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Studies of the properties of poly (ethylene oxide) as a substitute for gum arabic in the fountain solution

Orapan Chongpipatanasook

STUDIES OF THE PROPERTIES OF POLY (ETHYLENE OXIDE) AS A SUBSTITUTE FOR GUM ARABIC IN THE FOUNTAIN SOLUTION

by

Orapan Chongpipatanasook

A thesis submitted in partial
fulfillment of the requirements for the
degree of Master of Science in the School of Printing
in the college of Graphic Arts and Photography
of the Rochester Institute of Technology

June, 1976

Thesis adviser: Dr. Julius L. Silver

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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
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An Abstract

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ABSTRACT

Poly (ethylene oxide) is a polymer of ethylene oxide. It is one of the classes of synthetic water soluble resins which are commercially available. The properties of poly (ethylene oxide) as a desensitizer in the fountain solution were studied. The solution of this resin was compared to gum arabic solution.

The investigation included the study of the physical properties of the solutions at different concentrations as well as press performance. Comparisons were made as to wettability, viscosity, surface tension, the ability to clean the plate, the resistance to scum, printing sharpness, resolution, and the plate-press characteristic curve.

The experiments were made under controlled conditions; the only variable being one ingredient of the fountain solution. The properties of each solution were discussed and reported. The concentration of poly (ethylene oxide) necessary was determined. Most of the results were statistically analyzed by the two factors analysis of variance. The properties of poly (ethylene oxide) as a substitute for gum arabic in the fountain solution varied.

Poly (ethylene oxide) is comparable in regard to the ability to clean the plate, resistance to scum, and printing sharpness. The gum arabic solution gives better resolution. The plate-press characteristic curves appear to be alike and almost superimpose on each other. The advantage of poly (ethylene oxide) is its high resistance to bacterial attack.

Abstract approved: ____________________, thesis adviser

____________________, title and department

____________________, date

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CHAPTER I

INTRODUCTION

Dampening is one of the important aspects of the lithography process and it requires skill to control both ink and water balance for good printed results. Since a lithographic plate is planographic, the separation between image and non-image area is said to be chemically selective. The image area is ink receptive and water repellent and non-image area is water receptive and thus rendered ink repellent. Substances such as oil and water are composed of molecules which have affinity for each other because of forces acting between them.

> The forces arising between the molecules of one material are called cohesive forces and hold the molecules of a particular substance together to give the form, shape and characteristic to the materials that surround them. There are also forces existing between the molecules of two different materials which are called adhesive forces and these hold the molecules of two different substances together.[1]

When the cohesive force is greater than adhesive force, the substance do not mix. Therefore, oil molecules will associate with other oil attracting molecules that comprise the image areas of a plate, and the water molecules will associate with the water attracting areas. In order to arrange these two areas-oil attracting and water attracting areas- and balance between adhesive and cohesive forces to achieve the ink and water separation, the plate must be desensitized. The term desensitization as defined by G. Macdougall is:

> Desensitization is a subject which embraces all the methods employed to prevent ink acceptance in the non-image parts of the litho printing plate, and it therefore includes etching, gumming and graining of plates, and the composition of the solution used in the water fountain.[2]

If the desensitized film on the non-image areas of the plate remains there indefinitely, it would be possible to run such a plate with water as a fountain solution. However, the desensitized film of the non-image areas of plates usually wears off gradually as the plates run on the press. Therefore, it is necessary to rebuild this desensitized film. Chemicals in the fountain solution serve this purpose. Fountain solution usually contains:[3]

1. A desensitizing gum such as gum arabic, cellulose gum or hydrogum (mesquite gum).
2. An acid - usually phosphoric acid or an acid phosphate salt. Sometimes gallic or tannic acid is used.
3. Ammonium bichromate and/or a nitrate salt such as ammonium nitrate, zinc nitrate, or magnesium nitrate.

The most important thing in the fountain solution is the desensitizing gum. Other ingredients are added to improve the adherence of the desensitizing gum to the non-image area of the plate. The acid converts the desensitizing gum to its "free acid form" in which the molecules contain carboxyl groups (—COOH). These groups are able to form a good adsorption bond of the gum to the metal surface.[4]

The gum most generally used to protect the plate is gum arabic.[5] Gum arabic is a natural gum that comes from Acacia trees in the Middle East and North Africa. The type preferred in lithography is called "Select Gum Arabic Sorts".[6]

It is believed that gum arabic has been used as a desensitizer since Alois Senefelder invented lithography in 1796. He found that:

> A few drops of gum arabic, dissolved in water, if applied to a well polished stone, produces the effect such that the spot thus wetted will not take ink, as long as it remains wet. As soon as it becomes dry, the ink adheres to it, but is easily wiped off with a sponge and water.[7]

Besides being used as a desensitizer on the plate surface and as a basic ingredient in the fountain solution, gum arabic when combining with a dichromate in alkaline solution makes a light sensitive coating on lithographic plates. Also, it can be made into an emulsion with asphaltum to produce a one step washout and gumming solution.[8] It is a sizing and finishing agent in the textile industries and is also used in textile printing and waterproofing formulations.[9] The uses of gum arabic are wide and varied. Applications include uses in the food industry, pharmaceutical industry, as an adhesive medium, etc.

Statement of the Problem

Due to inflation and the energy crisis, shortages are potentially serious problems. Some natural resources are irreplacable, become depleted or are interrupted in the distribution system due to war, politics and increase in world consumption. This problem affects the printing industry and especially lithography because most of the plate-press room chemicals are derived from natural resources. Gum arabic is a natural gum from the Middle East and North Africa. It is gathered from the trees, separated from the bark and sand, graded and packed for shipment.[10] Gum dissolves slowly in water and consists mainly of a mixture of calcium, potassium and magnesium salts of arabic acid. A cation exchange resin converts the gum arabic which is in the "salt form" into arabic acid which is the "free acid form". The equation is:[11]

$$(XCOO)_2Ca + 2HR = 2XCOOH + CaR_2$$

Uses of gum arabic are increasing. Shortages inflated the retail price from $3 to $5 per gallon to $10 per gallon.[12] The higher price charged for gum arabic makes it attractive to develop substitutes. Various substitutes have been tested. Experimental work has shown that solutions of cellulose gum are less susceptible to bacteria and, in this way, it is a more suitable material to use but requires a high concentration of 4 grams/litre.[13] Sodium silicate is a good desensitizing agent but if used in excess it promotes ink emulsification and must therefore, be used in amounts not exceeding 0.01 percent.[14] Larger concentrations also lead to plate image blinding.

Ethylene oxide polymers are one of the newest classes of synthetic water-soluble resins from the standpoint of commercial availability. Ethylene oxide polymerizes to give a poly (ethylene oxide) chain.[15]

$$nH_2C \underset{O}{\text{——}} CH_2 \rightarrow -OCH_2CH_2\ (OCH_2CH_2)_{n-2}OCH_2CH_2\text{——}$$

The higher molecular weight polymers of ethylene oxide are referred to as Polyox resins (Registered trademark of Union Carbide Corporation). The unusual property of ethylene oxide polymer is water solubility. In water solution polyox resins show remarkable thickening or viscosity increasing ability. Water solutions of these resins are pseudoplastic – that is, their viscosity varies inversely with the shear forces applied to the solution.[16]

Poly (ethylene oxide) which has a completely linear structure, is an effective turbulent flow friction - reducing agent in any solvent in which it is soluble.[17] In other word, it decreases the surface tension of the solution.

Other properties of poly (ethylene oxide) are low atmospheric moisture pickup, high resistance to biological attack, and little reaction with most chemicals. Its properties in these regards has made it a material used for this study. Poly (ethylene oxide) is one of the few available water soluble resin which have not been studied as a gum arabic substitute in lithography.

The Purpose

The purpose of this study is to investigate the properties of poly (ethylene oxide) as a desensitizer compared to gum arabic. The variables involved are wettability, surface tension, viscosity, the ability of the solution to clean the plate, resistance to scum, printing sharpness, resolution, and the plate-press characteristic curves.

Wettability, surface tension and viscosity are measured by different instruments designed for each purpose. Test conditions are controlled through the experiments.

The ability of the solutions to clean the plate, resistance to scum, printing sharpness, resolution and the plate-press characteristic curves are measured on the press. The comparisons are made under equivalent press conditions, pH of the fountain solution, ink, plate and paper. The only variable is one ingredient of the fountain solution.

The Hypothesis

The hypothesis for this study is that if poly (ethylene oxide) is used as a substitute for gum arabic under equivalent press conditions, pH of the fountain solution, ink viscosity, plate and paper then plate desensitizing will be equivalent or superior. These are determined by wettability, surface tension, viscosity, the ability of the solution to clean the plate, resistance to scum, printing sharpness, resolution and the plate-press characteristic curves.

FOOTNOTES FOR CHAPTER I

[1]W. H. Banks, "Why Does Lithography Work?," British Printer (July 1970): p. 108.

[2]G. Macdougall, "Some Comments on the Desensitization of Lithographic Plate," The Penrose Annual (1949): p. 125.

[3]Paul J. Hartsuch, Chemistry of Lithography, (Pennsylvania: Graphic Arts Technical Foundation Inc., 1961), p. 300.

[4]Ibid.

[5]Robert F. Reed, Offset Lithographic Platemaking, (Pennsylvania: Graphic Arts Technical Foundation Inc., 1967), p. 70.

[6]Ibid., p. 11.

[7]A. Hyatt, ed., A Complete Course of Lithography by Alois Senefelder, (New York: Da Capo Press, 1968), pp. 146-147.

[8]Albert R. Materazzi, "Lithographic Chemical Shortages, Part I," Graphic Arts Monthly (February 1974): p. 88.

[9]Kirk-Othmer, Encyclopedia of Chemical Technology, Vol. 10., 2nd ed., (New York: John Wiley and Sons, Inc., 1966), p. 744.

[10]Hartsuch, p. 130.

[11]Ibid., p. 130 - 131.

[12]L. Olinghouse, "Gum Arabic Substitute," In-Plant Printer. (July/August 1975): p. 40.

[13]Bruce E. Tory, Offset Lithography, (Australia: Korwitz Publications Inc., 1957), p. 74.

[14]Ibid.

[15]Kirk-Othmer, Encyclopedia of Chemical Technology, Vol. 8, 2nd ed., (New York: John Wiley and Sons Inc., 1966), p. 527.

[16]L. D. Berger, Jr. and M. Thayer Ivison, "Ethylene Oxide Polymers" Water-Soluble Resins, ed. Robert L. Davidson & Marshall Sittig (New York: Reinhold Publishing Corporation, 1962), p. 174.

[17]J. W. Hoyt and Robert H. Wade, "Turbulent Friction Reduction by Polymer Solutions" in Polymer Science and Technology Vol. 2: Water Soluble Polymers, ed. N. M. Bikales, (New York: Plenum Press, 1973) , p. 142.

CHAPTER II

REVIEW OF THE LITERATURE

In the lithographic process, the plate is wet first with the fountain solution and then with ink before transfering the image to the rubber blanket. In order to separate the ink receptive areas from the water receptive areas, many technological applications of surface chemistry have been involved. It includes the surface characteristic of the plate itself, the treatment of the plate surface, the composition of the fountain solutions and the behavior when the liquid and oil interact on the press.

