowder and powder set resin is a polymid, of which nylon is an example; but these materials have much lower melt viscosity. The selection is based on color ranging from yellow to white, and full-gloss through semi-gloss to dull (see Figures 1 through 3 on the following pages). Various percentages of mica are customarily used for gloss control.

The complete process may be described as follows. Immediately upon the completion of the blanket to paper impression, the sheet is delivered (the vast majority of lithography is done in sheet-fed format) via the delivery system, be it chute or the more predominant chain delivery. Then, the sheet is dropped onto the conveyor portion of the thermographer which has been inserted into the delivery section of the press above the feed table. With the sheet riding on the conveyor, it passes underneath a powder reservoir which dispenses a steady stream of powder onto the sheet. Because of this distribution system, the powder covers the entire sheet, both image and non-image areas.

Immediately following the application of powder, the sheet passes under a vacuum which removes the unwanted powder from the non-image area of the sheet. This portion of the discussion is the crux of the matter at hand. Due to the tack of freshly printed ink, the vacuum is unable to remove the powder from the image area. The crucial role of the ink tack becomes apparent when it is understood that the amount of powder that remains on the sheet after submission to the vacuum determines the level and/or quality of the finished output.

The next step in the procedure is the application of heat from above and, in most cases, below the sheet. The types of heaters used

