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A study of the effect of ink tack, printing pressure, and printing speed on toning in the Driographic system

Thomas Rigg

School of Printing
Rochester Institute of Technology
Rochester, New York

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's Thesis of

Thomas C. Rigg

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 June, 1974.

Thesis Committee: Clifton Frazier
Thesis adviser

Robert G. Hacker
Graduate adviser

Mark Guldin
Director or designate

A STUDY OF THE EFFECT OF INK TACK, PRINTING PRESSURE, AND PRINTING SPEED ON TONING IN THE DRIOGRAPHIC SYSTEM

by

Thomas C. Rigg

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, 1974

Thesis adviser: Professor Clifton Frazier

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An Abstract

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ABSTRACT

An investigation was made into one of the newer planographic printing plates, specifically 3M's Dry Plate. This plate is part of the system more popularly known as driography. As with many new processes, driography is beset with several problems. These include plate durability, substrate suitability, and toning. This study deals with the problem of toning and a method for investigating it.

In driography, toning is defined as the inking of the non-image background of the plate. Several factors are thought to have an effect on the amount of toning. Factors such as ink tack, ink temperature, room temperature, humidity, speed, and pressure are included. This investigation specifically researched the relationships between toning and ink tack, inking pressure, and printing speed.

A parallel study of these relationships was made on both an IGT Printability Tester and on an ATF Chief 15 press. This was done in an attempt to show that the IGT Printability Tester could print driographically but, under the conditions used, it was a poor predictor of toning.

Two methods of recording the effects of toning were used. One method was the recording of absolute densities

taken in the non-image areas of the test sheets. The other method was the recording of a ratio of the density of a solid patch to the density of a tinted patch. It was hoped that the ratio would eliminate some of the extraneous variables that might affect the amount of toning. It was found, however, that the ratio result tended to record not only the pure toning, but also, the effects of some of the extraneous variables.

Several statistical methods were used to analyze the data accumulated. To compare one printing method with another and to compare one recording method with another, a correlation analysis was made and a graphical study done. To determine the reliability of the graphical analysis, a spot check was made using a paired comparison technique. An analysis of variance (ANOVA) was made of the data from each printing and recording method to determine the significant factors in the experiment.

This experiment showed that ink tack, inking pressure, printing speed, and their interactions all were significant factors in toning. Unfortunately it was impossible to include some other factors in the experiment which are known to have a significant effect on toning. These include such factors as ink temperature, room temperature, and humidity.

More work needs to be done in the area of driography, especially in toning. The crucial question is

whether this is a plate or an ink problem. As more control is obtained over toning, the use of driography should increase.

Abstract approved: Clifton Frazier thesis adviser
Asso. Prof. Printing, title and department
Sept. 17, 1974, date

INTRODUCTION

In recent years, there have been many developments within the field of printing plates. Until the 1950's, the methods of transferring an original image to the finished copy were relatively standardized. The onset of the use of computers, phototypesetting, and more reliable lithographic presses, combined with the nation's need for increased output, forced the development of new and better transfer methods. Along with the original qualifications of sufficient speed for processing, reasonable cost, and high quality, new plates should be able to use phototypesetting or other advancements of the technological age.

> Like most technological products, a printing plate is not spawned in some sudden and dramatic 'moment of birth.' Rather does it emerge from an original idea by way of a steady series of experiments -- some successful, many not -- until, one day, there is a finished product capable of working as successfully on a commercial basis as for the research team in the laboratory.[1]

Although the above quoted paragraph is quite dramatic in its presentation, it is very applicable when discussing driographic plates. These plates emerged from the laboratory as a means of answering one of the lithographer's problems -- water. However, there are still many problems associated with the new plate and its printing method. Hopefully, these will be solved after more experimentation and work by its developer, 3M Corporation, and other printing-related organizations.

As a background to future discussion, it is important to review the principles of lithography. It is basically a planographic process in which the printing and non-printing areas are in the same plane as the image carrier. In offset lithography, the most common form of lithography today, the offset to the rubber blanket reduces the abrasion of the plate. Since water tends to repel the greasy ink, the plates or image carriers depend on water to separate the non-image from the image areas.[2] There is a chemical differentiation made between image and non-image areas to maintain the ink and water covered areas.

Lithography has become an important process in today's market. In fact, it accounts for about 38 per cent of all the printing done in the United States.[3] The reasons for this relatively large percentage are lithography's advantages. These include the ability to print on a wide range of substrates, inexpensive plates, easily stored plates, relatively fast presses, easily made plates, the ability to print finer halftone screens, and some aesthetic advantages in reproducing some originals.

As with many technological processes, there also are disadvantages. The disadvantages have prevented lithography from expanding into many fields where the other methods of printing still have control. The disadvantages include the difficulty in delineating between image and non-image areas, the use of water, non-correctable plates (although image areas can be made non-image areas), easily damaged plates, higher ink cost, high paper waste, difficulty in numbering, difficulty in scoring or perforating, and the great pressure exerted on the sheet of paper.