Since Alois Senefelder invented lithography in 1796, explanation of the lithographic phenomenon is still vague. Many theories have been without complete knowledge and experimental confirmation. In 1928, the Lithographic Technical Foundation put forward views about the desensitizing role of "insoluble water-absorbent" films of gum arabic. The first scientific approach seems to have been made by G. L. Riddell at about this time. Riddell sought to establish experimentally that gum arabic was absorbed on lithographic surfaces thereby rendering them oleophobic.[1]

A further step was taken by F. J. Tritton who showed how the measurement of contact angles of oils on lithographic surfaces could be used as a quantitative measure of oil repellency.[2]

In 1956, R. A. C. Adams at PATRA studied contact angles and their significance. Adams emphasized that:

> The contact angle obtained is determined by the actual condition of the solid surface at the time of the experiment. Since, under practical lithographic conditions, the metal surface is subjected to the action of the aqueous solutions. It is necessary to determine the contact angle relationship for the metals when they are being subjected to the simultaneous action of the two immiscible liquid phases rather than to determine the separate actions of these liquids.[3]

This method is known as interfacial contact angle which is a development of the method described by Tritton. It is used for studying the affinity of liquids to surfaces since changes in the contact angle are a significant measure of the changes in the wettability of the surface on which the liquids rest. Most of the research have been done by using this method.

Various platemaking treatments also have a marked effect on the contact angle of oil placed on them. This was studied by F. J. Tritton in his Study of the Theory of Lithographic Printing. He indicated that:

> On the average, an etched plate has a lower contact angle than the unetched or sensitized plate, although it is possible that this difference is simply due to the thickness of the surface film produced by the etch.[4]

In 1946, Elton and Macdougall evaluated the grain of lithographic printing plates and confirmed that:[5]

> Graining the surface area of the plate considerably increases the area of metal exposed, allows reacting solutions to come into more contact, and so greatly increases the rate of chemical reaction at the surface. This in itself confers a degree of desensitization on the grained plate.

The Influence of Gum Arabic and Cellulose Gum

It has frequently been stated that gum arabic films on lithographic plate are not effective in their desensitizing properties unless they are fanned dry. Reed and King of the Lithographic Technical Foundation found that when gum films are dried down on solid surfaces, a certain amount of the film is insolubilised by oxidation and cannot be washed away by water.[6] This idea was confirmed by the PATRA interfacial contact angle.

The influence of gum arabic and sodium carboxymethyl cellulose (C. M. C.) has been studied by Macdougall. The question of whether or not a gum must be included in the fountain solution may best be settled by observing the interfacial contact angle.

> The contact angle technique provides a suitable and convenient means of finding out whether, in fact, the presence of gum or C. M. C. in the fountain solution has any desensitizing effect.[7]

The result showed that the addition of gum arabic to fountain solution has a beneficial desensitizing action if the effective concentration of gum is maintained at about 0.3 percent or over.[8]

It was noticed that gum arabic solutions, over a period of time, lost their power of reducing the contact angles. Macdougall explained that:

> This deterioration on storage was traced to the decomposition of the gum by bacteria and moulds. If 0.01 percent of the preservative 'Zephiran Chloride' (a long chain alkyl dimethyl benzyl ammonium chloride) is added to the gum solution while fresh its desensitizing effect is preserved intact over a period of more than three weeks.[9]

Sodium carboxymethyl cellulose (C. M. C.) solutions behaved in the same way as gum arabic. The concentration at which the minimum in the contact angle concentration curve occurred was 4 grams/litre. The deterioration effect on storage was absent which means that cellulose gum is much less susceptible to mould and bacteria deterioration than is gum arabic. From this point of view, C. M. C. makes a more reliable fountain solution.

Concentration of Substances in Fountain Solutions

The effect of lithographic fountain solution on plate scumming has been investigated by Adams and Lawson who concluded that concentration of substances in the solution is the important factor in scum prevention. It has also been assumed generally that acidity (pH) is an important factor.[10]

Adams and Lawson, however, suggested that provided the fountain solution contains certain minimum amounts of various substances, it does not matter whether the pH of the solution is as low as 3.8 or as high as 7.0.[11] Since the plate surface is corroded by acid and gum arabic or cellulose gum itself does not inhibit the corrosion, it is suggested that acid and gum should not be used alone in the fountain solution. When acid attacks the plate surface, the strength of the acid decreases until reactions cease. That is, the pH of the attacking solution rises. Thus, some salts are added in the solution to prevent plate corrosion and to buffer the fountain pH. This idea was confirmed by Adams and Ullman who found that:

> Corrosion was directly related to fountain solution pH and that dissolved gum did not inhibit corrosion. That is, the lower the pH of the fountain solution the greater the amount of corrosion. However, it was found that in the presence of a certain minimum amount of bichromate, corrosion was inhibited with a solution of pH as low as 3.9.[12]

Water-Air Boundary in the Mechanism of Lithography

Because of the nature of the vehicle, lithographic inks shed film of oils onto water with which they are in contact. These films are of molecular thickness and on the plate they spread across the boundary between the inked image and the adjacent desensitizing areas. The understanding of the mechanism of lithography derives mainly from the early work of R. A. C. Adams at PATRA. He identified that:[13]

> The properties of the printing surface determine

> whether it shows a preference either for ink or for water. The principles established were necessarily concerned with the situation at the boundary between plate and water on the one hand and ink on the other when all three components are brought together. The relevant is the situation at the water or fountain solution/air boundary.

This boundary assumes importance when the dampening solution evaporates, as, for example, during stoppage. Evaporation of the water from these areas will therefore result in deposition of ink on the metal with a consequent sensitizing of the non-image area.[14] It may also play a part in the accumulation of ink on the dampening rollers. Subsequent printing without the intervention of the usual treatment with gum arabic solution can lead to an overall tinting and scumming.

From the paper presented by W. H. Banks, D. H. Charlesworth and A. H. Smith showed that:[15]

1. Monolayers of oleic acid are sufficient to sensitize a plate;

2. The spreading is controlled by the surface tension of the aqueous layer;

3. All films likely to spread from inks as at present constituted can be prevented from doing so when the surface tension of the aqueous solution does not exceed 36 dyn cm^{-1}.

This idea lead to a new concept for the composition of fountain solution that will prevent the spreading which is responsible for the sensitization that can occur when a plate dries. An important role of surface tension, therefore, has been established. Its importance as stated by W. H. Banks was that:[16]

> The effect of surface tension on the spreading of films is independent of the composition of the fountain solution, and films cannot form when the surface tension is about 37 dynes/cm. Thus, as with pH, the control of surface tension should now be regarded as a general requirement of all fountain solution irrespective of their formulation.

FOOTNOTES FOR CHAPTER II

[1]W. H. Banks, "Some Physio-Chemical Aspects of Lithography," Proceedings of the First Conference, Association of Printing Technologists (1957): p. 16.

[2]Ibid.

[3]R. A. C. Adams, "Contact Angles and Their Significance in Lithographic Research," International Bulletin for the Printing and Allied Trades 73, (January 1956): p. 23.

[4]F. J. Tritton, "A Study of the Theory of Lithographic Printing, Part I," Journal of the Society of Chemical Industry 51, (September 2, 1932): p. 303.

[5]G. A. H. Elton and G. Macdougall, "The Evaluation of the Roughness of Lithographic Printing Plates," Journal of the Society of Chemical Industry 65, (July 1946): pp. 212-215.

[6]G. Macdougall, "Some Comments on the Desensitization of Lithographic Plates," The Penrose Annual (1949): p. 126.

[7]Ibid.

[8]Ibid.

[9]Ibid., pp. 126-127.

[10]Bruce E. Tory, Offset Lithography, (Australia: Korwitz Publications Inc., 1957), p. 75.

[11]Ibid.

[12]Ibid., p. 77.

[13]W. H. Banks et al., "A Development in the Theory of Lithographic Fountain Solutions," Printing Trade Journal, (July 1968): p. 41.

[14]Banks, "Some Physio-Chemical Aspects of Lithography, p. 27.

[15]W. H. Banks, D. H. Charlesworth and A. H. Smith, "The Behavior of the Water-Air Boundary in the Mechanism of Lithography," in Advance in Printing Science and Technology vol. 6: Recent Developments in Graphic Arts Research, ed. W. H. Banks (Great Britain: Pergamon Press Ltd., 1971), pp. 15-16.

[16]Banks et al., "A Development in the Theory of Lithographic Fountain Solutions," p. 41.

CHAPTER III

METHODOLOGY AND RESULTS

In order to compare the properties of poly (ethylene oxide) to those of gum arabic as a constituent of fountain solutions, the variables during the experiments were controlled. The tests were conducted in two parts:

Part I The test of physical properties of both solution.

Part II The printed results or the press performance.

The test included viscosity, surface tension, wettability, the ability of solutions to clean the plate, the resistance to scum, printing sharpness, resolution and plate-press characteristic curves.

Gum arabic is supplied in solution while poly (ethylene oxide) as a solid. Gum arabic was measured by volume/volume while poly (ethylene oxide) was measured by weight/volume.

Gum arabic solution, as recommended by the manufacturer, 3M Company, is one ounce of 14 Baume Gum Arabic, one ounce of Fountain Concentrate and one gallon of water. Poly (ethylene oxide) solution was determined by the preliminary test using different concentrations and different blending times. Due to reduction of molecular weight by shear during blending, the molecular weight varies with blending time. The concentration ranged from 2.0 to 0.5 grams per 100 cc. of water. The blending time ranged from 10 to 25 minutes using a Waring Blendor at 120 volts. Phosphoric acid was used to control the pH of both fountain solutions.

The press and other testing conditions were kept constant. The controlled variables and test objects are shown in Appendix A.

TEST PROCEDURE

Part I The Physical Property Test

Viscosity: Viscosity may be defined as:[1]

$$\text{Viscosity} = \frac{\text{Shear Stress}}{\text{Rate of Shear}}$$

The viscosity of both solutions was determined by the Brookfield Synchro-Lectric Viscometer, model RVT. The viscometer measures viscosity by measuring the force required to rotate a spindle in a fluid.[2]

The property of the desensitizer was a factor and therefore, the desensitizer alone was mixed with water. Different concentrations of solutions were measured. The amount of solution and the container for each measurement were controlled because viscometer ranges will generally change if a smaller or bigger container is used. According to the manufacturer, the Brookfield Viscometer is claimed to be accurate to within ± 1 percent and to be reproducable to within ± 0.2 percent.

The viscosity value was obtained by multiplying each scale reading by the factor number given by the manufacturer's literature. In this test, the viscometer model RVT, spindle number 2, speed 20 rpm. gives the factor number of 20. The viscosity is expressed in centipoise (cps.).

The instrument was operated according to the manufacturer instructions. Three scale readings were taken from each measurement. The first reading was taken five minutes after the instrument was started. The second and the third were taken three minutes thereafter.

Results:

Poly (ethylene oxide) is a dry chemical. To obtain a good solution in water, it is necessary to use shear blending. The results indicated that the longer it was blended, the lower the viscosity. (Figure 1) This is due to the chain molecule of poly (ethylene oxide) breaking apart to form smaller molecules while it was blended. As the rate of shear increases, the viscosity decreases. Viscosity, however, increases with concentration of the solution. The concentration at 2 grams per 100 cc. of water showed a marked fall in viscosity from 10 minute to 15 minute of blending time. (Figure 2)

For gum arabic solution, the viscosity increases as the concentration increases. (Figure 3) The viscosity of tap water was about 4 centipoise while that of 14 degree Baume Gum Arabic solution was about 43 centipoise.