Figure 1 - Full-gloss Thermography

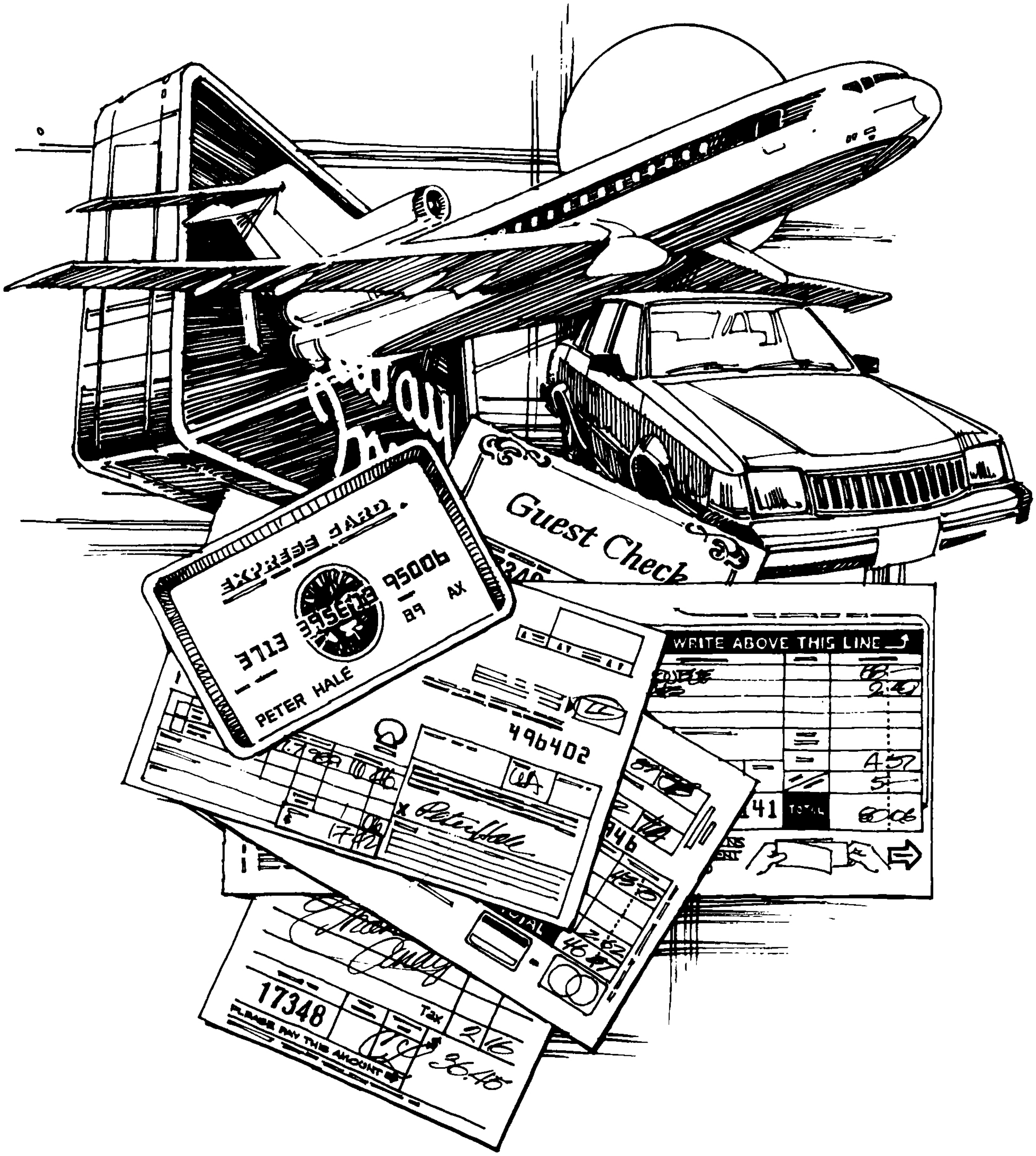

Figure 2 - Semi-gloss Thermography

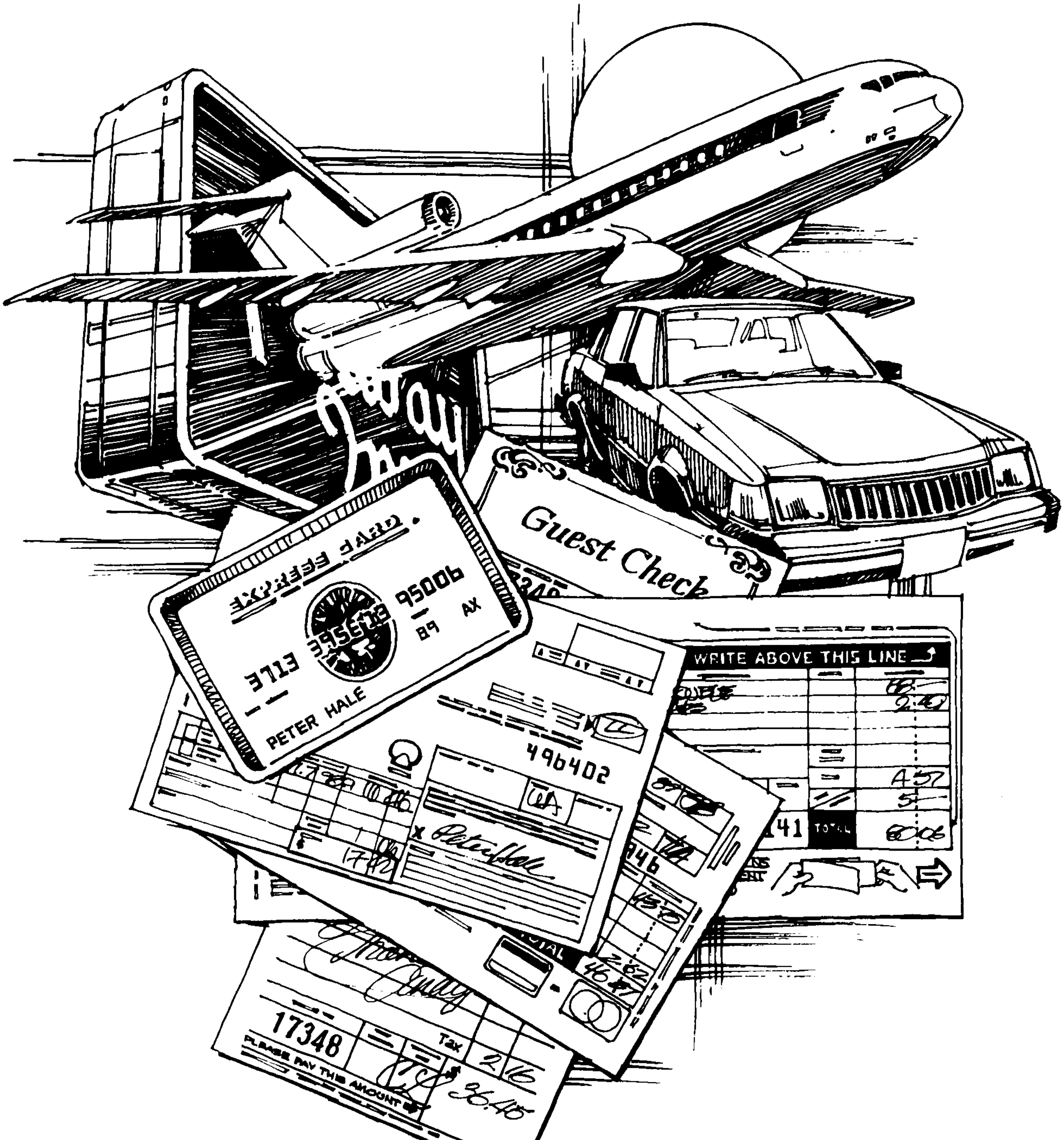

Figure 3 - Dull Thermography

in the equipment vary from manufacturer to manufacturer. The three most common types of heaters used are gas, calrod, and infrared. In all thermographers the heat source is fixed anywhere from three to eight inches from the conveyor. The paper needs to be brought up to approximately 200 degrees Fahrenheit in order to be able to transfer the heat to the powder. Melting points of various powders differ; however, 200 degrees is a common average for powders industry-wide. As the powder melts, it becomes fluid and flows. This change in state also results in the swelling of the powder as it becomes liquid. This occurrence continues only as long as heat is applied. That length of time is controlled by manipulation of conveyor speed which is a function, as determined by the press operator, of the requirements of the job at hand.

Once the application of the heat ceases, the liquid plastic instantaneously becomes a clear solid once again. The sheet is then cooled by the forced air that is blown through vents toward the end of the thermography unit.

The cooled sheet (although it is still warm to the touch) is then delivered into a receiving tray where the sheets gather and are ultimately collected.

The purpose of using powders that are transparent after thermographing is to reveal the actual color of the ink printed. The finishes of these also vary, from glossy, semi-gloss, semi-dull, and dull. However, in certain cases where a special effect is desired, a colored powder, usually silver or gold, is used in order to make it appear that special ink was used when, in reality, any color ink may be used when using colored powders because the powder fully masks the

ink upon which it lies. Fluorescent and metallic pigments have now been fully implemented by the industry in order to enhance the usual effects of thermography.

The reasons for performing this secondary procedure are many. As stated above, raised or relief printing was first associated with fine line work in order to duplicate the more expensive engraving process. It was used solely on wedding invitations, social stationery and business cards. While these products continue to remain a mainstay of the process in terms of output, the uses have grown over the years. Many corporations, in addition to business cards, have decided to have a large portion of all their correspondence materials thermographed. Corporate letterheads, envelopes, billheads, and labels, all bear the mark of thermography in order to enhance the image of the materials. The economic factors behind the greater usage of thermography over the years have been a driving force. The printer is able to sell to his customer something that looks much more expensive than has to be charged for it. This arrangement has allowed both parties to benefit.

The second market to bloom for thermography was the greeting card industry. The raised effect achievable was a natural for improving the appearance and appeal of artistic and esthetically oriented greeting cards. At first it was used to highlight portions of a design. Luminescent metallic powders and high gloss finishes applied to both the design and line areas of the cards created a unique product that lent itself well to the desires of both the manufacturers and the buying public. Greeting card manufacturers have found that a small increase in production costs has yielded improved sales which offset

any additional costs.

Another field arising for thermography is in the area of "product simulation." This is used in areas of advertising and promotional displays where a three-dimensional effect is needed. The ability to make printed paper feel like leather, wood or brick creates a sensory effect that supplements merely looking at a display. Thermography in this area may be used to simulate, for instance, the feel of a leather shoe, gauze bandage, cloth upholstery, a vinyl car top or the smoothness of ceramic tile. These images reproduced in advertising circulars and displays by the preliminary printing and secondary powder application have enabled thermography to expand in a way that has proved to be huge in terms of greater market share and consumer awareness.

Yet another use for thermography is in fine art reproduction. The re-creation of brush stroke patterns that appear on original oil paintings is readily made. Combinations of coarse and fine powders add the sense of touch to the depth of color and dimension.

Thermography has even gone beyond the bounds of its association with printing by finding other industrial uses. The production of ceiling tiles and the decoration of glass panels are made possible through thermography. It is also used as an etching resist in the production of aluminum name plates.

Obviously, the scope of thermography is large. It has become an industry unto itself, and since its union with printing provides its main support, the association of the two merit a closer look in terms of their technical interactions. It is a part thereof that is of

concern here. As in all interrelations, the microscopic knowledge of the inner workings of the process yield more sufficient and highly favorable output.

Examples of thermography were shown previously in Figures 1-3.

CHAPTER III

LITERATURE REVIEW

Throughout the pertinent literature, the topic of ink drying and the factors that influence it have been discussed in detail. The characteristics such as vehicle type, pigment content and concentration, state of emulsification, and dryer content are some of the factors that play a significant role in drying. Absorbency of the sheet, paper pH, and fountain solution acidity are all aspects of lithographic printing that have been shown to have a bearing on the drying rates.

However, the scope of this research was only meant to encompass the question of paper moisture. Graphic Arts Technical Foundation's Lithographers Manual speaks of increased drying times that simultaneously occur with an increase in the relative humidity of the air. This occurs because drying oil inks intended for lithographic use are designed to absorb water due to the system requirements as far as plate dampening and back trapping are concerned. This characteristic, while necessary, can also prove to be troublesome because after printing the ink can absorb water from the air and prolong final drying.

Both the Lithographers Manual and other Graphic Arts Technical Foundation sources very briefly discuss the moisture in paper aspect of ink drying and they agree that excess moisture retards drying. But here, however, they are discussing the full or complete drying of ink or, at the very least, the path upon which the printed ink film

travels toward that state. They do not address the effect moisture has on the induction period alone and the tack considerations that this research explores. Also, when consulted references speak of excessive moisture in paper having an effect on ink drying, it is usually done with the understanding that the moisture in question has been absorbed by the sheet as it was printed. This moisture then has the fountain solution as its source, and since fountain solutions are generally acidic by nature, the effect on ink drying is more pronounced in its inherent ability to retard drying rates. Acid present in the fountain solution attacks the drier component in drying oil ink configurations and renders it less effective.

All of the considerations presented above via what is present in the literature really do not address the initial stages of ink drying. Here, the concern is with ink tack, not on the press, but on the printed piece. In most discussions on ink behavior after it is printed, the emphasis is on thorough and uniform absorption of oxygen from the surrounding air and subsequent hardening of the ink film. While establishing the concept of moisture's incompatibility with ink drying needs in general, the literature failed to address the tack subject that is of prime consideration here. This is hardly surprising though, since the scope of this study is particularly narrow in its applications to printing systems other than thermography.

CHAPTER IV

HYPOTHESIS

After examination of the set of circumstances and the sought after goals of this study, the hypothesis that has been formulated is as the percent moisture content of the paper samples is increased, there will be a concordant increase in the induction period of the ink.