Of all the disadvantages, the use of water is probably the most serious because it contributes to many of the other problems. Water causes problems related to the dimensional stability of the sheet of paper and to the emulsification of the ink and ink film consistency. These effects of water are directly related to the problems of registration, color consistency, higher cost inks, higher paper waste, higher tack inks with related problems of picking, linting, and scumming, and fountain solution formulations.[4]

Lithography, the author feels, is a steadily growing field of printing. Although its percentage of the market may not increase significantly, it will still command a large amount of a steadily growing industry. Dry planographic printing or driography is a process that will at first have its greatest application in traditional lithographic fields. Today its most appropriate application is business forms, because of their need for dimensional stability. It is believed that as lithography grows, so will driography. As some of its problems are overcome, driography, in fact, may start taking a larger and larger share of the work away from lithography.

In August of 1972, a spokesman for 3M Company made an optimistic appraisal of the future of driography;

> We are committed to the driographic system and have made a great deal of technical progress during the past year in identifying our problems with driography and either minimizing or eliminating those problems. However we are not totally 'out of the woods' in all respects and will continue to move ahead carefully but deliberately with the driographic system.[5]

The 3M Company would give such an optimistic statement for promotional reasons. However, it is felt by the author that even with the present Dry Plate's problems, the principle behind it is sound and one on which future printing will be based. It is only logical that over time a process which is fraught with many problems will change.

As has already been mentioned, driography was the development of a process of planographic printing which would eliminate water. It is a process that has the same advantages as lithography when comparing it to other methods of printing. Its basic advantage over lithography is the elimination of water. This is a large advantage. Driography is a logical development of lithography, regardless of the success of 3M's Dry Plate System.

Some of the problems with 3M's Dry Plate are durability, toning, ink set-off, drying in the ink train, picking of paper, need for high tack ink, and susceptibility to scratching. Specifically, the plate's durability on the press is relatively short, about 50,000 impressions.[6] Toning and scumming refer to the non-image area of the plate accepting ink. In driography, toning occurs when the silicone coated background area accepts ink.[7] The term scumming, on the other hand, refers to this occurance on lithographic plates.[8] The silicone coated surface of the Dry Plate is easily damaged and is very susceptible to abrasion.[9]

As indicated earlier, set-off is a problem with driography. Set-off is the transfer of ink from one sheet to the back of another.[10] The bare aluminum image area accepts more ink and transfers more ink than the coated areas of the lithographic plates. Set-off can, therefore, be more pronounced than in lithography.

Driographic inks generally have a higher ink tack than lithographic inks. Also they contain more pigment, perhaps more driers, and proportionately less vehicle. Therefore, there is a tendency for the ink to dry on the rollers or in the ink train.[11]

Another problem with the driographic process is paper picking, which refers to the lifting of small clumps of fibers from the paper's surface.[12]

Generally, a motivating factor for studying problems with technological processes is to attempt to solve or define a problem for the current users of the process. Driography itself was a result of this type of investigation. The author's motivation in studying one of the problems of driography was to help current users of 3M's Dry Plate. Also, establishing the methodology with which to study future dry planographic systems would be useful to industry.

The selection of an ink tack appears to be one of the important problems with the Dry Plate. It is directly related to many of the problems already stated and therefore is quite important. Ink companies and 3M have made investigations in this area, but it has been of a proprietary nature and is not available to the general public.

Research has shown that there is a relationship between the tack of the ink selected and toning, drying in the ink train, and picking of paper. The topic of this study will be to investigate the relationship between ink tack and toning at various levels of inking pressure and printing speed when using 3M's Dry Plate.

FOOTNOTES FOR CHAPTER I

[1]"Development of Howson Algraphy's Marathon Offset Plate," Printing Trade Journal, No. 1014 (August, 1971) p 42.

[2]Victor Strauss, The Printing Industry (Washington, D.C.: Printing Industries of America, 1967) p 37.

[3]Quarterly Industry Report, U.S. Department of Commerce, Bureau of Domestic Commerce, Printing and Publishing (July, 1972) p 15.

[4]Charles W. Latham, Lithographic Offset Press Operating (Pittsburgh, Pennsylvania: Graphic Arts Technical Foundation Incorporated, 1967), p 43.

[5]David P. Sorenson, "Driography -- A Status Report," Printing Magazine, Vol. 96, No. 8 (August, 1972) p 52.

[6]Max Barbour, "The Man Who Developed Driography," Modern Lithography, Vol. 38, No. 9 (September, 1970), p 51.

[7]Lars G. Rudstrom and Nelson R. Eldred, "Driographic Printing -- An Evaluation," GATF Research Progress Report, No. 88 (February, 1972) p 2.

[8]Strauss, The Printing Industry, p 614.

[9]Gerald A. Silver, "A New Kind of Lithography," Printing Management, Vol. 100, No. 12 (September, 1970). p 54.

[10]Sorenson, "Driography -- A Status Report," p 52.

[11]Ibid.

[12]Strauss, The Printing Industry, p 575.