The data obtained are shown in Table 1 and Table 2.

TABLE 1

RELATIONSHIP BETWEEN VISCOSITY
AND POLY(ETHYLENE OXIDE) CONCENTRATION

Concentration grams/100 cc.	Viscosity(cps.) VS Blending Time(min.) 10	15	20	25
0.5	13.33	12.00	9.33	5.33
1.0	16.00	12.67	11.33	10.00
1.5	43.33	30.00	28.67	24.00
2.0	150.67	80.67	64.67	52.67

TABLE 2

RELATIONSHIP BETWEEN VISCOSITY
AND CONCENTRATION OF GUM ARABIC SOLUTION

Concentration oz./gal.	Viscosity (cps.)
0.2	4.00
0.4	4.67
0.6	5.33
0.8	6.00
1.0	6.67
1.2	6.67
1.4	7.33
1.6	8.00
1.8	8.67
2.0	9.33

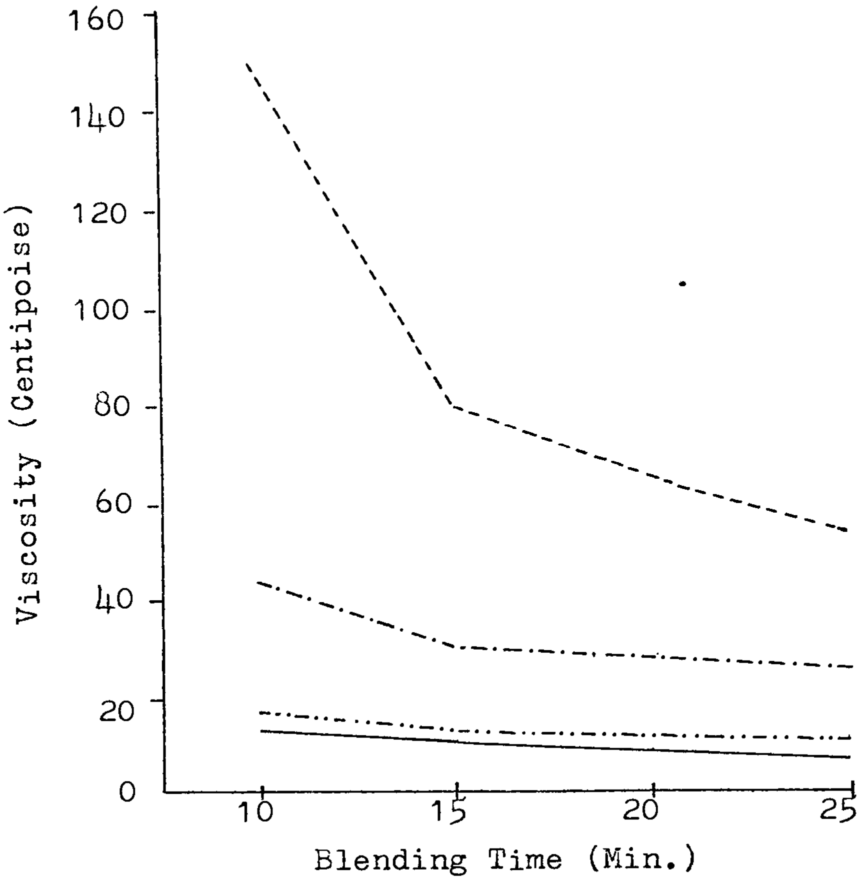

Figure 1 Relationship Between Viscosity and Blending Time of Poly (ethylene oxide) Solutions

-------- 2.0 grams/100 cc. of water
-.-.-.-.- 1.5 grams/100 cc. of water
-..-..-..- 1.0 grams/100 cc. of water
———— 0.5 grams/100 cc. of water

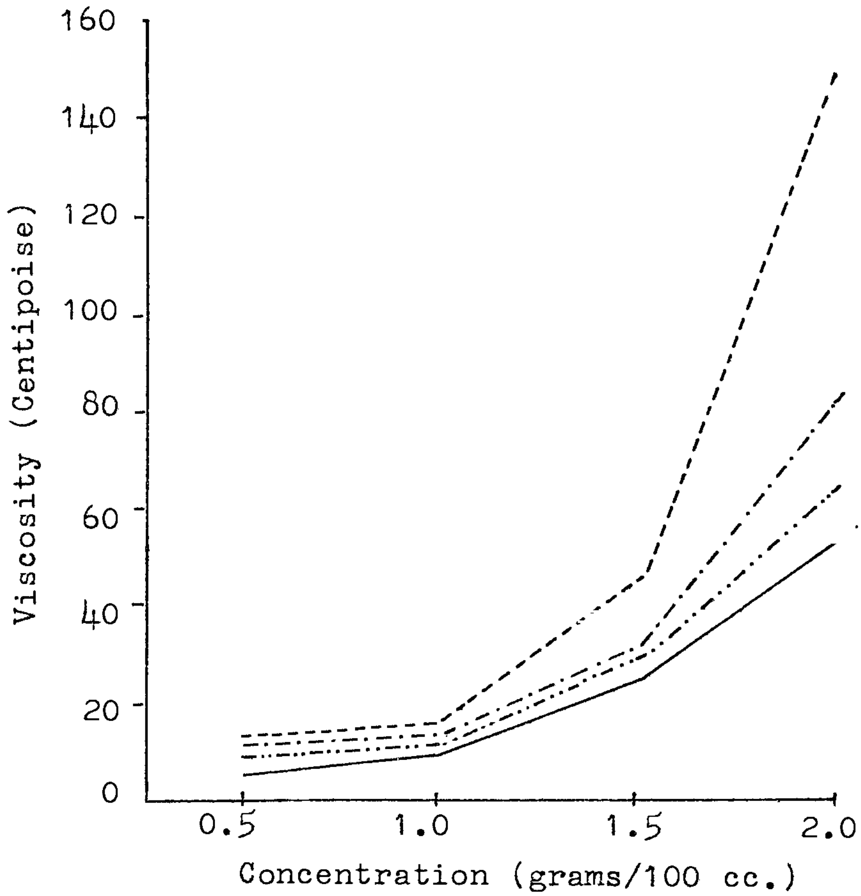

Figure 2 Relationship Between Viscosity and Concentration of Poly (ethylene oxide) Solution

--------	10 minute blending time
-.-.-.-.-	15 minute blending time
-..-..-..-	20 minute blending time
————	25 minute blending time

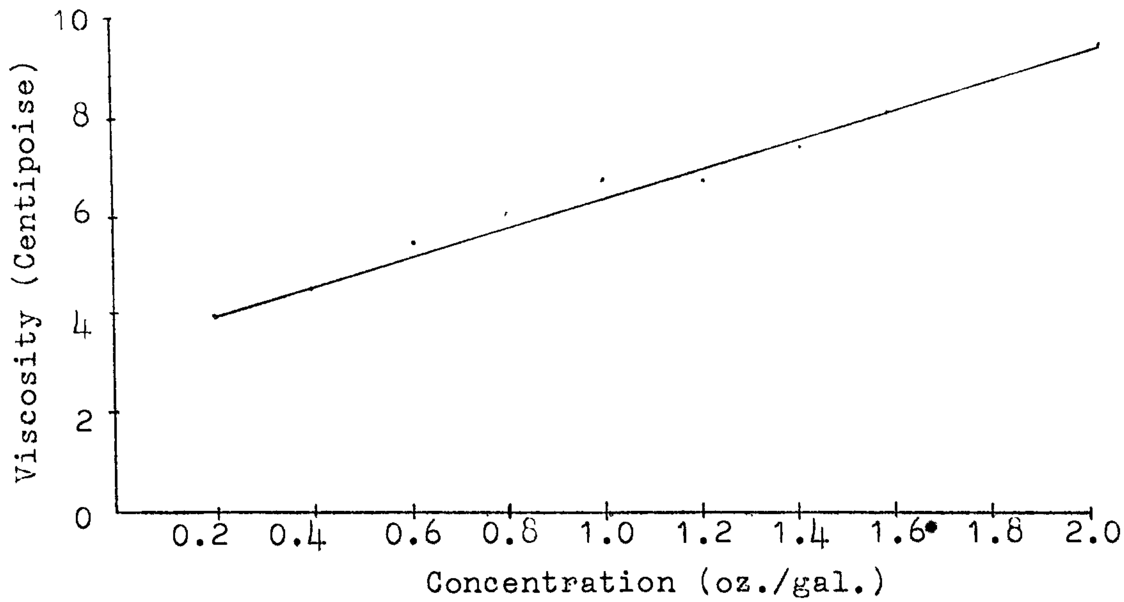

Figure 3 Relationship Between Viscosity and Concentration of Gum Arabic Solution

Surface Tension: To determine the surface tension of the solutions, a du Nouy Tensiometer, Ring method was used. The surface tension relates to the force required to detach a metal ring from the surface of a liquid.

The tensiometer was calibrated according to the manufacturer instructions. The standardized weight of 500 milligrams was used for calibration. The dial reading called "gamma-c" was then calibrated as the following equation:[3]

$$\sqrt{c} = \frac{M \times g}{2L}$$

where:

M = weight placed on the paper platform, in grams,

g = gravity constant (note 1), in cgs. units, and

L = mean circumference of the ring (furnish by the manufacturer with each ring).

therefore

$$\sqrt{c} = \frac{0.5 \times 980.3}{2 \times 5.996}$$

$$= 40.87 \text{ dynes/cm.}$$

(Note 1 The gravity constant is 980.3 at Chicago; in other localities it will differ very slightly from this value).

The reading obtained from a dial is the uncorrected surface tension value. It must be multiplied by a conversion factor, F, to give the corrected surface tension value.

The conversion factor, F, is obtained as follow:

$$F = \frac{\sqrt{c}}{\text{Scale Reading of Standard}}$$

Results:

The surface tension of poly (ethylene oxide) and gum arabic solution were measured at different concentrations. The mean was obtained from three values. The results showed no significant difference in surface tension of various poly (ethylene oxide) solutions. The surface tension ranged from 67.58 to 74.88 dynes/cm. (Table 3)

The surface tension of the gum arabic solution was highest at the 0.8 oz./gal. concentration. Gum arabic solution of 1.0 oz./gal. had a surface tension of about 83.07 dynes/cm.

Comparing poly (ethylene oxide) solution to gum arabic solution, the surface tension of poly (ethylene oxide) was lower than that of gum arabic. The 14 degree Baume gum arabic has a surface tension of 60.84 dynes/cm. while water has 73.95 dynes/cm.

The data are shown in Table 3 and Table 4.