It has been shown that the tack of an ink will generally parallel its viscosity. Therefore, the hypothesis is connected to the rate of increase of the ink's viscosity as it displays a corresponding increase in tack.

For the hypothesis to hold true, a marked increase in induction period length will occur as the test lots of paper show an increase in moisture content indivdually. By determining how quickly an ink film begins to show an increase in viscosity and tack, the findings should reveal under what set of circumstances it is necessary to condition paper before it is printed. The hypothesis and its implications relate to thermography's need for as much surface tack as possible.

CHAPTER V

METHODOLOGY

The methodology involved was devised to incorporate basic and elementary procedures that were designed to yield easily applicable data. Three types of paper (examples of which may be described as commonly used in the thermographic industry), an uncoated bond (Cranes Distaff Linen, 100% cotton 24 lb. bond white wove), a chemical pulp offset (Finch Opaque Offset, 60 lb. uncoated), and a coated stock (Champion 60 lb. coated offset), were each exposed to four different levels of relative humidity at the same temperature--30 degrees centigrade. This was done solely to alter and influence the moisture contents of the sample papers. This was achieved by the placement of four super-saturated salt solutions in airtight enclosed glass containers along with the paper samples. The paper samples were cut into strips measuring 1½" wide x 9½" long. The glass containers were placed in a temperature-controlled oven to assure the temperature consistency required over time, in this case being four days. Due to the hygroscopic nature of paper, the paper samples were exposed to conditions that allowed either the absorption or release of water from their fiber walls dependent upon the amount of water vapor present in the air of the individual humidity chambers.

This method is effective in producing and maintaining various relative humidity environments by the alteration of the aqueous surface tensions of the water by the salt compounds. In general use,

saturated salt solutions can be expected to control the relative humidity to within one percent relative humidity of the theoretical values. The four salt solutions obtained by chemically pure salts with distilled water and the relative humidity environments they were chosen to create were as follows:

Lithium Chloride - 12%

Sodium Dichromate - 50%

Sodium Chloride - 75%

Potassium Sulphate - 95%

Originally, this experimentation intended to use Magnesium Chloride in order to obtain a 30% relative humidity environment. However, due to the unavailability of that chemical at the time of testing, Lithium Chloride was substituted for it. This posed no problems, due to the fact that a dry environment was desired (below 50% RH) and the alternate compound suited this requirement adequately.

Each of the paper samples had their percent moisture content measured before and after their exposure to their respective relative humidity environments in order to see how much moisture pickup or loss there was, and to know the specific moisture content of the paper that was applied with ink.

Immediately upon completion of the moisture content determination, a thin layer of black lithographic drying oil ink was applied to all the samples involved. This was achieved by applying a three-gram quantity of ink with a metal roller in order to assure that the entire surface of the paper was equally layered with the ink. A uniform ink film was accomplished via continuous and even pressure. Then, sheets of coated paper (to maximize ink holdout) were placed on top of each

ink film and a weight administered from above forced the sheets into firm contact with one another. This procedure was repeated on approximately eight areas of the sheet at timed five (5) minute intervals in order to see the rate at which the ink on the sample in question becomes more or less tacky. The amount of setoff on the top coated sheet was designed to signify the tackiness of a particular ink film on a specific example. The principle relied on here was, the tackier the ink, the greater the degree of setoff. In order to quantify the degree of setoff, the top sheets were evaluated through the implementation of a reflection densitometer. The density readings of the offset ink provided for the need to assess the results without relying on purely subjective means such as the eye, although the apparent setoff was visually obvious.

The relationship of the amount of moisture in a sheet of paper to the ink setoff over time will determine the correlation between moisture content and the viscosity increase rate. By using timed intervals throughout the course of the drying period of the ink, the procedural mode of operation was enabled to incorporate the concept of a momentary lapse in the normal thermographic procedure.

From the densitometric recordings of the setoff areas, graphs were plotted in order to see the relationship of moisture present and time required for ink tack results.

CHAPTER VI

MODEL

The model for the aforementioned situation may be characterized as an analogue model. The application of a drying oil ink to a sheet of paper might be compared to the application of an oil based paint to a wood surface. When first applied out of the can, the paint has a low viscosity in order to facilitate its application. Once put down in a thin film, however, the surface quickly begins to absorb oxygen from the air and its viscosity and tack begin to rise. Oxygen is absorbed and added to the double bonds of the molecules of the drying oil. Polymerization then takes place through the action of the drying oil molecules hooking together. After the initial induction period where there is no absorption of oxygen, the viscosity of the paint increases with time. It is this model upon which the previously described ink/paper relationship may be compared.

CHAPTER VII

ANALYSIS OF THE DATA

An analysis of the data here will revolve around the point at which the level of measured ink tack on the surface of the sample sheets began to level off or rise after the across-the-board initial drop-off in tack.

The first to be looked at was the cotton paper sample. The graphed results in Figures 4-7 show that the reflection density readings for this sample began to level out at the 15-minute mark in the case of all the relative humidity environments except for the highest (95%), where a leveling was noted at the 10-minute mark.

The second paper sample evaluated was the uncoated offset sheet. In this case, the graphed findings show that the reflection density readings began to level out at the 15-minute mark except in the case of the 75% RH environment where a leveling was seen at the 10-minute mark.

The third paper sample tested and analyzed was the coated sheet. Going into this study, it was thought that results seen might very well differ for the coated sample due to the insulating nature of the coating ingrained and embodied within the fiber walls of the paper. This turned out not to be the case. For the 12% and 50% RH environments, the density measurements leveled off at the 15-minute mark. For the 75% and 95% conditions the readings leveled out at the 10-minute mark.

All of the above discussed may be seen via graphic representation

in Figures 8-10.

For the results discussed here to have corresponded to the premises laid down in the hypothesis, a leveling off or increase in tack would have occurred at later and later time marks as the percent of moisture on the samples increased. This would have signified the relevance of increased moisture lengthening the induction period. However, as denoted in the evaluation and as presented here, it can be understood that, regardless of the level of moisture or its particular relevance to a specific paper, the leveling point stayed within the parameter of five minutes. This shows that the ink used in the experiment in combination with the surrounding air at the time of drying were the dominant determinant factors in influencing drying rates, tack and measurable reflection density readings.