CHAPTER II

STATEMENT OF PROBLEM

The only printing plate currently available for printing by driography is 3M's Dry Plate. The plate is negative working aluminum with separate light-sensitive, bonding, and silicone elastomer coatings. When the plate is exposed to actinic light, the bottom photosensitive layer is softened and is removed with development. This leaves a bare aluminum image area and a silicone coated non-image area. The polymer coated area has a low surface energy and tends to repel any greasy substance, such as ink.[1]

The plate is primarily suited to medium runs of 50,000, although runs up to 90,000 have been achieved.[2] The advantages of the plate, in addition to those already mentioned, include no requirement for gumming of the plate, a visible image produced on exposure, and no need for new production equipment.[3]

Lithography, as well as driography, works on the theory of differential adhesion in relation to ink and, in the case of lithography, water. This theory was explained by John L. Curtin, the inventor of driography, "The principle (is) that under certain circumstances ink will adhere to the image areas of a printing plate, but not the background."[4] In other words, there is a difference in the adhesive properties of various surfaces. The theory is based on the principles of cohesion and adhesion. Cohesion is the molecular attraction of particles of a body or mass,[5] in this case ink and water. Adhesion is the molecular attraction exerted between the surfaces of bodies in contact,[6] in this case the surfaces of plate, blanket, ink, and water.

Generally, ink is a higher cohesive mass than water. Tack, as measured on a GATF Inkometer, is considered to be related to the cohesiveness of ink, although it may be an indirect relationship. Probably as ink tack increases, the cohesiveness increases. Water, on the other hand, has low cohesiveness.

In lithography, ink adheres better to the ink rollers and image areas of the plate than to the water covered non-image areas. In other words, the cohesive qualities of the ink and the adhesive qualities of the rollers and chemically treated image areas combine to form the inked image. This is often referred to as the oleophilic and hydrophilic qualities of lithographic plates. In driography, the same principle holds true, but there is no water. The background or non-image area has low adhesive qualities and repels the ink. The bare metal image areas and the ink rollers hold the ink. The forces of cohesion are greater than those of adhesion.[7]

Each printing process in order to print efficiently requires an ink which falls within a specific range of cohesiveness. While there is no direct way to measure this cohesiveness, generally the reading called "tack" taken from a GATF Inkometer or some similar instrument is used as the measure. "An easily understood definition of tack is stickiness. This is the force required to split an ink film between two surfaces."[8] Flexographic and gravure printing generally require a low tack ink. Letterpress, lithographic, and driographic printing each require an increased ink tack. The 3M Company states that a high tack ink must be used with their Dry Plate.[9] In fact, for some inks, they recommend the addition of resins (i.e. Ashland Resin No. 533) to the ink to increase the tack.[10]

Although a particular tack is needed for a particular process, its actual selection is very critical. An extremely high tack ink may pick, pluck, or tear the paper surface. A low tack ink, on the other hand, may be incapable of producing sharp images.[11]

In driography, the ink tack or ink's cohesive force must be high enough to produce sharp images, but not so high that it picks the paper being printed. Paper fibers that are picked and reach the plate surface will scratch its delicate non-image area. Obviously, the amount of picking depends not only on the ink, but also on the paper itself. Low ink tack will cause a loss in the resolution of the image and toning of the background area. Toning is defined as the phenomenom of the non-image ink-repelling area accepting ink.[12] It is the failure of the theory of differential adhesion that causes toning.

The relationship between ink tack and the printability of the driographic plate has been found to be an important one. The topic of this study will be to examine in detail the relationship between ink tack and toning. A sub-problem will be to determine if the IGT Printability Tester can be used to study the relationship and if there is a positive correlation between its results and actual press conditions.

Several hypotheses have already been made in relation to this study and will be assumed true without testing. These are:

1. As the cohesiveness and adhesiveness of ink increase, the ink tack also increases.
2. A measure of ink tack can be obtained by using a GATF Inkometer.
3. Driography requires a high tack ink to print effectively.
4. As ink tack increases, the degree of paper picking increases.

5. A measure of the pick resistance of paper can be obtained through several tests (IGT Test, Dennison Wax Test, GATF Pick Test).
6. The density of ink in the background area (toning) can be measured on a reflection densitometer.
7. As the ink tack increases, the length or stringiness of the ink increases.[13]
8. The temperature and humidity of the testing room will have an effect on ink tack and therefore also on toning, but the exact relationship is unknown.

The following hypotheses will be tested:

1. As ink tack decreases, the amount of background toning on a driographic plate increases.
2. As ink roller to plate pressure increases, the amount of toning increases.
3. As the printing speed increases, the amount of toning increases.

This study will investigate how ink tack, printing pressure, and printing speed affect toning. There are other factors that may affect toning, but these will not be investigated (i.e. ink temperature, type of paper, size of image area, temperature and humidity of testing area). An assumption will be made that the results of this study will be valid only for the conditions described.

FOOTNOTES FOR CHAPTER II

[1]Lars G. Rudstrom and Nelson R. Eldred, "Driographic Printing -- An Evaluation," GATF Research Progress Report, No. 88 (February, 1972), pp 1,2.

[2]Max Barbour, "The Man Who Developed Driography," Modern Lithography, Vol. 38, No. 9 (September, 1970), p 51.