TABLE 3

RELATIONSHIP BETWEEN SURFACE TENSION AND CONCENTRATION OF POLY (ETHYLENE OXIDE)

Concentration grams/100 cc.	Surface Tension (dynes/cm.) at Different Blending Time (min.) 10	15	20	25
0.5	67.58	71.62	72.06	70.69
1.0	73.08	71.99	71.19	74.30
1.5	72.59	74.16	73.88	71.84
2.0	74.88	72.36	73.95	72.36

TABLE 4

RELATIONSHIP BETWEEN SURFACE TENSION AND CONCENTRATION OF GUM ARABIC SOLUTION

Concentration oz./gal.	Surface Tension (dynes/cm.)
0.2	74.31
0.4	74.17
0.6	79.60
0.8	84.45
1.0	83.07
1.2	82.78
1.4	83.00
1.6	83.29
1.8	80.61
2.0	76.34

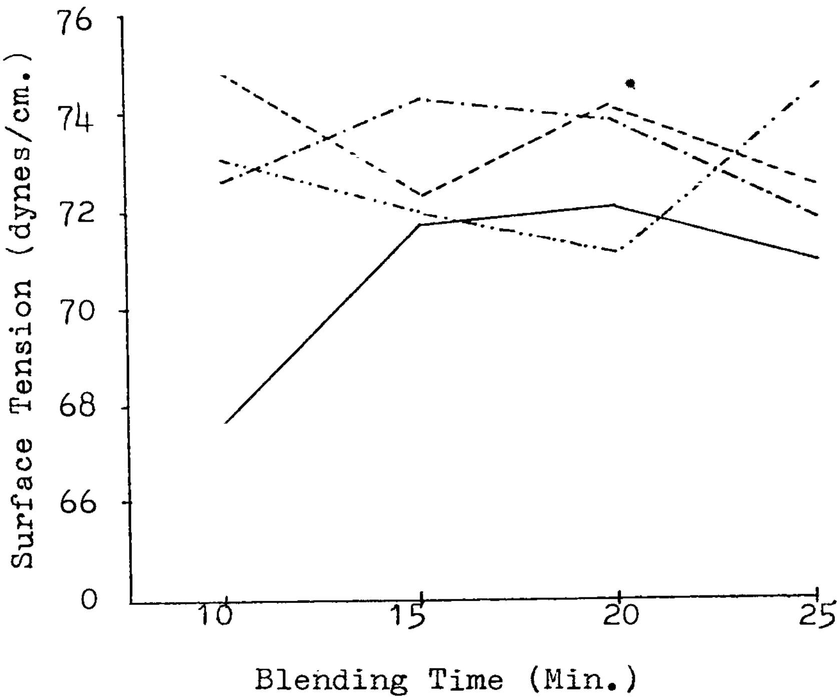

Figure 4 Relationship Between Surface Tension and Blending Time of Poly (ethylene oxide) Solution

------ 2.0 grams/100 cc. of water

-·-·-·- 1.5 grams/100 cc. of water

-··-··- 1.0 grams/100 cc. of water

——— 0.5 grams/100 cc. of water

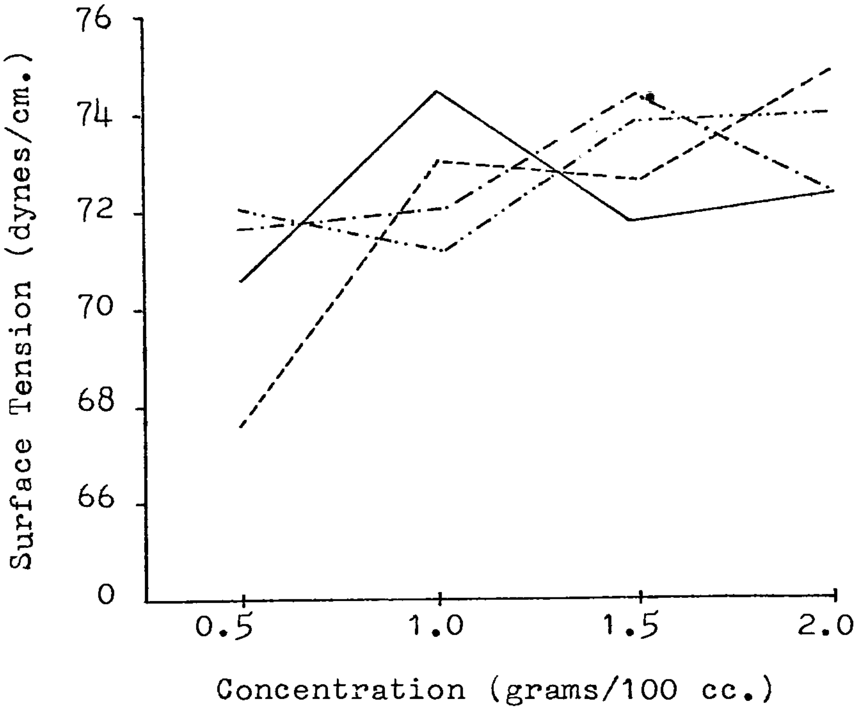

Figure 5 Relationship Between Surface Tension and Concentration of Poly (ethylene oxide) Solution

------- 10 minute blending time

-·-·-·- 15 minute blending time

-··-··- 20 minute blending time

——— 25 minute blending time

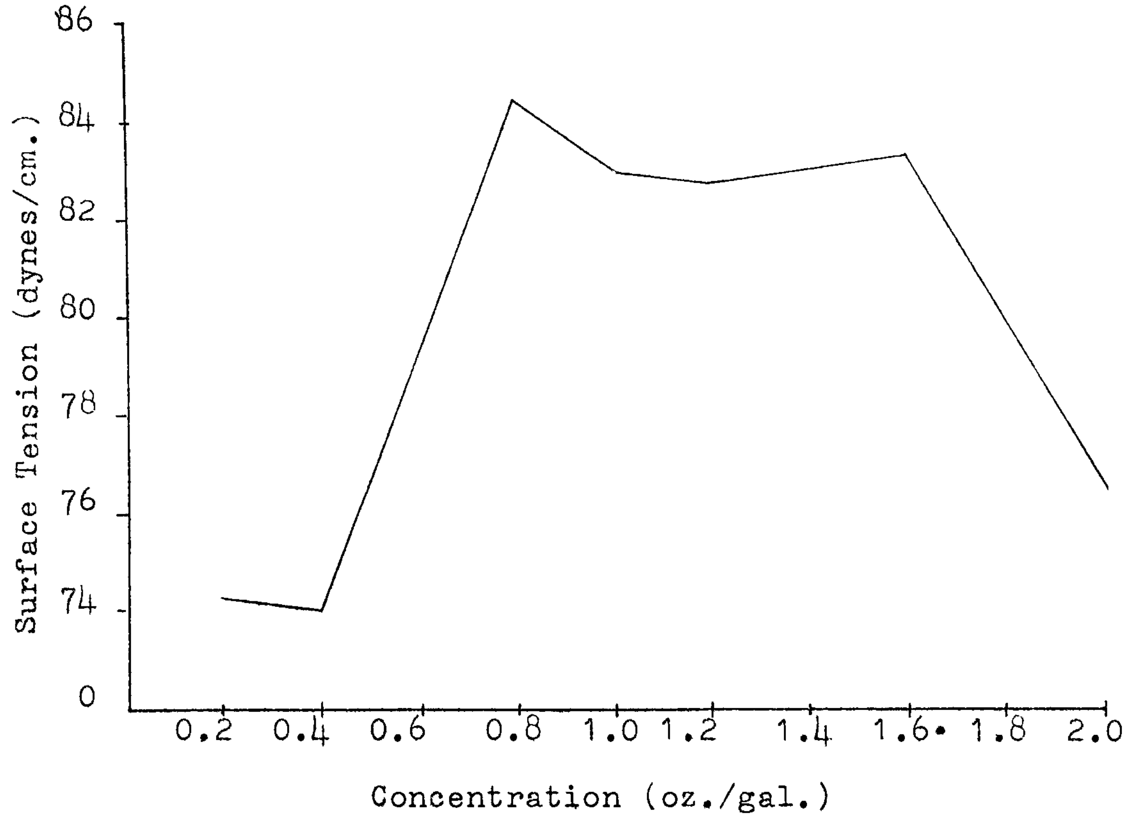

Figure 6 Relationship Between Surface Tension and Concentration of Gum Arabic Solution

Wettability: The behavior of a liquid on a solid is characterized by a quantity called the contact angle. The contact angle of water and two fountain solutions at different concentrations were measured by a photographic method. A drop of liquid was photographed using a combination of close up lens number 1, 2 and 3. The photographic technique diagram is shown in Figure 7.

Each drop of liquid was 5 microliters which was formed using a Hamilton Microliter Syrings #701. A drop was placed on the non-image area of a desensitized subtractive K plate. The millimeter scale was attached to the edge of the plate to measure the drop spread. The image was photographed within 10 seconds after the drop of liquid had been placed on the plate. It was enlarged 40 times. The angle was then measured with a protractor.

Results:

The contact angle results show that as the concentration of the poly (ethylene oxide) solutions increases, the contact angle increases for a given blending time. However for a given concentration, the contact angle falls as the blending time increases.

For gum arabic solution, as the concentration increases the contact angle decreases. The data are shown in Table 5 and Table 6.

TABLE 5

THE CONTACT ANGLE OF POLY (ETHYLENE OXIDE) SOLUTION AT DIFFERENT CONCENTRATIONS AND BLENDING TIMES

Concentration grams/100 cc.	Contact Angle (degrees) at Different Blending Time (min.)			
	10	15	20	25
0.5	18.0	18.0	16.5	16.0
1.0	24.5	22.5	22.0	19.5
1.5	25.5	23.5	23.0	22.5
2.0	31.5	29.0	29.0	27.5

TABLE 6

CONTACT ANGLE OF GUM ARABIC SOLUTION

Concentration oz./gal.	Contact Angle (degrees)
0.2	16.5
0.4	15.0
0.6	14.0
0.8	14.0
1.0	13.5
1.2	13.0
1.4	13.0
1.6	12.5
1.8	12.5
2.0	12.5

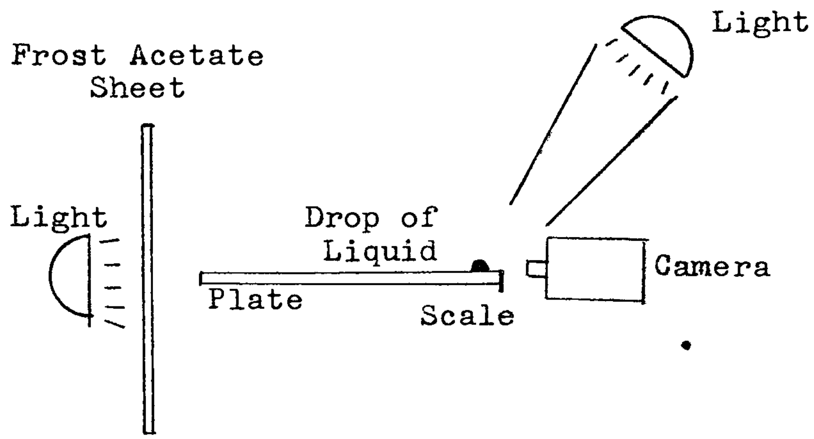

Figure 7 Diagram of Contact Angle Photographic Technique

Part II Press Performance

To compare printed results obtained with each fountain solution, the tests were performed with controlled variables such as press conditions, plate, blanket, paper, ink and pH of the fountain solution.

The conventional gum arabic solution used was one ounce of 14 Baume gum arabic and one ounce of 3M Fountain Concentrate to a gallon of water. The solution of poly (ethylene oxide) used was varied. The concentrations ranged from 2.0 grams to 0.5 grams/100 cc. of water and the blending times ranged from 10 to 25 minutes. Under controlled conditions, different concentrations were run on the press one at a time.