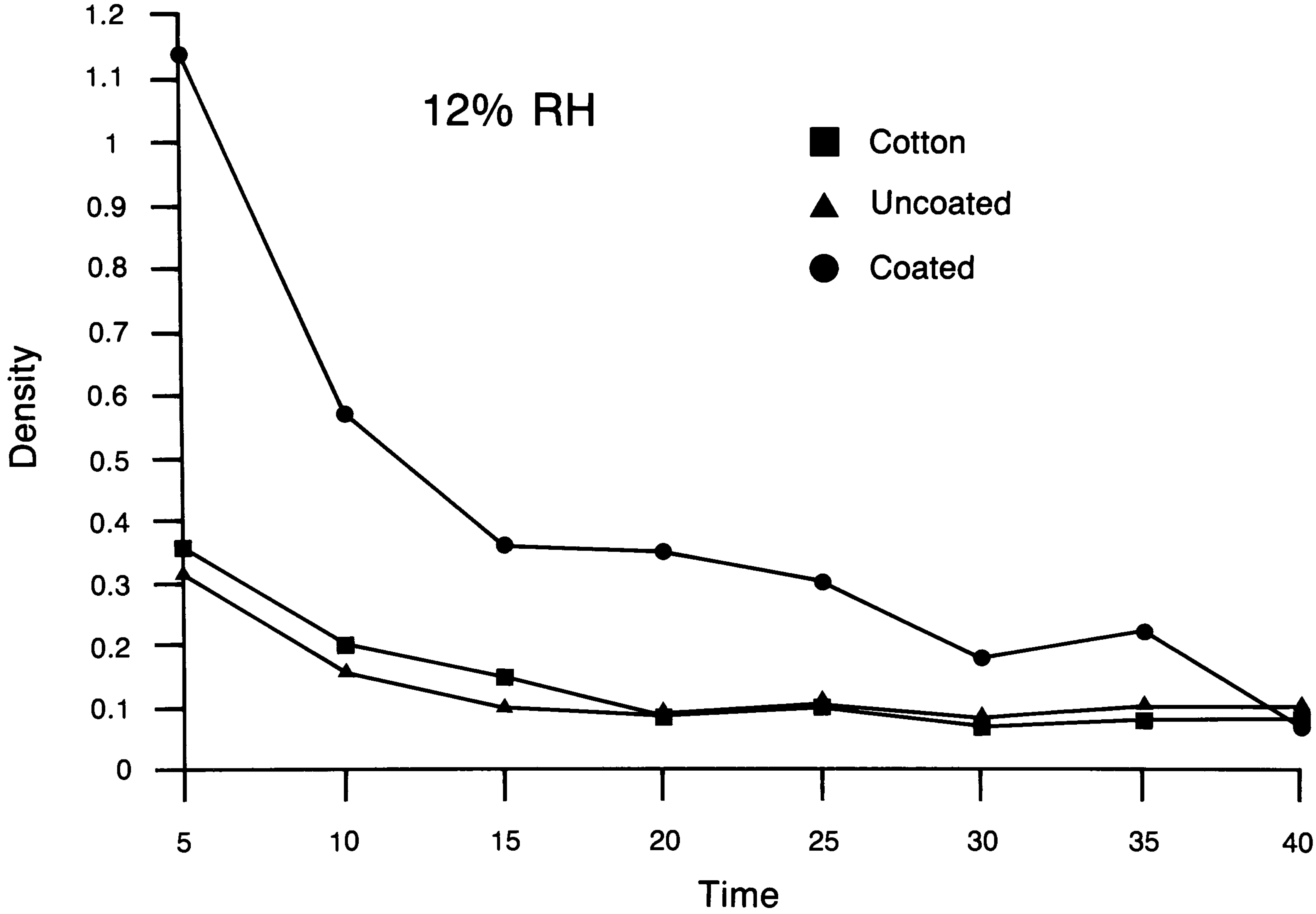

Figure 4 - 12% Relative Humidity

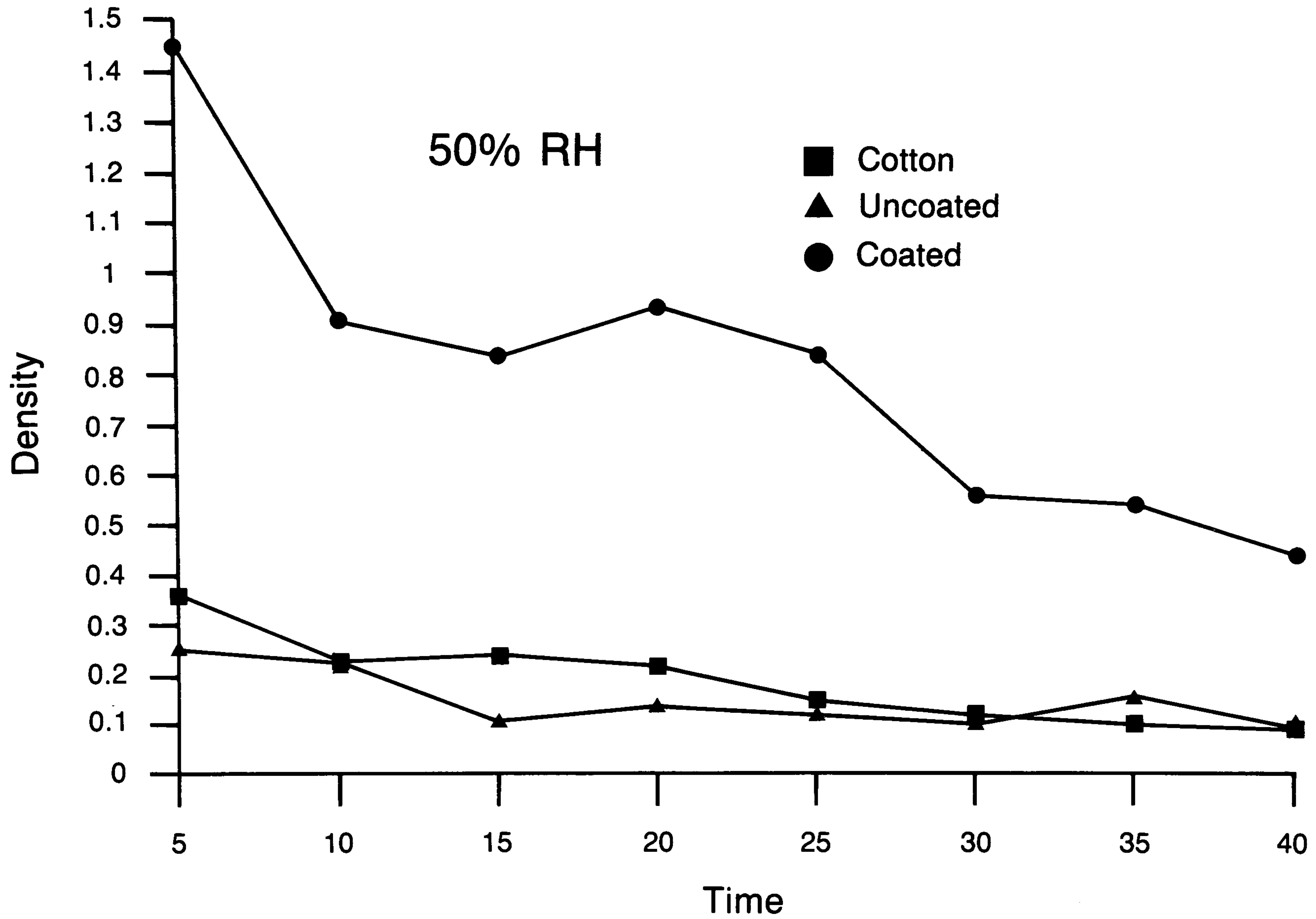

Figure 5 - 50% Relative Humidity