[3]"Driography," Graphic Arts Buyer, Vol. 3, No. 8 (March 4, 1971), p 27.

[4]"Two Breakthroughs in Lithographic Technology," Modern Lithography, Vol. 38, No. 6 (June, 1970), p 28.

[5]Webster's Seventh New Collegiate Dictionary, 7th edition, (1971), p 161.

[6]Ibid., p 11.

[7]G. Leyda, "Inks for Driography," Modern Lithography, Vol. 38, No. 11 (November, 1970) p 52.

[8]Robert F. Reed, What the Lithographer Should Know About Ink (New York: GATF Publication, 1960), p 44.

[9]Leyda, "Inks for Driography," p 52.

[10]Dr. David P. Sorenson, "Driography -- A Status Report," Printing Magazine (August, 1972) p 35.

[11]Victor Strauss, The Printing Industry (Washington, D.C.: Printing Industries of America, 1967), p 583.

[12]Leyda, "Inks for Driography," p 52.

[13]Stringiness refers to the property of a liquid to be drawn out in strings.
Andries Voet, Ink and Paper In The Printing Process (New York: Interscience Publishers Inc., 1952), p 79.

CHAPTER III

REVIEW OF THE LITERATURE

Ink companies, 3M Company, and probably some paper companies have performed some investigations into the relationship between the driographic plate, ink tack, and toning. As far as the author was able to determine, most of these investigations have been of a proprietary nature and are not available to the general public.

Upon personal request, 3M sent the author a copy of a technical report written by Mr. L. J. Stulc for ink manufacturers. In this report it is stated that an increase in temperature, an increase in ink film thickness, and a decrease in press speed will increase the amount of toning.[1] It was also stated that the viscosity of ink decreases as the temperature increases.[2] Generally speaking, the best driographic inks were lithographic inks with an operable range between 45 degrees Fahrenheit and 75 degrees Fahrenheit. This range of temperatures changed for different inks and also with various press speeds and film thicknesses.[3] The ambient temperature was also found to have an effect on the operable range.[4] It was determined that the best inks have a low maximum tack, below 30 to 35 at

400 RPM, but higher than 15.[5] Finally, the best inks for driography are made from varnishes in which the components are on the verge of incompatibility.[6]

Mr. Robert Crowe, a 3M Technical Service Representative, pointed out that 3M realizes that toning is one of the most serious drawbacks to the Dry Plate. According to 3M's current research, the two major factors which contribute to the toning are ink temperature and tack. These factors are not independent of one another. The temperature of the ink tends to rise while it is moving through the ink train of the press; thus the ending temperature of the ink is higher than the beginning temperature. Because of this temperature change, ink tack is reduced.[7] In Stulc's article it was stated that as ink tack decreases the amount of toning increases.[8] The general relationships between time, temperature, tack, and toning can be seen in Figures 1 through 4.

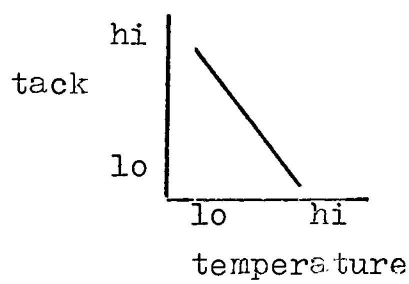


Figure 1

Ink Tack As A Function Of Temperature

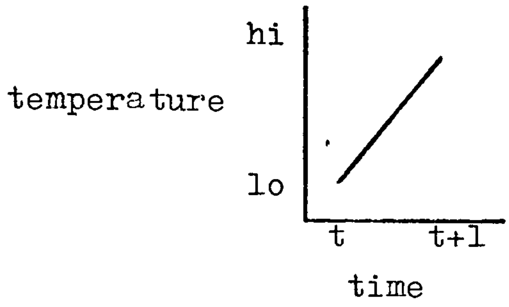


Figure 2

Ink Temperature As A Function of Time On a Moving Press

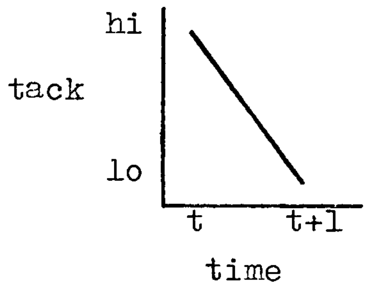


Figure 3

Ink Tack As A Function of Time On A Moving Press

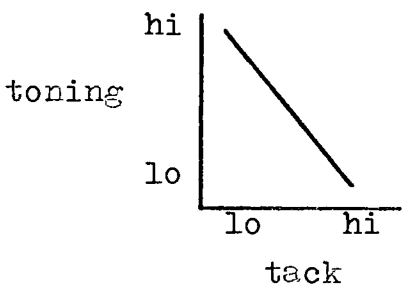


Figure 4

Toning As A Function of Tack On A Moving Press

According to Robert Crowe, 3M had two choices in trying to solve its problem of toning. The ink could be adjusted so the tack would not be reduced with increased temperature or the temperature of the ink could be controlled so it did not affect the tack. At first, 3M took what it felt was a simple and logical approach to the problem -- adjusting the ink. After spending a great deal of time, money, and effort on this approach, the problem still has not been solved. Recently, 3M decided to take the other approach -- controlling ink temperature.