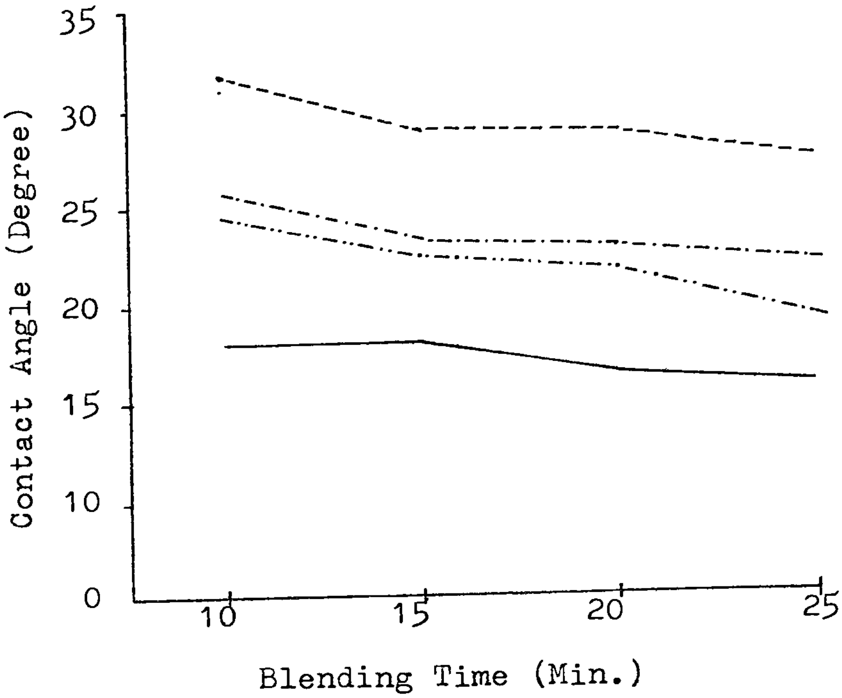

Figure 8 Relationship Between Contact Angle and Blending Time of Poly (ethylene oxide) Solution

-------	2.0 grams/100 cc. of water
-.-.-.-.	1.5 grams/100 cc. of water
-..-..-..-	1.0 grams/100 cc. of water
———	0.5 grams/100 cc. of water

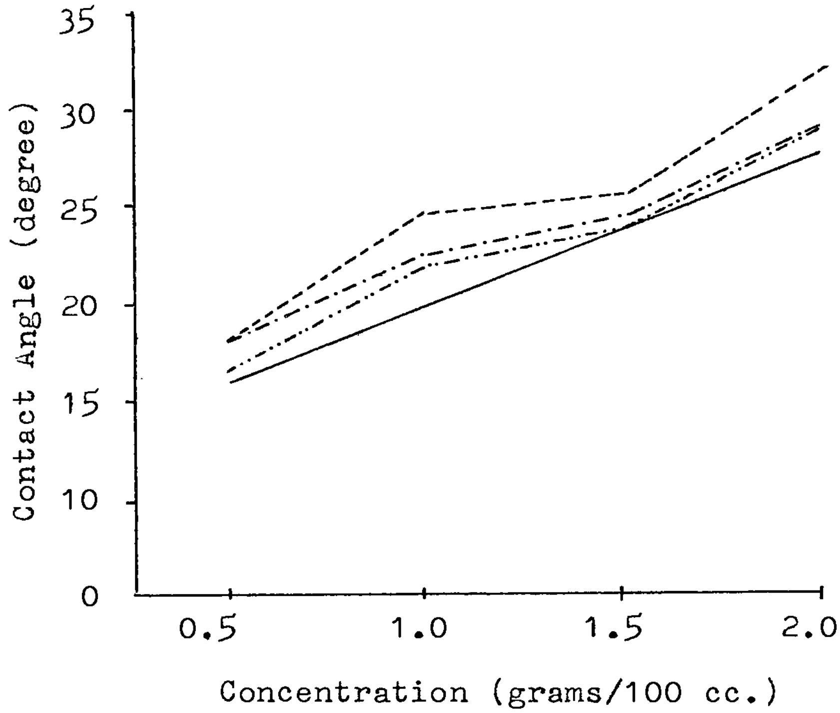

Figure 9 Relationship Between Contact Angle and Concentration of Poly (ethylene oxide) Solution

--------	10 minute blending time
-·-·-·-·-	15 minute blending time
-··-··-··-	20 minute blending time
————	25 minute blending time

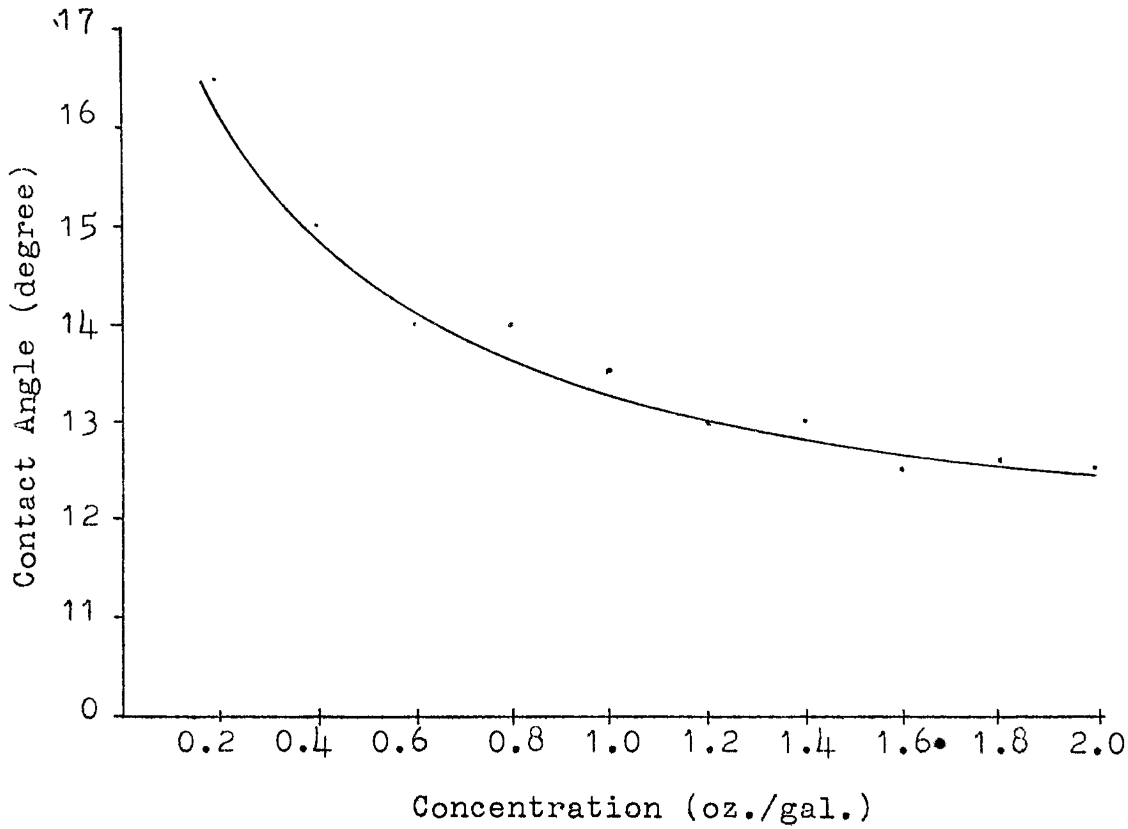

Figure 10 Relationship Between Contact Angle and Concentration of Gum Arabic Solution

The concentration which gave no problems (See below) was used in the comparison with gum arabic solution.

The results showed that poly (ethylene oxide) at high viscosity and high concentration caused problems on the press. The physical characteristic of poly (ethylene oxide) is gel-like when dissolved in water. At high concentration the viscosity is high. When the droplets of the fountain solution came in contact with the plate, it deposited some droplets on the surface of the ink rollers causing slippage among ink rollers, ink-in-water emulsion and tinting. Also, it caused ink mist which gave a dirty print on the background. The ink and water balance seemed hard to control. The solution was diluted until no problem occurred and a clean printed sheet was obtained.

The concentration of poly (ethylene oxide) at 0.5 grams per 100 cc. of water blend for 25 minutes was determined. The equivalent amount of 3M Fountain Concentrate used in the gum arabic solution was added to the poly (ethylene oxide) solution. In this case, it is about 0.8 cc. of 3M Fountain Concentrate per 100 cc. of poly (ethylene oxide) solution. The reason for adding the Fountain Concentrate to the poly (ethylene oxide) solution is that there will be only one variable in each testing solution; gum arabic and poly (ethylene oxide).

The "Ability to Clean the Plate" Test

A fountain solution has certain function. One of its functions is to keep the non-printing areas clean by maintaining a continuous water film over such areas. The better the fountain solution, the less time it takes to clean up the plate after over-run with ink. For this test, two identical plates were made. The plates were put on the press and were allowed to dry out. Then the plates were over-inked by lifting the dampening form roller. The over-inking time for each plate was 30 seconds. The dampening form roller was dropped and sheets were fed through. When the dampening roller contacted the plate, it cleaned up the plate. The test was run twice with three replicates for each run. Sheets were counted to show how many sheets were needed to obtain clean prints and good overall images. The same procedure was applied to the other fountain solution.

Results:

The results of the experiments showed that conventional gum arabic solution took less sheets to clean up the plate after the plate was over-inked compared to poly (ethylene oxide) solution. The data and analysis of variance are shown in Table 7 and Table 8. The calculated F ratio did not exceed the critical F ratio. This indicates that there is no statistical significant difference between the two fountain solutions due to the ability to clean the plates.

TABLE 7

THE ABILITY OF EACH FOUNTAIN SOLUTIONS TO CLEAN THE PLATES

Fountain Solution	No. of Sheets to Obtain Clean Prints 1st Run 1	2	3	2nd Run 1	2	3	$\bar{X}$
Gum Arabic	14	18	16	20	17	16	18.5
Poly(ethylene oxide)	19	22	27	26	24	22	23.5

TABLE 8

ANOVA SUMMARY TABLE FOR ABILITY TO PRINT CLEAN

Source	Sum of Squares	Degree of Freedom	Mean Square	F ratio
Type of Solutions	119.50	5	23.90	1.7599 N.S.
Error	81.50	6	13.58	
Total	200.92	11		

Critical $F_{5,\ 6,\ .05} = 4.3874$

N.S. No Statistical Significant Difference

$$\text{Calculated F ratio} = \frac{\text{Variance of Mean}}{\text{Variance of Error}}$$

$$= \frac{23.90}{13.58}$$

$$= 1.7599$$

The "Resistance to Scum" Test

Scumming[5] can be defined as the adherence of ink to part of the non-image areas of a lithographic plate. Sometimes this is called "greasing". Scumming is caused by (a) a poorly desensitized plate; (b) a greasy ink which contain materials which adhere easily to the non-image areas of the plate; (c) an improperly formulated fountain solution; (d) possibly a paper with excess alum in it.

Since all the variables; such as press conditions, pH of the fountain solution, ink, plate, paper were controlled the only variable was the fountain solution ingredient itself. To test the resistance to scum, the testing solution was run on the press. The press was adjusted until an overall good image was obtained. The dampening form roller was then lifted up and sheets were run through. The better fountain solution resistance to scum, the more sheets it can print without scumming. The test was run twice with three replicates for each run. The same procedure was applied to another testing fountain solution. The data and the analysis of variance are shown in Table 9 and Table 10.