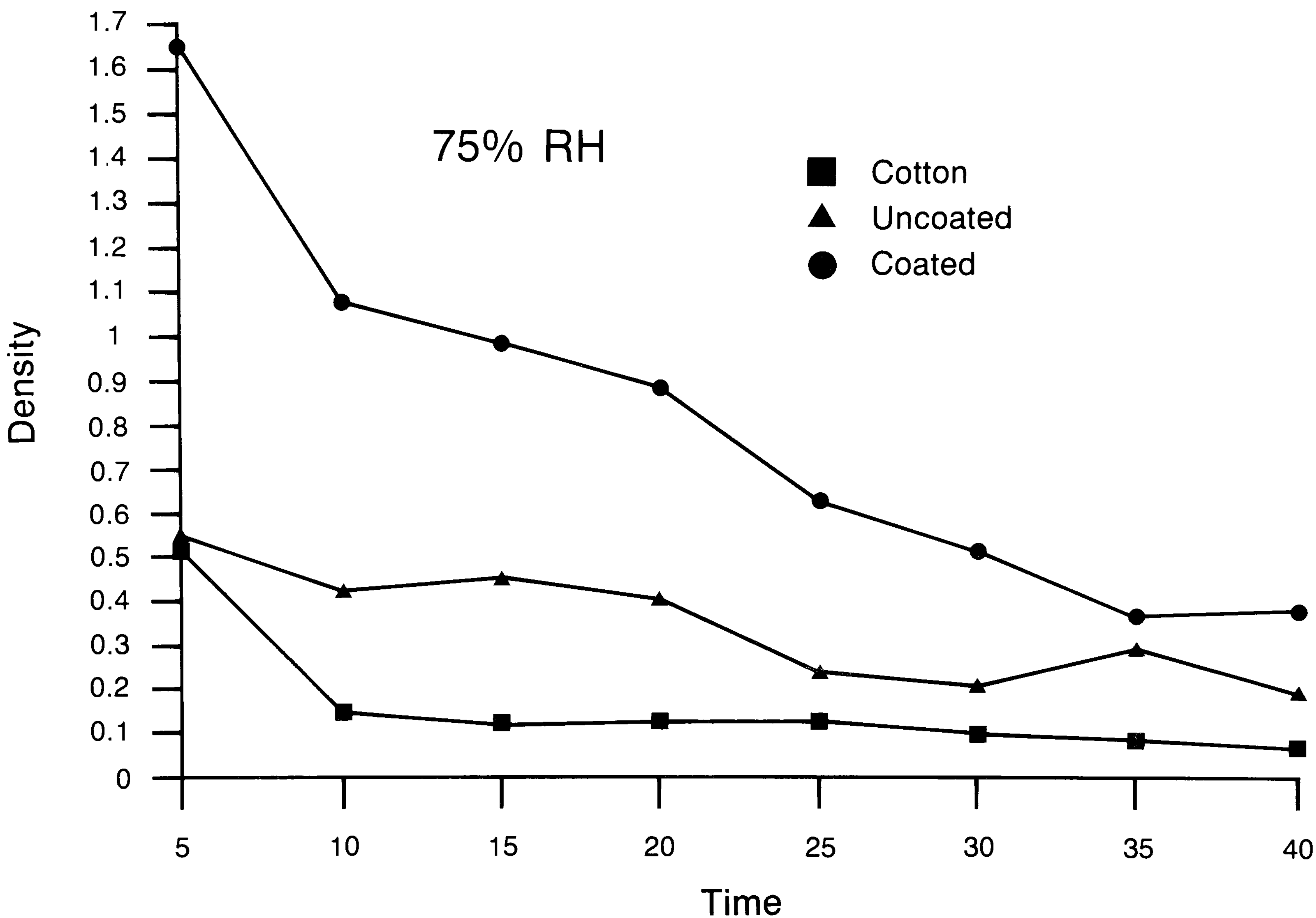

Figure 6 - 75% Relative Humidity

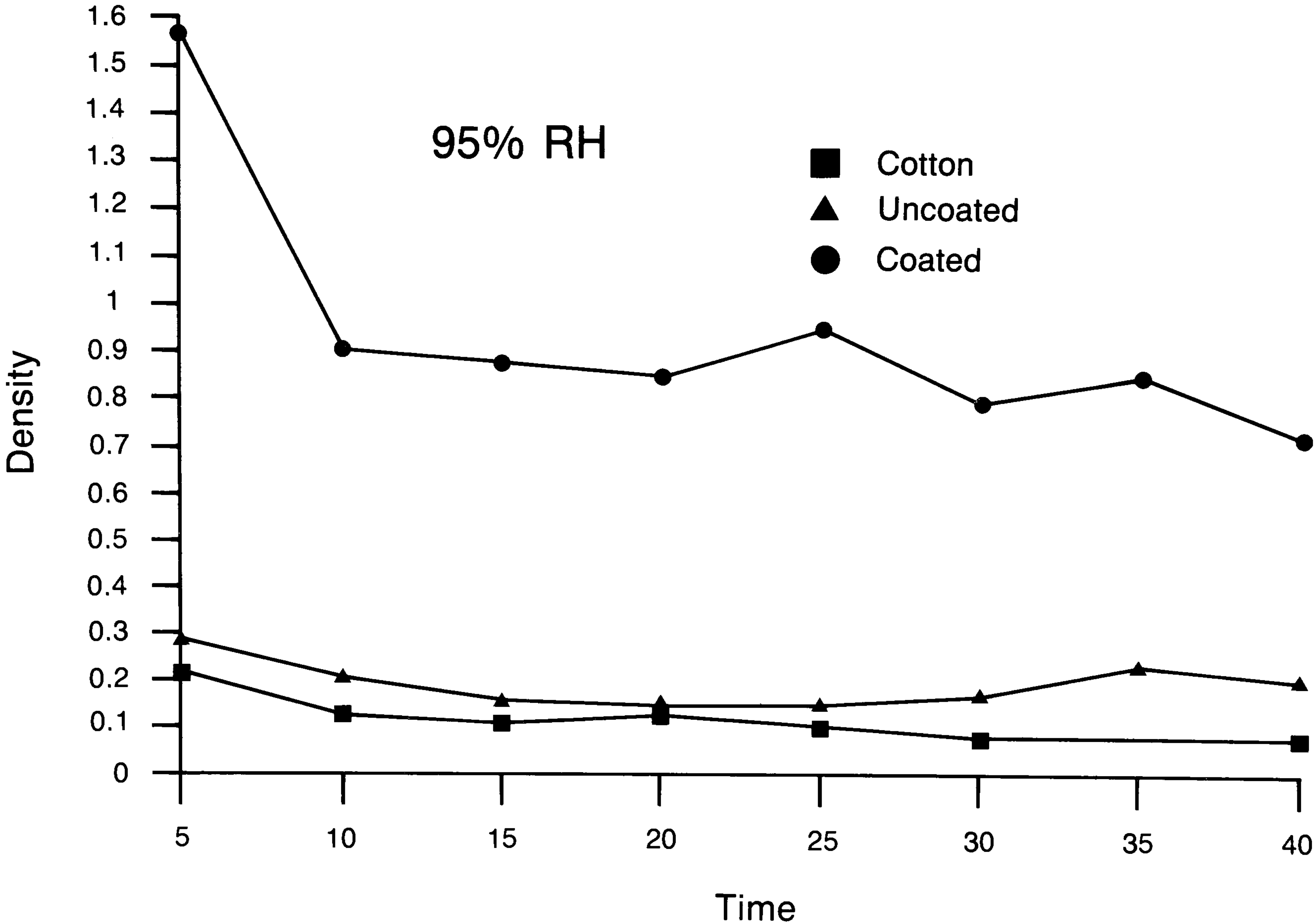

Figure 7 - 95% Relative Humidity