At present, the Dry Plate is being sold as a system which includes a chill roller conversion for the ink train of the press. This roller, manufactured by Baldwin Ink Systems, maintains the ink temperature at 72 degrees to 75 degrees Fahrenheit by a circulating water system. The experiments have shown that when ink train temperatures exceed 85 degrees Fahrenheit toning occurs. The ideal temperature seems to be in the 72 to 75 degree range.[9]

Testing will be continued by 3M to find a satisfactory ink; but in the meantime they hope the chill roller will get the Dry Plate off the ground. These current developments seem to be just a further extension of the research discussed by Stulc. They are 3M's attempt to make driography more marketable.

Graphic Arts Research Center (GARC) of Rochester Institute of Technology and the Graphic Arts Technical

Foundation (GATF) have both done some work with 3M's Dry Plates. GARC determined that the factors of ink tack, ink release, and temperature of the ink train were critical in obtaining satisfactory results with the Dry Plate. They also felt that special blankets, rollers, and paper were needed in the process. However, the specific results of their testing were not published.[10]

GATF performed some very comprehensive tests on the Dry Plate. The results were reported in February, 1972 by Lars Rudstrom and Nelson Eldred in GATF's Research Progress Report. They attempted to answer several questions: "What are the limitations of the plates? Do they resist aging and abuse? Do driographic plates transfer ink as well as conventional wet plates? What are the limitations on paper and ink? How well do driographic inks perform?"[11] In their experiments, they used inks which were specially formulated for driography and produced by several different companies. Rudstrom and Eldred found that the plastic viscosities of the inks covered a wide range, but generally were higher than conventional lithographic inks. They also found that the inks were longer and generally had a higher tack, as measured on the GATF Inkometer. The driographic inks were more sensitive to increases in ink roller (press) speed than lithographic inks. One of their inks, in fact, began to gloss on the rollers and cause a slippage problem.[12] Driographic inks were found to have a greater tendency to set-off. The driographic plates transferred ink as well as, if not better than, lithographic plates.[13]

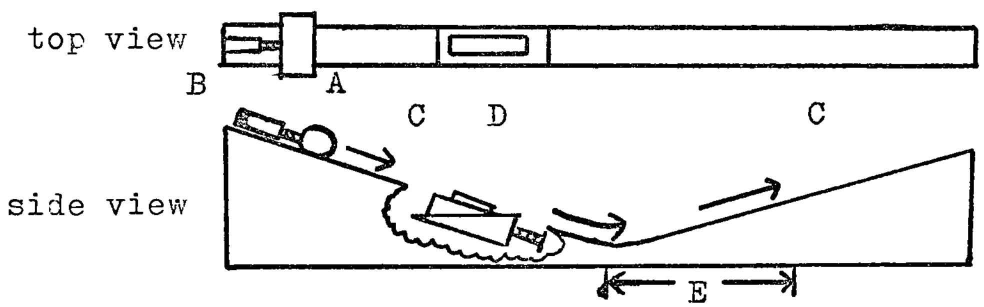
George Leyda of 3M Company listed some of the requirements for driographic inks:

> Tack must be high enough to assure a clean background relative to the wettability of the ink for the plate background. For any range of adhesive forces, the cohesive forces must be high enough to preclude any adhesion.
>
> Tack must be relatively stable with regard to time, temperature and other press variables such that the first requirement is met throughout the press run.
>
> Flow necessary for transfer through an ink train and to printing cylinders to assure image transfer must be maintained.
>
> All the other common ink characteristics must be provided, such as color, drying, penetration, rub resistance, pollution control, etc.[14]

Based on these requirements, ink manufacturers have developed the appropriate inks. These inks have the following characteristics: they are based on a large molecule very non-polar varnish, which provides the needed adhesion; the tack is high relative to lithographic inks; the tack is relatively stable in regard to time and temperature; and the ink is formulated to flow properly.[15]

Andries Voet pointed out that several instruments have been designed to measure ink tack. J. Stefen, the first to experiment with tack, developed a parallel plate instrument to measure it. It was similar to a parallel plate viscometer except that the plates moved away instead of approaching one another. J. Bekk developed a viscometer with which he could observe the motion of a steel hemisphere through a thin film of printing ink. H. Green developed an instrument known as a tackmeter, which operated like a mechanical finger. It performed finger tap-out tests with which the pull resistance could be measured at a controlled and constant temperature.[16]

Voet also mentions a rolling cylinder tackmeter. It consists of a metal cylinder which is allowed to roll down an inclined plane over a layer of ink. The cylinder then rolls up another inclined plane. Tack is the linear measure of the distance that the cylinder rolls up the plane.[17]



A -- metal cylinder
B -- electromagnetic catch
C -- tracks
D -- ink plate
E -- distance measured

Figure 5

Voet's Rolling Cylinder Tackmeter[18]