TABLE 9

THE RESISTANCE TO SCUM OF BOTH SOLUTIONS

Fountain Solution	No. of Sheets Resistance to Scum 1st Run			2nd Run			$\overline{X}$
	1	2	3	1	2	3	
Gum Arabic	4	8	5	5	7	4	5.50
Poly(ethylene oxide)	3	4	4	5	6•	4	4.33

TABLE 10

ANOVA SUMMARY TABLE FOR RESISTANCE TO SCUM

Source	Sum of Squares	Degree of Freedom	Mean Square	F ratio
Type of Solutions	13.417	5	2.6834	1.6948 NS.
Error	9.50	6	1.5833	
Total	22.917	11		

Critical $F_{5,\ 6,\ .05} = 4.3874$

NS. No Statistical Significant Difference

Results:

As shown in Table 10, the two fountain solutions are shown to be not significantly different since the calculated F ratio did not exceed the critical F ratio. Both gum arabic and poly (ethylene oxide) solutions should be equivalent for quality press performance.

PRINTING SHARPNESS, RESOLUTION AND PLATE-PRESS CHARACTERISTIC CURVE

To determine the printing sharpness, resolution and plate-press characteristic curve obtained from the two fountain solutions the printed sheets included test objects were measured and evaluated.

The test objects and controlled variables are listed in Appendix A. The comparisons of poly (ethylene oxide) solution to gum arabic solution were made under equal solid ink density. The density was 1.25 ± .05 for high ink film thickness and 0.95 ± .05 for low ink film thickness. The density was determined by solid patches across the printed sheet.

Two plates, one for each fountain solution, were identical. The press was made ready and set up so that good printed results and expected ink density were obtained. The test was run twice for both high and low ink film thickness. Twenty five samples from each run were collected for evaluations.

Printing Sharpness

It is apparent that differences in solid ink density influence the tint density values.[6] Printing sharpness is a measure of how well an offset press can maintain detail. If there is slippage or excess packing squeeze between cylinders or a poor ink-water balance the sharpness will be affected.[7]

Printing sharpness values are obtained by dividing the density of tint by the density of solid. The data are shown in Table 11 through Table 13. Two factors with two replicates is used as an analysis of variance. Table 14 summarized the ANOVA table. The statistical results show that there is no significant difference in printing sharpness due to gum arabic or poly (ethylene oxide) solution at equal solid ink density.

Resolution

Resolution is the ability to produce fineness of detail. In this experiment, the standard USAF 1951 target was used for the resolution evaluation. The target[8] consists of a series of patterns decreasing in size as the sixth root of 2 over a variety of ranges. The standard element consists of two patterns at right angles to one another. Each pattern consists of three equal bars separated by spaces of equal width. Each bar is five times as long as it is wide.

TABLE 11

PRINTING SHARPNESS VALUES OF PRINTS USING GUM ARABIC SOLUTION AT BOTH HIGH INK FILM THICKNESS(1.25 ± .05) AND LOW INK FILM THICKNESS(0.95 ± .05)

Sample	High Ink Film Thickness		Low Ink Film Thickness	
	1st Run	2nd Run	1st Run	2nd Run
1	56.20	55.65	47.36	52.08
2	53.97	51.58	49.47	54.16
3	53.28	57.02	51.02	52.63
4	55.00	58.59	54.16	53.19
5	53.66	57.25	52.08	54.63
6	51.58	56.91	52.63	54.44
7	52.46	57.93	55.10	55.67
8	52.76	54.40	53.19	56.70
9	50.40	61.60	53.68	57.60
10	51.20	56.91	53.12	55.55
11	51.61	60.98	52.12	56.04
12	53.66	61.60	52.63	55.91
13	53.17	58.07	55.55	59.14
14	52.42	55.74	54.63	58.94
15	52.85	56.35	55.67	58.06
16	54.40	56.56	51.54	52.08
17	55.20	59.52	53.19	53.19
18	55.28	58.20	48.42	56.25
19	52.42	60.80	53.12	57.89
20	50.79	60.16	50.51	52.57
21	53.60	56.00	52.57	52.63
22	51.22	55.29	47.36	52.68
23	48.82	54.03	50.51	55.20
24	52.00	58.19	51.54	50.15
25	52.03	56.19	54.16	55.31
	$\bar{X}$ = 52.80	$\bar{X}$ = 57.45	$\bar{X}$ = 52.21	$\bar{X}$ = 54.90

TABLE 12

PRINTING SHARPNESS VALUES OF PRINTS USING POLY(ETHYLENE OXIDE) SOLUTION AT BOTH HIGH INK FILM THICKNESS(1.25 ± .05) AND LOW INK FILM THICKNESS(0.95 ± .05)

Sample	High Ink Film Thickness 1st Run	High Ink Film Thickness 2nd Run	Low Ink Film Thickness 1st Run	Low Ink Film Thickness 2nd Run
1	52.80	53.66	60.64	55.10
2	56.00	55.12	56.84	53.12
3	54.40	55.65	59.79	47.37
4	54.03	57.81	58.94	53.19
5	53.28	56.35	57.29	52.63
6	52.03	54.69	58.59	50.52
7	56.35	56.59	58.33	52.08
8	54.47	52.42	58.16	50.54
9	54.76	52.76	60.00	53.12
10	51.58	53.91	55.79	51.02
11	54.68	54.26	56.99	54.17
12	52.84	56.70	55.91	53.12
13	52.45	56.19	55.32	48.42
14	51.61	55.91	57.45	53.68
15	53.12	55.65	56.38	53.19
16	52.75	60.31	57.58	55.67
17	52.03	58.20	54.74	51.55
18	53.28	58.40	59.79	55.13
19	54.33	55.29	57.90	52.63
20	55.11	56.00	56.84	54.64
21	53.12	54.40	55.32	50.52
22	54.40	56.70	59.18	59.78
23	53.17	54.03	58.95	54.17
24	55.90	56.80	58.06	52.58
25	53.28	56.45	57.89	57.89
	$\bar{X}$ = 53.67	$\bar{X}$ = 55.77	$\bar{X}$ = 57.71	$\bar{X}$ = 53.03

TABLE 13

PRINTING SHARPNESS DATA FROM TWO FOUNTAIN SOLUTIONS AT BOTH HIGH AND LOW INK FILM THICKNESS

Fountain Solutions	High	Low
Gum Arabic	52.80 , 57.45	52.21 , 54.90
Poly(ethylene oxide)	53.67 , 55.77	57.71 , 53.03

TABLE 14

ANOVA SUMMARY TABLE FOR PRINTING SHARPNESS

Source	Sum of squares	Degree of freedom	Mean square	F ratio
Type of Solutions	1.10	1	1.10	0.1595 NS.
Solid Ink Density	0.50	1	0.50	0.0725 NS.
Interaction	2.40	1	2.40	0.3480 NS.
Error	27.58	4	6.896	
Total	31.50	7		

Critical $F_{1,\ 4,\ .05} = 7.7086$

NS. No Statistical Significant Difference

The resolution is expressed in cycles/mm. A 40 power micrometer was used for the evaluation. The data are shown in Table 15 through Table 17. They were analysed by the two factors analysis of variance with two replicates. Table 18 summarized the ANOVA Table. The statistical results show that the calculated value exceeds the table value. It is concluded that there is a significant difference in resolution due to changing fountain solution. The gum arabic solution gave better resolution. The resolution decreased when the ink film thickness increased.

Plate-Press Characteristic Curve

A tone reproduction study of a printing process will scientifically evaluate every phase of the printing system from the tones of the original print to the tones of the final reproduction.[9] The relationship between the density of the printed sheet and the percent dot area of the half-tone negative is termed the plate-press characteristic curve. This curve represents the gain or loss of the plate press combination.

The plate-press characteristic curves obtained from the two fountain solutions are shown in Figure 11 and Figure 12. The percent dot area of each step of the half-tone negative step tablet was plotted against the resulting densities of each step on the printed sheet. Under controlled conditions, the curves are alike and almost

TABLE 15

RESOLUTION VALUES PRINT FROM GUM ARABIC SOLUTION AT BOTH HIGH INK FILM THICKNESS (1.25 ± .05) AND LOW INK FILM THICKNESS (0.95 ± .05)

Sample	High Ink Film Thickness		Low Ink Film Thickness	
	1st Run	2nd Run	1st Run	2nd Run
1	32.0	35.9	40.3	45.3
2	35.9	32.0	45.3	50.8
3	32.0	35.9	45.3	50.8
4	35.9	35.9	45.3	45.3
5	32.0	35.9	40.3	50.8
6	28.5	40.3	50.8	57.0
7	32.0	28.5	45.3	50.8
8	32.0	28.5	40.3	50.8
9	32.0	32.0	45.3	50.8
10	35.9	32.0	35.9	40.3
11	35.9	32.0	40.3	50.8
12	32.0	35.9	45.3	50.8
13	32.0	35.9	40.3	50.8
14	40.3	28.5	40.3	45.3
15	35.9	35.9	45.3	45.3
16	28.5	40.3	40.3	40.3
17	32.0	40.3	40.3	40.3
18	35.9	35.9	50.8	45.3
19	32.0	32.0	45.3	50.8
20	32.0	32.0	45.3	40.3
21	28.5	28.5	50.8	50.8
22	40.3	32.0	50.8	45.3
23	35.9	32.0	57.0	45.3
24	28.5	35.9	45.3	40.3
25	40.3	32.0	50.8	50.8
	$\bar{X}$ = 33.528	$\bar{X}$ = 33.840	$\bar{X}$ = 44.892	$\bar{X}$ = 47.408

TABLE 16

RESOLUTION VALUES PRINT FROM POLY (ETHYLENE OXIDE) SOLUTION AT BOTH HIGH INK FILM THICKNESS(1.25 ± .05) AND LOW INK FILM THICKNESS(0.95 ± .05)

Sample	High Ink Film Thickness		Low Ink Film Thickness	
	1st Run	2nd Run	1st Run	2nd Run
1	32.0	22.6	25.4	32.0
2	32.0	25.4	28.5	28.5
3	28.5	25.4	25.4	25.4
4	25.4	22.6	32.0	25.4
5	28.5	22.6	25.4	32.0
6	28.5	25.4	22.6	40.3
7	32.0	25.4	28.5	22.6
8	28.5	32.0	32.0	25.4
9	28.5	28.5	25.4	25.4
10	25.4	25.4	25.4	28.5
11	20.1	28.5	35.9	45.3
12	22.6	25.4	28.5	28.5
13	25.4	25.4	25.4	32.0
14	22.6	28.5	32.0	28.5
15	22.6	32.0	40.3	28.5
16	28.5	25.4	40.3	32.0
17	25.4	25.4	32.0	22.6
18	28.5	22.6	25.4	28.5
19	20.1	25.4	35.9	25.4
20	17.9	25.4	28.5	20.1
21	22.6	20.1	32.0	35.9
22	22.6	25.4	35.9	25.4
23	22.6	20.1	32.0	32.0
24	25.4	20.1	28.5	22.6
25	22.6	17.9	32.0	25.4
	$\bar{X}$ = 25.552	$\bar{X}$ = 24.916	$\bar{X}$ = 30.208	$\bar{X}$ = 28.728

TABLE 17

RESOLUTION DATA FROM TWO FOUNTAIN SOLUTIONS AT BOTH HIGH AND LOW INK FILM THICKNESS

Fountain Solutions	High	Low
Gum Arabic	33.528 , 33.840	44.892 , 47.408
Poly(ethylene oxide)	25.552 , 24.916	30.208 , 28.728

TABLE 18

ANOVA SUMMARY TABLE FOR RESOLUTION

Source	Sum of squares	Degree of freedom	Mean square	F ratio
Type of Solutions	315.82	1	315.82	280.029 *
Solid Ink Density	139.44	1	139.44	123.638 *
Interaction	33.88	1	33.88	30.041 *
Error	4.51	4	1.13	
Total	493.67	7		

Critical $F_{1,\ 4,\ .05} = 7.7086$

* Statistical Significant Difference

superimpose on each other.