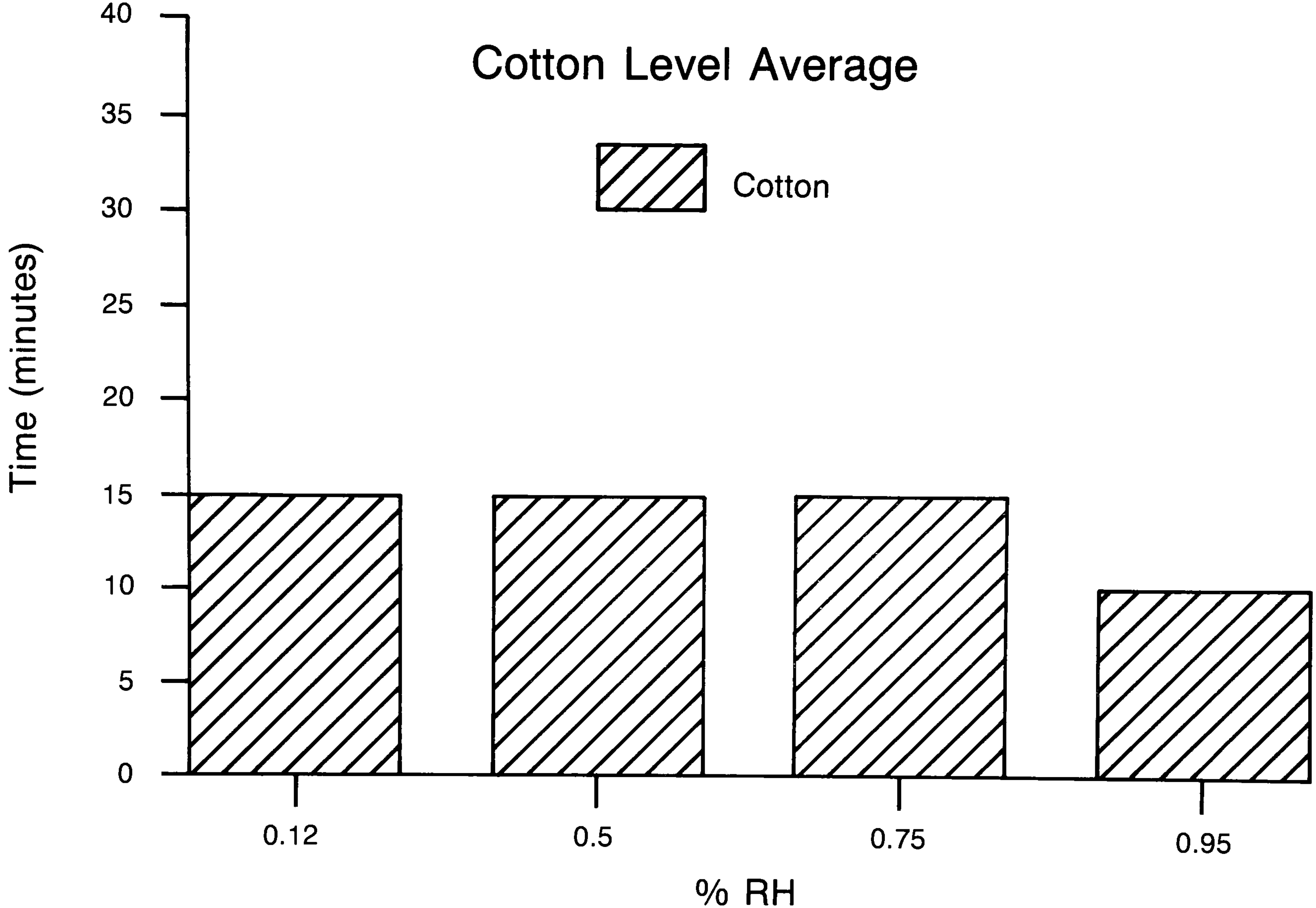

Figure 8 - Cotton Level Ave.

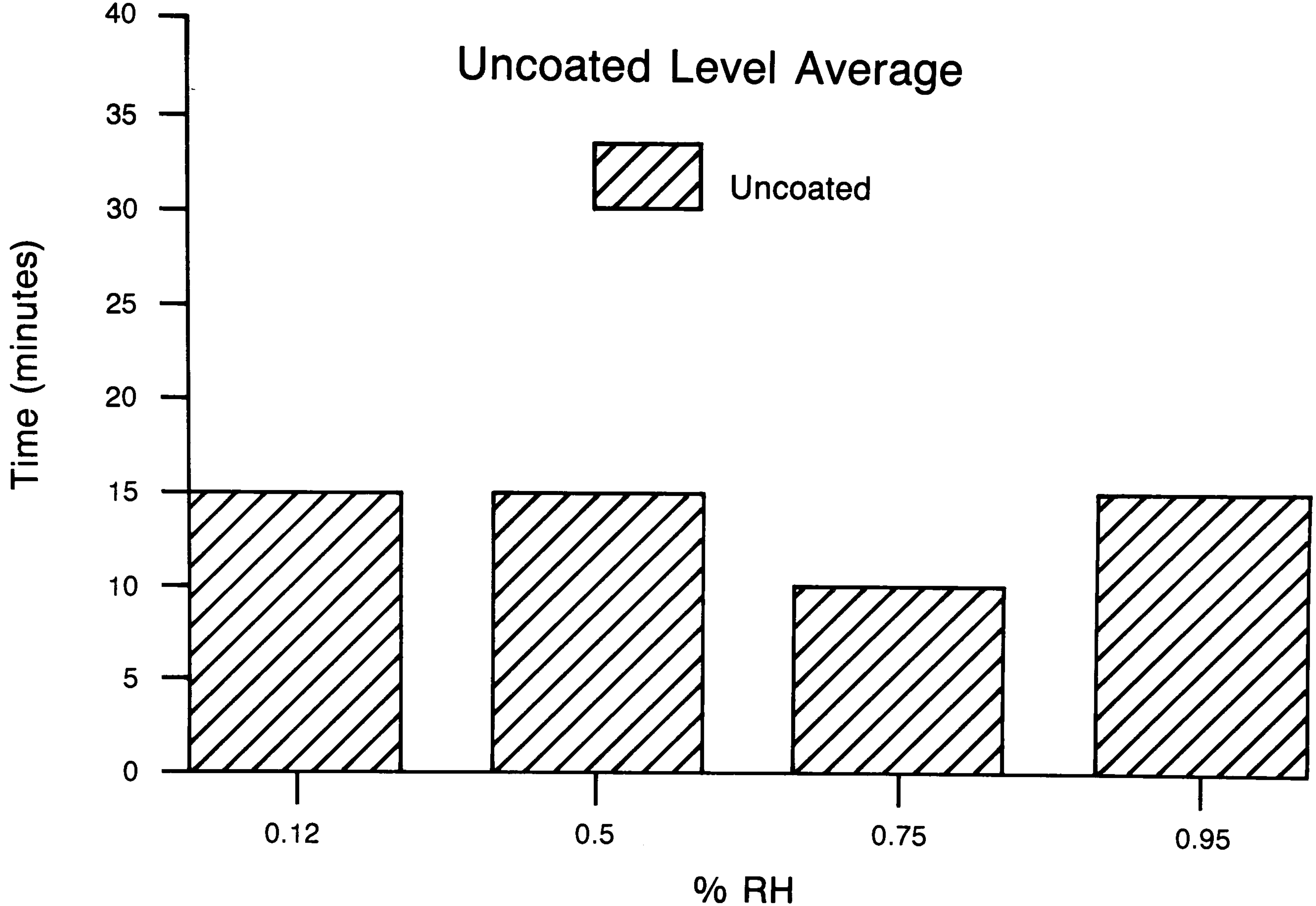

Figure 9 - Uncoated Level Ave.