Another tack measuring instrument is the "Tack-O-Scope," developed by Rudolph Meyer's Incorporated. It measures the viscosity of ink in terms of the frictional force developed between the inked rollers. The tack of the ink is directly related to the frictional forces between the rollers. The device consists of a relatively large diameter center roller driven at variable speeds from 155 to 1400 r.p.m. A laterally oscillating roller distributes the ink on the center roller. A rider roller rides on top of the center roller and is balanced by a spring. As the rollers turn with a given amount of ink on them, the rider roller is deflected forward. The amount of this deflection is measured by a light source and an optical system. The ink is kept at a constant temperature by a circulating water system. The main differences between this instrument and the Inkometer, to be discussed later, are the optical measurement system and the elimination of forced dampening between the rollers.[19]

Two other tack measuring instruments are the PATRA Tackmeter and the Churchill Tackmeter. Both were developed in England and neither are in common use.

Robert F. Reed of GATF developed the first commercially successful and scientifically accurate instrument to measure tack. Called the Inkometer and made by the Thwing-Albert Instrument Company of Philadelphia, it measures tack under the dynamic conditions that might be found on a printing press. According to Voet, it is an ink film dyanmometer which "measures the force required to cause two inked rollers, X and Y, to rotate in contact with one another at a predetermined pressure, speed, and temperature. The rubber roller, Y, rotates around shaft Q, while the metal roller, X, is driven by shaft P. The swinging frame Z has an arm L and a counterweight C."[20] This is illustrated in Figure 6.

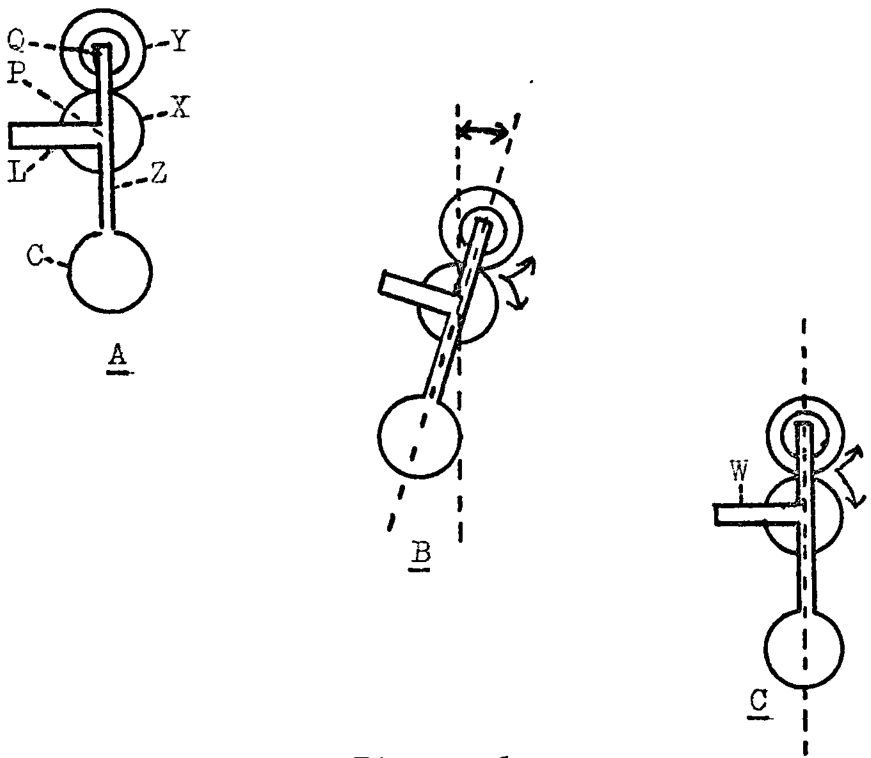


Figure 6

Schematic of GATF Inkometer[21]

In operation, the instrument is first zeroed at the equilibrium position A. When ink is applied to the rollers the instrument is thrown off equilibrium as B of Figure 6. The measurement of tack is the amount of weight (W) needed to bring the instrument back into equilibrium, or the amount of torque required.[22]

The Inkometer has found many practical applications in ink testing. One important area is in determining tack levels for wet on wet printing. It is used in the control of heat set inks where the rate of evaporation and press speeds are important. Its use in comparing inks, however, is only valid for inks of similar composition, or those made of the same vehicles, solvents, and binders.[23]

As a scientific instrument, the Inkometer's validity is somewhat doubtful. One objection is its inability to give data in fundamental units independent of instrumental constants. Low viscosity liquids do not distribute properly on the rollers. On the other hand, high viscosity liquids are drawn out in filaments and are thrown-off or "mist." Another objection is that the composition and rubber rollers deform and have an effect on the data. The balancing weight is not independent of the speed; the arm must be rebalanced for every speed. Also, it has been found that the distance between the rollers is not constant and varies with the speed.[24]

Voet gives a rather detailed description of the mechanism of tack:

> When subjected to stress the response of the ink, and of any liquid, may be of a viscous and of an elastic nature. Splitting of ink films will occur by viscous flow when the rate of separation is slow. The liquid ink will respond to the stress by viscous flow, since the time element involved is long enough to allow