During the experiments, it was observed that poly (ethylene oxide) when run on the press at high ink film thickness, required more ink to reach the expected density. The ink and water balance, therefore became critical. Tinting and slur tended to develop. Slur is observed from the GATF Dot Gain (Slur Gauge) and GATF Star Target. The word "SLUR" is visible and the center of the Star target spreads to an oval shape.

When poly (ethylene oxide) solution was used on the press, the ink rollers nip produced some "smoke". This happened only when starting the press. After a few revolution of the press, this problem disappeared.

The advantage of poly (ethylene oxide) solution over gum arabic solution may be its high resistance to bacterial attack. It was noticed that poly (ethylene oxide) solution can keep for a few weeks without bacteria deterioration, while gum arabic solution can keep for only a few days. This deterioration on storage can result in increasing the contact angle.

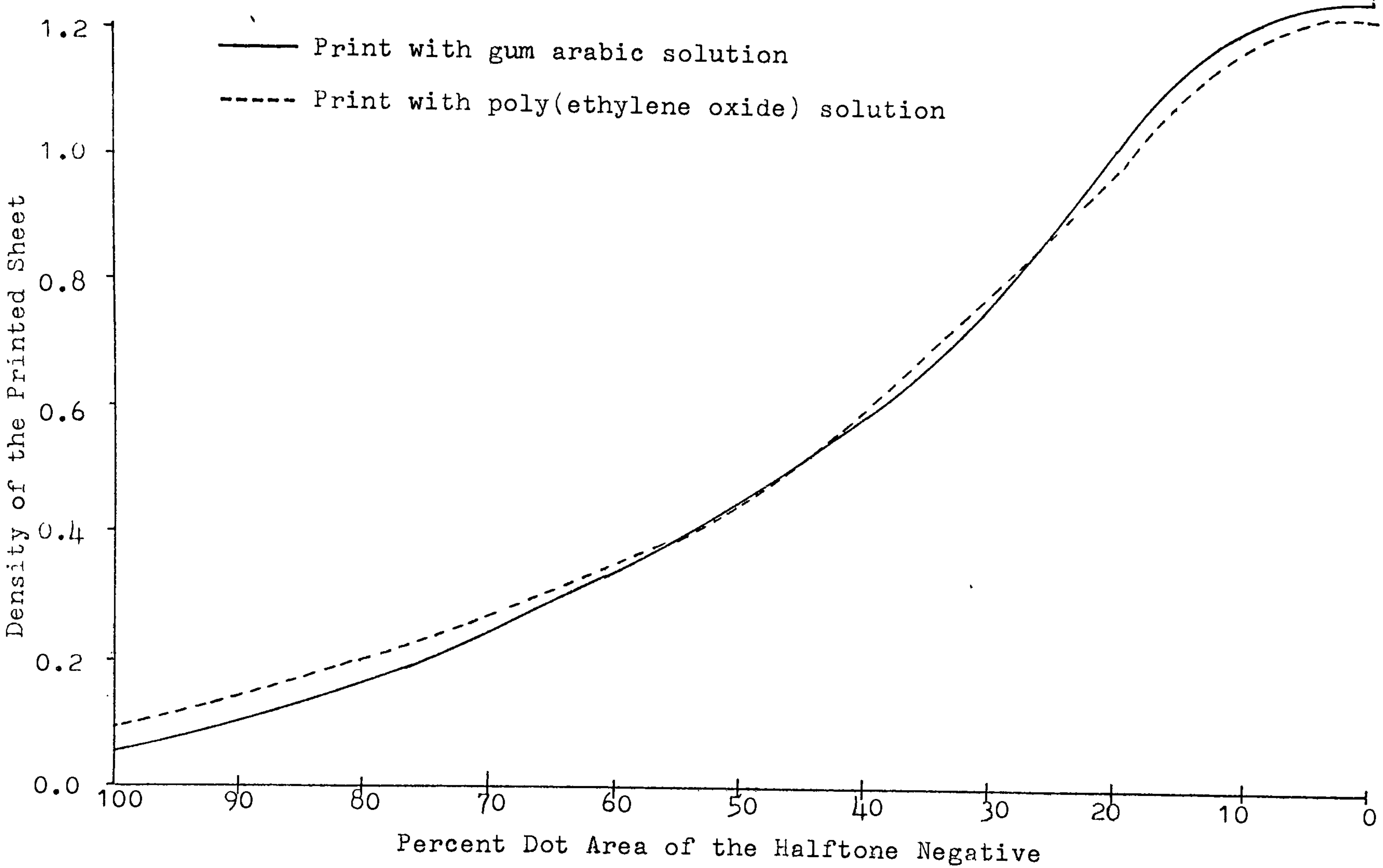

Figure 11 Tone Reproduction Curve of Both Solutions at High Ink Film Thickness

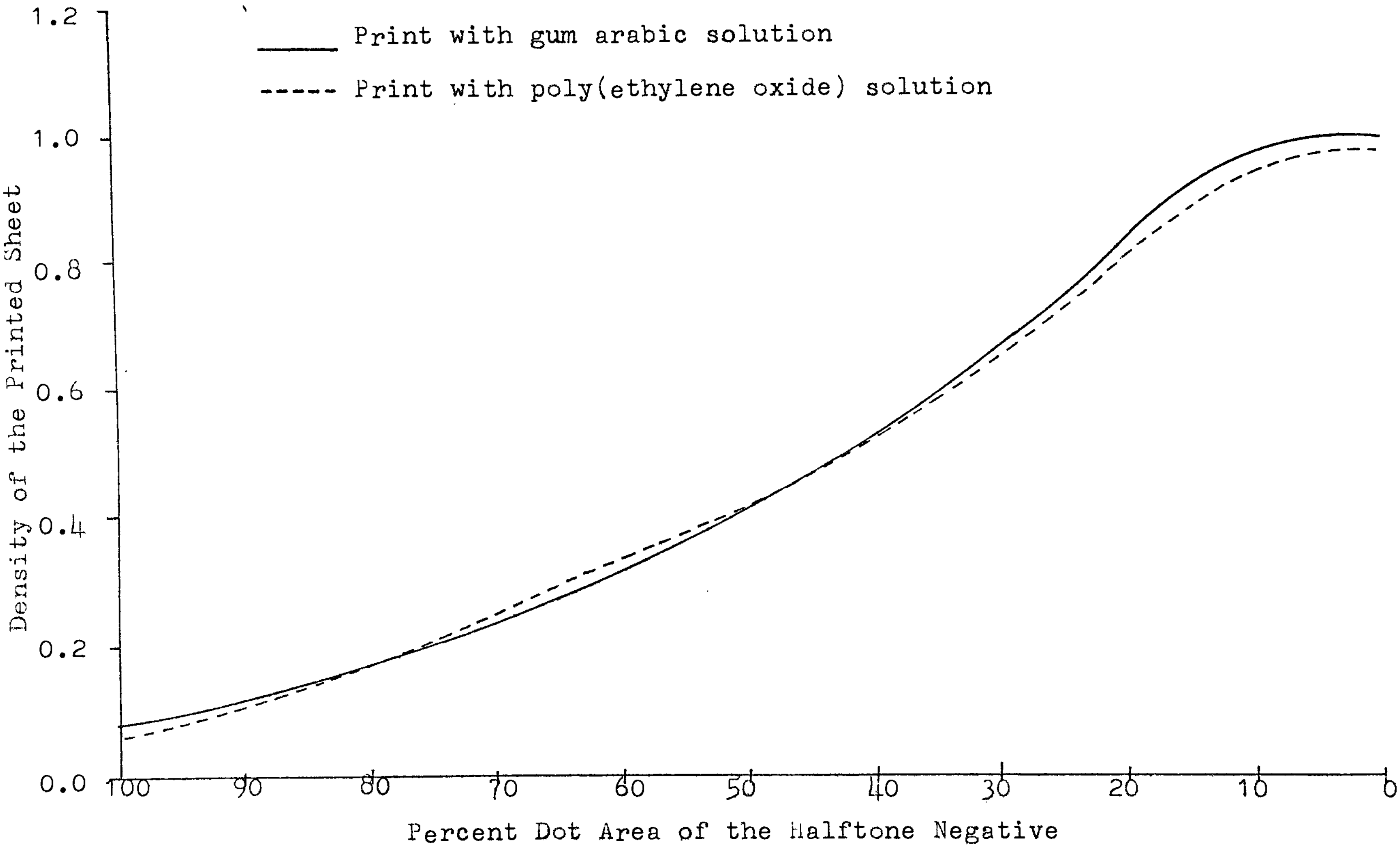

Figure 12 Tone Reproduction Curve of Both Solutions at Low Ink Film Thickness

FOOTNOTES FOR CHAPTER III

[1] "Solutions to Sticky Problems," (Massachusetts: Brookfield Engineering Laboratories Inc.), p. 9.

[2] Ibid., p. 1.

[3] "1974 Annual Book for ASTM Standards, Part 30," (Pennsylvania: American Society for Testing and Materials), p. 206.

[4] Albert D. Rickmers and Hollis N. Todd, Statistics: An Introduction (New York: McGraw-Hill Book Inc., 1967), p. 160.

[5] Paul J. Hartsuch, Chemistry of Lithography (Pennsylvania: Graphic Arts Technical Foundation Inc., 1961), pp. 305-306.

[6] Warren L. Rhodes, "Study of Objective Methods for Evaluating Sharpness in Lithography," TAGA Proceedings (1955), p. 103.

[7] Miles F. Southworth, Color Separation Techniques (Pennsylvania: North American Publishing Company, 1974), p. 213.

[8] Itek Optical Systems Division, "Resolving Power Test Target".

[9] Miles F. Southworth, "Objective Tone Reproduction in the Graphic Arts," Rochester Institute of Technology, 1974. (Typewritten.)

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

This study investigated the properties of poly (ethylene oxide) as a constituent of fountain solution. The solution of this synthetic water soluble resin was compared to the gum arabic solution.

The non-press investigations included wettability, viscosity and surface tension measurement of each solution at different concentrations.

The viscosity of both poly (ethylene oxide) and gum arabic solution measured by Brookfield Synchro-Lectric Viscometer showed no differences. The viscosity increased as the concentration increased. But the viscosity of poly (ethylene oxide) solution decreased as the rate of shear (blending time) increased. In this case, low viscosity with high concentration can be obtained by increasing the rate of shear.

The surface tension was measured by the du Nouy Tensiometer, Ring method. It showed that the surface tension of poly (ethylene oxide) is lower than that of gum arabic solution.