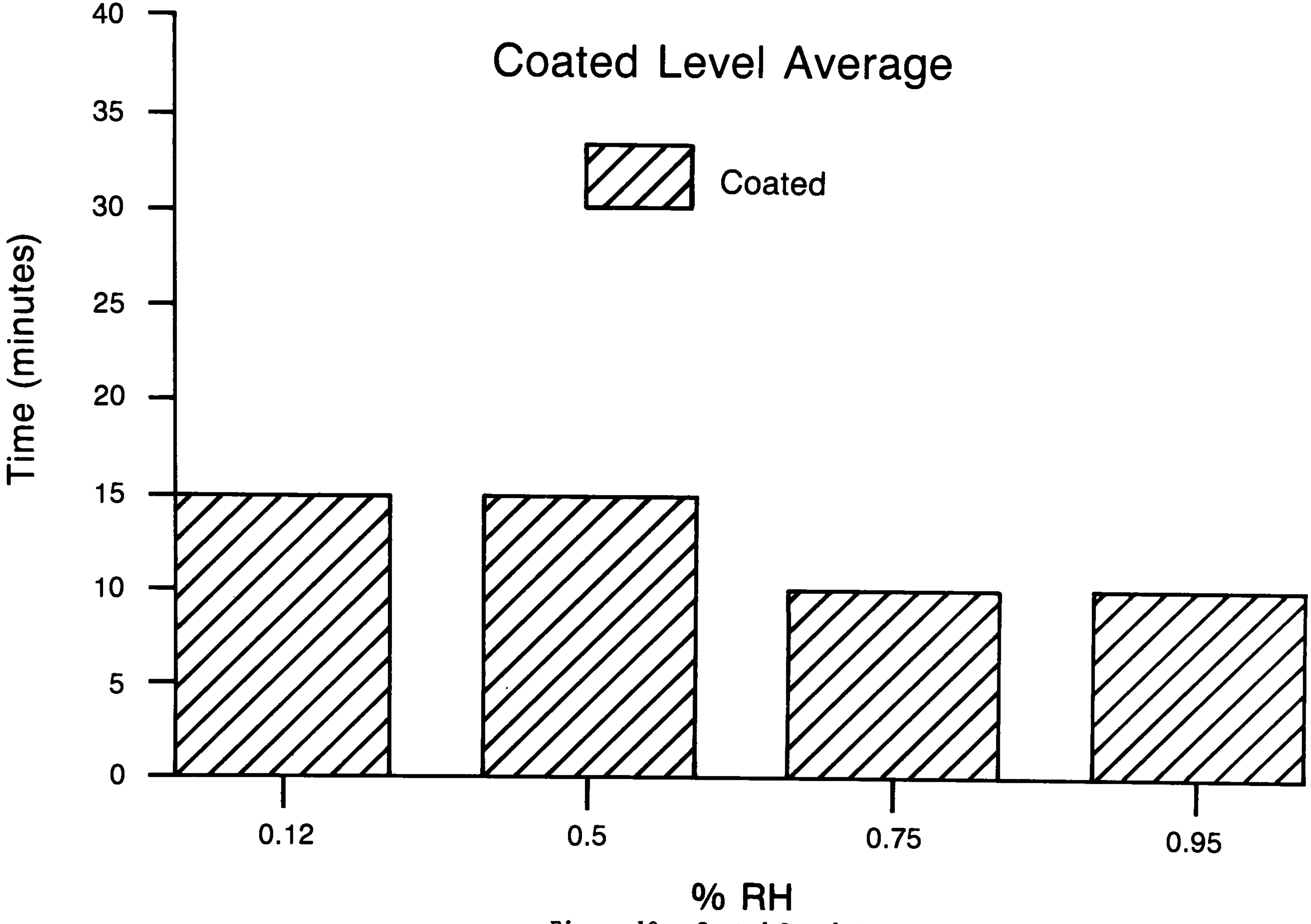

Figure 10 - Coated Level Ave.

CHAPTER VIII

DISCUSSION OF THE RESULTS

From the graphed lines representing the presence of tack on the sheet surface, it can be seen that the increased percentage of water present within the cell walls of the cellulose structures does not have a significant bearing on the induction period of the applied ink film. In all cases, the ink tack experienced on the samples involved dropped off dramatically within and immediately after the five-minute interval. Approximately 70% of the samples displayed a leveling of ink tack falloff at around the 15-minute mark. The remaining 30% of the samples reflected an evening out soon thereafter at around the 10-minute mark.

This information seems to emphasize the narrow importance in actuality of water present in paper as related to thermography. Since in all the samples, the ink was at its tackiest within five minutes after the application of ink, it would seem that the consideration of pressroom relative humidity as a conditioning factor for about to be thermographed paper is insignificant.

For the above reasons, it may be stated that the hypothesis of this work may be disproved according to the data representing the outcome of the experimentation. Regardless of the marked increases in percent water content of the test paper samples, the length of the induction period did not correspondingly increase along the lines theorized initially. For the hypothesis to have been proven correct, the results seen would have differed from those recorded in the

following way. As the ink tack measurements taken from the paper samples moved from dry to wet paper, there should have been a leveling off of the decrease in tack later and later as the percent of water in paper increased. However, this was not the case. Rather, there was virtually no difference in the delineated point at which it showed that the tack began to experience a "rise" in tack. Actually, a rise in tack was never experienced per se. However, for these purposes the point at which the tack readings began to show signs of leveling out in contrast to the precipitous decline shown throughout the many test samples was taken to represent the point from which interpretation could start. For purposes here, "leveling" may be defined as the point at which a decrease in reflection densitometric measurement was less than .10. Figures 8-10 show that the point at which the ink tack began to level off from its drop stayed approximately the same across the board. This signifies the role of moisture present in paper before it is printed thermographically as virtually unimportant.

It had been expected that as the paper "printed" on became damper, the ink would have taken longer to show an increase in the ink drying induction period. This proved not to be the case for the induction period throughout the sample population did not show a correlation in regard to the moisture factor. For the tenets of the formulated hypothesis to have been proven, as the moisture present in the paper samples increased, the induction period would have had to have shown a similar increase. This proved not to be the case due to the fact, as shown via the data collected, that the induction period focused on here did not increase or show a marked lengthening due to the higher percentage of moisture in those paper samples designated as such.

Also worthy of note is the fact that the trends established and recorded as results were consistent across all three types of paper chosen for the study. This realization may yield hints along the lines of what factor(s) may most fully be responsible for displays of induction period length. From the factors present and weighed accordingly, it would seem that the type of ink used is most probably the most significant factor in influencing induction period lengths as applied in the case of ink tack measurements taken from ink films applied to paper that has not undergone the normal process whereby other factors that enter the picture introduce new variables. The most important of these would be fountain-introduced water that mixes with the ink on the rollers, creating an entirely different animal in terms of the chemical nature of the ink that is applied to the paper surface.

CHAPTER IX

SUMMARY AND CONCLUSION

The hypothesis stated that as the percent moisture content of the paper samples was increased, there would be a concordant increase in the induction period of the ink. As shown via the analysis of the data, the increased moisture content did not lengthen the induction period of the ink film. This finding has laid the grounwork for the understanding that the hypothesis does not hold true.

In summary, this treatise has proven fruitful to the author due to the fact that it has, in effect, laid to rest the desire to explore the significance factor regarding any effect moisture present in unprinted paper may have in the staging and planning of thermographic printing. This desire has been quelled by the findings that reflect the minimal, if any, bearing varying degrees of paper moisture have as a contributing factor to final thermographic output. As broached earlier, the idea for this study was conceptualized as an inquiry into the myriad of possible mitigating factors that could influence the practice of printing thermographically. The subject focused upon the question of paper moisture in unprinted paper, i.e., paper yet to enter a lithographic press, and the effect, if any, it could have on the tack of the ink film laid down upon it. This subject was in part chosen due to the absence of its consideration in the literature and to examine what possible influence more appropriate care in the conditioning of paper might yield in terms of a more positive way of coming to terms with the several variables and system requirements associated with thermographic printing.

Careful consideration was taken to abide by the most common of actions undertaken in the majority of thermographic printing. The papers chosen were accurate representations of commonplace stocks used, along with the corresponding use of drying oil lithographic ink. While under associated circumstances, the presence of water in the lithographic system usually denotes a lengthening effect on the proper drying of ink, it can be said and concluded from the results that these known relationships do not significantly carry over to the situation without the use of a printing press. The chief area of concern may still be regarded to be the implementation of a stringent control on the amount of water introduced and maintained during the printing process on press. While the continued thought and control of paper stored in pre-press situations in regard to its proper conditioning and proper handling is recommended from the standpoint of assuring runnability in press and post-press operations, the metered absorption and release of moisture cannot be said to have significant and meaningful importance in relation to the effect it could have on the ink tack, once it is printed at a later time.