> flow to take place. Upon increasing the rate of film separation, however, the flow response to stress of the liquid, being proportional to the elapsed time, will become less and less pronounced. On the other hand, the elastic response, of an instantaneous nature, becomes more and more important. We may thus expect that with a given, critical, high rate of film separation the ink, though a plastic liquid, actually has more of the behavior of an elastic solid. Rupture will then occur when the applied force exceeds the cohesive material strength.[25]

Ink flying, also known as misting, spraying, clouding, or fogging, is a serious problem for many reasons. It is a health hazard to employees, it contaminates the pressroom, it can be a fire hazard, it can indirectly limit the speed of the presses, and it might contribute to toning. Basically, the term ink flying refers to the small ink droplets being thrown from the rollers of a moving press. This is not caused by centrifugal force, but by the rupture that occurs when an ink film is rapidly separated. Often the filament of ink formed is ruptured in two places simultaneously, and the middle part is ejected as a droplet.[26]

Voet discusses many of the factors which influence ink flying: press speed, low absolute humidity, imperfect mechanical conditions, presence of air currents, the elastic forces of the ink (which increase with viscosity), the temperature, and the electric conductivity of the ink. Yield values and surface tension have little influence on ink flying.[27]

After using the GATF Inkometer to measure the tack of the inks, the IGT Printability Tester will be used to conduct the experiment. The IGT Printability Tester is essentially a miniature model of a press which permits the experimenter to control many variables. Although there are many limitations in its use, it has proven its value. The following quote from Thomas Linden of the International Paper Company seems to support this contention:

> The prediction of printing results on paper is extremely difficult. Until recently a number of properties affecting the printing quality were measured separately such as strength, hardness, and smoothness. Unfortunately, a given apparatus does not always measure the properties for which it was designed. It is not surprising that considerable differences between the predicted and the actual results were often found. This method therefore is both unreliable and tedious. There has been a definite need for instruments by which various factors may be determined in advance of actually having the printer apply the ink to the paper and noting the results.[28]

The IGT Tester is made by the Research Institute for the Graphic and Allied Industries TNO in Amsterdam, Holland. It consists of an inking mechanism and a printing mechanism which operate independently of one another. The tester operates basically on the letterpress principle, but it can be converted to print by offset.[29] The final results have generally been shown to have a good correlation with actual press results, although the opposite has also been shown.[30]

Of the several printability testers on the market, the IGT Tester is the most widely known, accepted, and used. It is an instrument which is simple to use, quick, and relatively inexpensive; but it gives control over such variables as pressure, speed, ink film thickness, etc.[31]

J. A. Cheatham did an interesting experiment to discover the relationship between the IGT pick testing method and actual picking on an offset-lithographic press. Although the results are not directly related to toning, they had a significant effect on the test method used in this study. The conclusions of the Cheatham study were as follows: "This investigation has shown that the standard method of using the IGT Printability Tester (letterpress method) for determining the picking strength of paper is a suitable method of testing coated litho paper."[32]

The densitometer will be used in this study to measure the amount of toning. Victor Strauss expresses the importance of this area. "Densitometry makes it possible to measure different tones with precision instruments and to express these measurements in numbers."[33] The scale on which density is measured was developed to express variations in tones in the same proportion that the eye sees the differences in tone. The densitometer will therefore give a valid response variable for this experiment. The author was interested only in the visible toning that occured.

The preceeding discussions of various aspects of the experiment gave some direction in the experimental design. There is apparently no documentation in published literature of studies having previously been done on toning as related to ink tack when printing by driography. Therefore, the experiences of those in related areas have been drawn upon to set up the hypotheses. These hypotheses will be tested and hopefully a theory of toning with driographic plates will be proposed.

FOOTNOTES FOR CHAPTER III

[1]L. J. Stulc, "Driographic Ink," (unpublished report to ink manufacturers, 3M Company), p 3.

[2]Ibid. p 7.

[3]Ibid. p 4.

[4]Ibid.

[5]Ibid. p 6.

[6]Ibid. p 7.

[7]Robert Crowe, 3M Technical Service Representative, Personal Interview, Harrisburg, Pa., March, 1974.

[8]Stulc, "Driographic Ink," p 3.

[9]Crowe, Personal Interview

[10]Richard McAllen, "Driography's Position Today," Graphic Arts Progress, Vol. 18, No. 10 (October, 1971), p 12.

[11]Lars Rudstrom and Nelson R. Eldred, "Driographic Printing -- An Evaluation," GATF Research Progress Report, No. 88 (February, 1972) p 1.

[12]Ibid. p 3.

[13]Ibid. p 4.

[14]G. Leyda, "Inks for Driography," Modern Lithography, Vol. 38, No. 11 (November, 1970) p 52.

[15]Ibid.

[16]Andries Voet, Ink and Paper In the Printing Process, (New York: Interscience Publishers Inc., 1952) pp 56, 57.

[17]Ibid. p 66.

[18]*Ibid*.

[19]Herbert Jay Wolfe, *Printing and Litho Inks*, (New York: MacNair-Dorland Company, 1967) pp 104-105.