The wettability of a liquid on a solid surface was measured by the contact angle method. The contact angle obtained from poly (ethylene oxide) solution increased as the concentration increased while the contact angle of gum arabic solution decreased as the concentration increased.

The on-press investigations included the ability of the solution to clean up the plate, the resistance to scum, the printed results such as printing sharpness, resolution and plate-press characteristic curve. The press performance was under controlled press conditions, plate, blanket, paper, ink and pH of the solutions. The ink film thickness was also controlled. At high ink film thickness the optical density was 1.25 ± .05 and it was 0.95 ± .05 at low ink film thickness.

The concentration of poly (ethylene oxide) necessary was determined. The poly (ethylene oxide) solution was 0.5 grams/100 cc. of water. The solution of gum arabic was one ounce of 14 Baume Gum Arabic and one ounce of 3M Fountain Concentrate to a gallon of water. The equivalent amount of 3M Fountain Concentrate used in gum arabic solution was added to the poly (ethylene oxide) solution. Phosphoric acid was used to control the pH of the fountain solutions. The pH ranged between 4.0 to 5.0. This was measured by "pHydrion" short range paper.

The statistical analysis indicated that there is no significant difference between both solutions in terms of the ability to clean up a plate, the resistance to scum and printing sharpness. This indicated that poly (ethylene oxide) is comparable in these regards. Gum arabic solution gives a better resolution at both high and low ink film thickness. The plate-press characteristic curves appear to be alike and almost superimpose on each other.

Recommendations For Further Study

The formula of the gum arabic solution used in this study is the one being used in most of the lithographic plants and it is recommended by the manufacturer, 3M Company. The 3M Fountain Concentrate is added in both testing solutions. A possible question is whether the addition of ammonium bichromate (which is contained in the 3M Fountain Concentrate) improves the properties of solution containing poly (ethylene oxide). Study of this question would be interesting.

The experiment was done on one type of plate, ink, and paper. A study with different types of plates, inks and papers would be helpful for the selection of materials to be used with this desensitizer.

It would be interesting to study the effect of poly (ethylene oxide) solution at different levels of acidity (pH).

Since for a given concentration of poly (ethylene oxide) the contact angle falls as blending time increases, it would be of interest to test fountain solutions of poly (ethylene oxide) as a function of blending time.

APPENDICES

APPENDIX A

CONTROLLED VARIABLES AND TEST OBJECTS:

1. Plate: 3M presensitized, negative working aluminium plate, type "K". The exposure time was 1 ½ minutes and developed to the critical step No. 6 of the GATF Sensitivity Guide.

2. Ink: Litho Ink, IPI Speed King, neutral black(PMS).

3. Paper: 8 ½ x 11, white Paloma matte, dull finish, 70 lbs.

4. pH of the fountain solutions: between 4.0 to 5.0 as recommended by GATF. The pH was measured by the pHydrion paper.

5. Press: ATF Chief 15. The press was adjusted as recommended by the manufacturer. The speed was 3,500 IPH.

6. The test objects consisted of:

a. solid patches and tint patches of 133 line. The solid patches were used to control the density across the press sheet as well as to provide the printing sharpness data.

b. GATF Sensitivity Guide, a 21 steps of continuous tone gray scale. This guide was used in order to give a uniform scale of light transmission for measuring plate exposure.

c. GARC Plate-Press Test Target, a 10 steps scale to determine plate-press curves for a number of different presses and plate conditions.

d. Slur target, a test image designed to show variations in the amount of slur along and across the press sheet.

e. GATF Star Target, a small circular pattern of solid and clear pie wedges. It provides.a quick and effective measure of any ink spread, slur and doubling in the presswork.

f. GATF Dot Gain Scale, a visual device indicating dot area changes. It is made up of ten steps of 200 line screen tints which are graduated in density from step to step. These steps are in the form of numbers from 0 to 9 on a background of a 65 line tint of uniform strength.

g. The Standard USAF 1951 Resolution Target, a series of patterns decreasing in size. Each pattern consists of three bars separated by space of equal width.

h. The Halftone Gray Scale, 12 steps, 150, 133 and 120 line.

APPENDIX B

SURFACE TENSION

Young[1] gave an explanation of surface tension in terms of the attractive and repulsive forces between the molecules constituting the liquid. In the body of liquid, a molecule is attracted equally in all directions while a molecule at the surface is subjected to an unbalanced forces that acts inwards to the surface.

The force, acting perpendicular to a centimeter length of surface, and in the surface is known as the surface tension. It is expressed in dynes/centimeter.

Surface tension can be measured quantitatively by various means,[2] including the pulling of a wire ring from the surface of a liquid, the weighing of drops which fall from a special glass tip, the determination of the shape of a hanging drop, the reflection of light from ripples on the surface of a liquid and the pressure required to blow gas bubbles in the liquid.

If the lithographic plate has been well desensitized, it is possible to run the plate with just plain water. But water has a high surface tension. If water is used alone it will require greater amounts for dampening the plate.

Therefore, some wetting agents, such as gum arabic, cellulose gum, alcohol, etc. are added to reduce the surface tension of water and cause the liquid to readily wet a solid surface.

FOOTNOTES FOR APPENDIX B

[1]J. T. Davies and E. K. Rideal, Interfacial Phenomena, (London: Academic Press Inc., 1963), p. 1.

[2]Farrington Daniels, Outlines of Physical Chemistry, (New York: John Wiley and Sons Inc., 1948), pp. 184-186.

APPENDIX C

WETTABILITY OF THE NON-PRINTING AREAS

When a drop of liquid is placed on the solid, it sometimes spreads out immediately to cover the whole surface of the solid, but usually it remains in the form of a lens.

Wettability[1] is the behavior of a liquid and a solid when the liquid is trying to spread on the solid. The degree of wetting can be described numerically by the magnitude of the three interfacial tensions: the liquid/solid, the liquid/air and the solid/air. Thus the criterion for wetting is whether the solid/air interfacial tension is greater than that for solid/liquid or not. If it is, the liquid will wet the solid and the contact angle will be less than 90 degrees. If it is not, the liquid will not wet the solid and the contact angle will be greater than 90 degrees.

The behavior of a liquid on a solid surface is characterized by a quantity called the contact angle.[2] A contact angle of zero implies complete wetting of the solid surface by the liquid, while a value of 180 degrees would correspond to absolute non-wetting. In the lithographic process, the non-image areas should show contact angles approaching zero towards water while the image areas should show a contact angle approaching 180 degrees.

The factors that most affect the water-receptivity of non-image areas are:[3] (1) the metals themselves; (2) the surface treatments given the metal; (3) the desensitizing process; (4) the fountain solution with which the plate is run; (5) the gumming.

Metals like chromium, aluminium and stainless steel form hard, tenacious oxides which are easily wet by water and retain their wettability for a long time. Zinc or iron is not wet as readily by water because zinc forms loose corrosion products similar to rust. The wettability of metals changes as they go through different stages of corrosion.

The ability of a metal to be wet with water is enhanced or reinforced by the application of a solution of a gum. How well the gum or etch sticks to the metal depends on the composition of the etch and the condition of the metal surface. If the metal surface is corroded or if a foreign material is adsorbed to its surface, the gum will not stick. The surface treatment is thus needed to eliminate difficulties caused by these defects and to improve the wettability of metals.

A surface-treated metal does not corrode, does not react with coating, and is not affected by the solutions used in the lithographic process; coating and gum stick well to the treated metal.

The purpose of an etch is to deposit a water-receptive material on the non-image areas of the plate. A good etch should leave a film of water-receptive material which lasts for a long time on the press, and wet with a minimum of water.

An etch usually consists of gum, an acid and one or more salts. The main ingredient of the etch is the gum, usually gum arabic. Gum arabic contains carboxyl groups which give a firm bond between the gum and the metal. The gum swells in the presence of water, but the carboxyl bond keeps the gum from dissolving away from the metal.

Phosphoric acid is used to convert more of the groups in the gum molecule to carboxyl groups in order to improve the adhesion. But too much acid attacks the metal which in this case, instead of forming a film on the metal, removes metal.

FOOTNOTES FOR APPENDIX C

[1]R. R. Coupe, Science of Printing Technology, (London: Cassell and Company Ltd., 1966) , pp. 73-74.

[2]R. A. C. Adams, "Contact Angles and Their Significance in Lithographic Research," International Bulletin for the Printing Allied Trades 73. (January 1956) , p. 20.

[3]Charles Shapiro, ed., The Lithographers Manual, (Pennsylvania: Graphic Arts Technical Foundation Inc., 1974) , pp. 10:17-10:19.

APPENDIX D

pH

One of the principal factors that control the chemical reaction of fountain solutions is the pH of the solution. The pH value of a solution is a number used to express the concentration of ionized hydrogen (the acid part) in a dissociated liquid, and is thus a measure of the degree of acidity or alkalinity.[1]

As the hydrogen ion concentration increases, the pH of the solution decreases and the greater the acidity of the solution, the lower the pH value.[2] The pH scale runs from 0 to 14. The middle points, 7, indicates a neutral solution while the values above 7 are alkaline and below 7 are acid.

Two methods are used for measuring the pH of a solution, the colorimetric method and the electrometric method.[3]

The colorimetric depends on the change of color of materials called indicators which are added to the solution. Indicators change color over a range of about two pH units. Different indicators must be used for accurate measurement over the scale. Paper strips for the colorimetric measurement of pH are also available, such as the "pHydrion pH

Paper."

The electrometric method depends on the change of the voltage of a little electrical cell, as the pH of the solutions of the electrical cell changes. The cell is calibrated by measuring the voltage when the cell is filled with a solution of known pH. By knowing that the voltage of such cells change, it is possible to calculate the pH of any unknown solution. In practice, the meters have been calibrated to read directly in pH units.

The fountain solution is usually acid. The proper amount of phosphoric acid is used in the solution to improve the adherence of the desensitizing gum to the non-image area because the acid converts the desensitizing gum to its "free acid form" in which the molecules contain carboxyl groups (-COOH). These groups are able to form a good adsorption bond of the gum to the metal surface.[4] If excess amount of acid is added to the fountain solution, it will remain in the solution as a free phosphoric acid and begin to react with the metal of the plate. The plate then loses its desensitization and ink adheres to the non-image area causing scumming. Plate blinding and roller stripping may occur in conjunction with plate scumming. Also, inks with a strongly emulsified acid fountain solution take longer to dry.

However, the correct amount of acid in the fountain solution depends on materials being used such as ink ingredients, plate treatments and pH of paper. As recommended by the GATF, usually a fountain solution with a pH between 4.0 and 5.0 is satisfactory. It is suggested that the pH of the solution be checked when printing trouble develops.[5] The reason is that a fountain solution may change in pH on the press during the run.

FOOTNOTES FOR APPENDIX D

[1] Bruce E. Tory, Offset Lithography, (Australia: Korwitz Publications Inc., 1957) , p. 82.

[2] Paul J. Hartsuch, Chemistry of Lithography, (Pennsylvania: Graphic Arts Technical Foundation Inc., 1961) , p. 51.

[3] Ibid., pp. 53-56.

[4] Ibid., pp. 300-301.

[5] Charles Shapiro, ed., The Lithographers Manual, (Pennsylvania: Graphic Arts Technical Foundation Inc., 1974) , p. 12:47.

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