The tested papers showed that the ink tack of freshly printed sheets falls off in a relatively linear fashion over time. However, the degree to which the tack begins to level off in its descent or even begins to rise after falling over time failed to show that it can be influenced by the varying degrees of moisture that may be present in different grades of paper stored under several sets of circumstances.

Another point that may be addressed concerning thermographic printing and its tack requirements revolves around the fact that thermographically produced materials are printed and then soon thereafter entered into the thermographic unit. The amount of time that customarily passes from the time a sheet of paper is printed until the time it is subjected to its secondary input into the thermographer may range from several seconds, in the case of automatic thermography, to several minutes, in the case of hand-fed means. The implication of this situation is clear. If automatic thermography will be employed, there exists no condition that would call for special conditioning of the paper because the amount of time that passes between the point of impression and the application of thermoplastic powder is usually within the range of several seconds. Hence, the most important tack determinator here is the press conditions that create the level of tack with the ink used. The amount of time that elapses from impression to the sheet passing under the thermographer vacuum would seem to be too short for the pre-conditioning of paper to matter.

However, in the case of manual thermography, the care given to proper moisture levels of paper seems to theoretically have more importance. The time that passes from the point of press impression until thermography in hand-fed thermography can be significantly longer than is the case with automatic. This period can range anywhere from a few to several minutes, causing much more attention to be given to the tack level on the printed sheet.

Although the above described differences are real and exclusive to the requirements of each process, the results of this thesis do not support the associated needs of thermography. It has been shown that

the amount of moisture in a sheet of paper that has the surrounding environment as its source does not lengthen or significantly change the time period which encompasses the drying or induction period of the printed ink film.

In conclusion, the induction period of the ink was not lengthened by an increase in the moisture content of the three paper samples used. The real area of concern and consideration, as implied by these results, lies in a more stable and stringent control of the ink itself and how it might be altered by press conditions at time of printing.

CHAPTER X

RECOMMENDATIONS FOR FURTHER INVESTIGATION

The subject of moisture's interaction with thermographic printing is one that lends itself to many areas of study. The topic of this thesis is but one; however, its applications are exhausted by the results tabulated and espoused here. Where the recommendations for further study come in are in the continued exploration of paper moisture and thermography in the area of fountain solution water.

Between the unknown answers to questions of fountain solution acidity and the influence water mixed with ink affects its tack, there are a myriad of possibilities in terms of new vistas to seek. The opinion here is that moisture's role in thermography is a very important variable that has the power to radically alter the conditions under which thermography may be optimally done. Based on this opinion, further conduits leading to gained insight should be created as a means to the end, in this case being proper systematic control of an increasingly practiced printing technique.

The key to understanding the true nature of what causes or brings out the best thermographic printing has to offer is to fully comprehend the water factor in the process. As stated previously, the use of water in lithography is an undeniable necessity that must be corralled if one is to realize maximum productivity and esthetic excellence.

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APPENDIX

TABLE 1 - Percent Moisture Content of Test Paper Stocks

	Cranes (100% cotton)	Finch (Uncoated offset)	Champion (Coated offset)
LiCl	5.26%	3.125%	2.56%
$NaCrO_3$	8.29%	6.25%	7.69%
NaCl	11.76%	7.67%	10.47%
KS	15.90%	14.28%	12.32%

TABLE 2 - Reflection Densities of Receiving Sheet - 5-minute Intervals

LiCl - 12% RH

Cotton:	.42	.22	.15	.07	.06	.09	.09	.10
	.38	.17	.15	.09	.17	.07	.08	.09
	.28	.22	.14	.11	.07	.06	.07	.05
Avg.	.36	.20	.15	.09	.10	.07	.08	.08
Uncoated:	.25	.19	.11	.08	.09	.09	.10	.12
	.27	.13	.09	.08	.11	.06	.10	.09
	.42	.15	.11	.10	.10	.09	.09	.09
Avg.	.31	.16	.10	.09	.10	.08	.10	.10
Coated:	1.31	.60	.42	.27	.43	.24	.22	.08
	1.29	.34	.28	.31	.20	.14	.12	.05
	.83	.76	.39	.48	.26	.16	.33	.07
Avg.	1.14	.57	.36	.35	.30	.18	.22	.07

$NaCrO_3$ - 50% RH

Cotton:	.32	.20	.30	.29	.15	.09	.09	.09
	.37	.34	.17	.19	.19	.13	.09	.10
	.39	.16	.26	.18	.12	.14	.11	.09
Avg.	.36	.23	.24	.22	.15	.12	.10	.09
Uncoated:	.23	.22	.13	.14	.15	.09	.12	.09
	.26	.19	.12	.15	.12	.10	.18	.12
	.25	.27	.08	.14	.09	.11	.17	.06
Avg.	.25	.23	.11	.14	.12	.10	.16	.09
Coated:	.88	.83	.69	1.05	.80	.75	.45	.36
	1.72	.85	.87	1.11	.94	.52	.70	.53
	1.75	1.05	.97	1.45	.78	.40	.48	.44
Avg.	1.45	.91	.84	.94	.84	.56	.54	.44

TABLE 2 (continued)

NaCl - 75% RH

Cotton:	.57	.17	.15	.17	.16	.12	.08	.06
	.63	.18	.11	.12	.10	.09	.11	.07
	.36	.11	.10	.11	.13	.08	.09	.07
Avg.	.52	.15	.12	.13	.13	.10	.09	.07
Uncoated:	.37	.31	.45	.58	.21	.25	.40	.06
	.52	.57	.47	.44	.22	.21	.31	.14
	.77	.42	.47	.22	.30	.17	.17	.38
Avg.	.55	.43	.46	.41	.24	.21	.29	.19
Coated:	1.70	1.43	.83	.75	.67	.40	.46	.45
	1.65	.81	1.15	1.18	.90	.41	.39	.40
	1.59	1.01	.99	.75	.34	.75	.27	.29
Avg.	1.65	1.08	.99	.89	.63	.52	.37	.38

KS - 95% RH

Cotton:	.20	.11	.13	.12	.08	.06	.06	.08
	.24	.16	.12	.10	.12	.07	.09	.09
	.21	.11	.09	.16	.10	.11	.08	.08
Avg.	.22	.13	.11	.13	.10	.08	.08	.08
Uncoated:	.11	.24	.14	.11	.13	.09	.22	.24
	.25	.19	.15	.15	.14	.18	.23	.16
	.52	.21	.18	.18	.19	.24	.23	.22
Avg.	.29	.21	.16	.15	.15	.17	.23	.20
Coated:	1.60	.93	.97	.94	1.03	.69	.63	.49
	1.54	.86	.98	.65	.86	.83	1.01	.85
	1.57	.93	.70	.97	.97	.85	.93	.82
Avg.	1.57	.91	.88	.85	.95	.79	.85	.72

TABLE 3 - List of Equipment and Materials Used

Equipment:	Thelco Scientific Instrument Company Temperature controlled oven (30 degrees centigrade)
	OHAUS Moisture Determination Balance
	MacBeth RD-574 Reflection Densitometer
Materials:	Cranes Distaff Linen 100% cotton bond white wove 24lb. (60lb. offset)
	Finch Opaque Offset 60lb. uncoated
	Champion Coated Offset 60lb.
	Morrison Printing Ink Co., Cleveland, Ohio Drying Oil Black Litho Ink