[20]Voet, *Ink and Paper*, p 58.

[21]*Ibid*.

[22]*Ibid*.

[23]*Ibid*. p 60.

[24]*Ibid*. p 62.

[25]*Ibid*. pp 62, 63.

[26]*Ibid*. pp 79, 80.

[27]*Ibid*. pp 82-84.

[28]T. E. Linden, "Use of the IGT Print Tester, " *TAPPI*, Vol. 42, No. 7 (1959), pp 127A, 128A.

[29]"Testing Paper on the IGT Printability Tester," *The Litho Printer*, Vol. 2, No. 1, (1959) p 40.

[30]"Pick Measurement," *American Ink Maker*, Vol. 33, No. 10 (November, 1955) p 42.

[31]*IGT Printability Tester* (Amsterdam, Holland: Research Institute for the Printing and Allied Industries TNO), p 2.

[32]J. A. Cheatham, "The Relationship Between IGT Pick Testing and Picking On An Offset-Lithopress," *Printing Technology*, Vol. 6, No. 2 (1962) p 50.

[33]Victor Strauss, *The Printing Industry* (Washington, D.C.: Printing Industries of America, 1967), p 178.

CHAPTER IV

METHODOLOGY

An experiment was designed to test the three hypotheses:

1. As ink tack decreases, the amount of background toning on a driographic plate increases.
2. As ink roller to plate pressure increases, the amount of toning on the driographic plate increases.
3. As the printing speed increases, the amount of toning on the driographic plate increases.

Essentially, the experiment was an investigation of how ink tack, inking pressure, printing speed, and their inter-relationship affect toning in driographic printing. In addition, a test was made to determine how well an IGT Printability Tester can predict press results in these areas.

The IGT And The Press

The experiment was conducted on both the IGT Printability Tester and on a duplicator press. The IGT Printability Tester is often considered a miniature press with which the experimenter can control several variables.

Speed, pressure, and ink film thickness can be varied and controlled within limits. The speed and ease of operation of the IGT enables the experimenter to quickly adjust his variables to different levels. The tester chosen for the experiment was a single wheel, spring driven device, located in the Physical Testing Laboratory of GARC at the Rochester Institute of Technology.

The press chosen for the experiment was an ATF Chief 15 which was also located in the Physical Testing Laboratory of GARC. It was chosen not only for its location and size but also because it is a press often used by business form printers, a primary user of driography. A significant correlation between the results on the IGT and those on the press would indicate that the IGT could be considered a predictor of press results in driography.

Response Variable

Since toning was being investigated, some value had to be assigned to the amount of toning. The value was assigned by measuring the density of the toning in a particular non-image area on the sheet. Several precautions were taken in order to eliminate external variation. The location of density measurement was kept constant and was in an area approximately one eighth inch away from an image. The paper density was zeroed out in the reading, the densitometer head was placed on the paper in the same orientation and with approximately the same pressure, and the reading was taken on the same base of two sheets of plain twenty-pound white bond.

It was felt that a valid indication of the amount of toning might also be obtained by taking the ratio of the density of a solid to the density of a tint. Taking density readings in an image area might show a different effect of toning. To eliminate or minimize variations in toning caused by slurring or variations in ink film thickness, a ratio of tone to solid was computed. The location and method of taking these readings were kept constant.

Absolute and ratio responses were obtained for both the IGT and press sections of the experiment. Each response variable gave the final result a different appearance. They both were evaluated.

The density for each response was measured with a Macbeth RD 100 reflection densitometer, which was carefully calibrated just prior to use and at fifteen minute intervals during use. The densitometer was located in the Physical Testing Laboratory of GARC.

The test object printed consisted of a section of the Gretag RIT Color Control Bar. It is a one-quarter by three-quarter inch area known as the four step halftone wedge section. Each wedge contains a tint area of 15, 45, and 73 per cent dot area plus a solid area. The 15 and 73 per cent areas are tones made from screens with 180 lines per inch. The middle tint area consists of 220 lines per inch in a vertical and horizontal pattern, so that it can be used as a slur target.[1] For this experiment, twelve of these bars were numbered and placed in a row. The arrangement was made to fit the dimensions of the printing area on the IGT Printability Tester, as shown in Figure 8. The arrangement was then duplicated several times and some lines of type were added to make a plate for the ATF Chief 15, as shown in Figure 9. The solid sections of the wedge were alternated in their placement to avoid any possible problems caused by image arrangements. The precise areas where density readings were taken for each part of the experiment are defined in Figure 7.

IGT Absolute Readings --	1/8 inch under the numbers 3, 5, 7, 9 and 1/8 inch to the left of the step wedge
IGT Ratio Readings --	ratio of density readings of solid areas of blocks 3, 5, 7 and 9 to readings of the 73 per cent tone areas of the same blocks
Press Absolute Readings -	1/8 inch to 1/4 inch under the number 5 and 1/8 inch to the right of the solid area in the row of wedges under the lines of type
Press Ratio Readings --	ratio of the readings in the solid to the readings in the 73 per cent tone area in block 6 under the lines of type

Figure 7

Areas of Density Readings

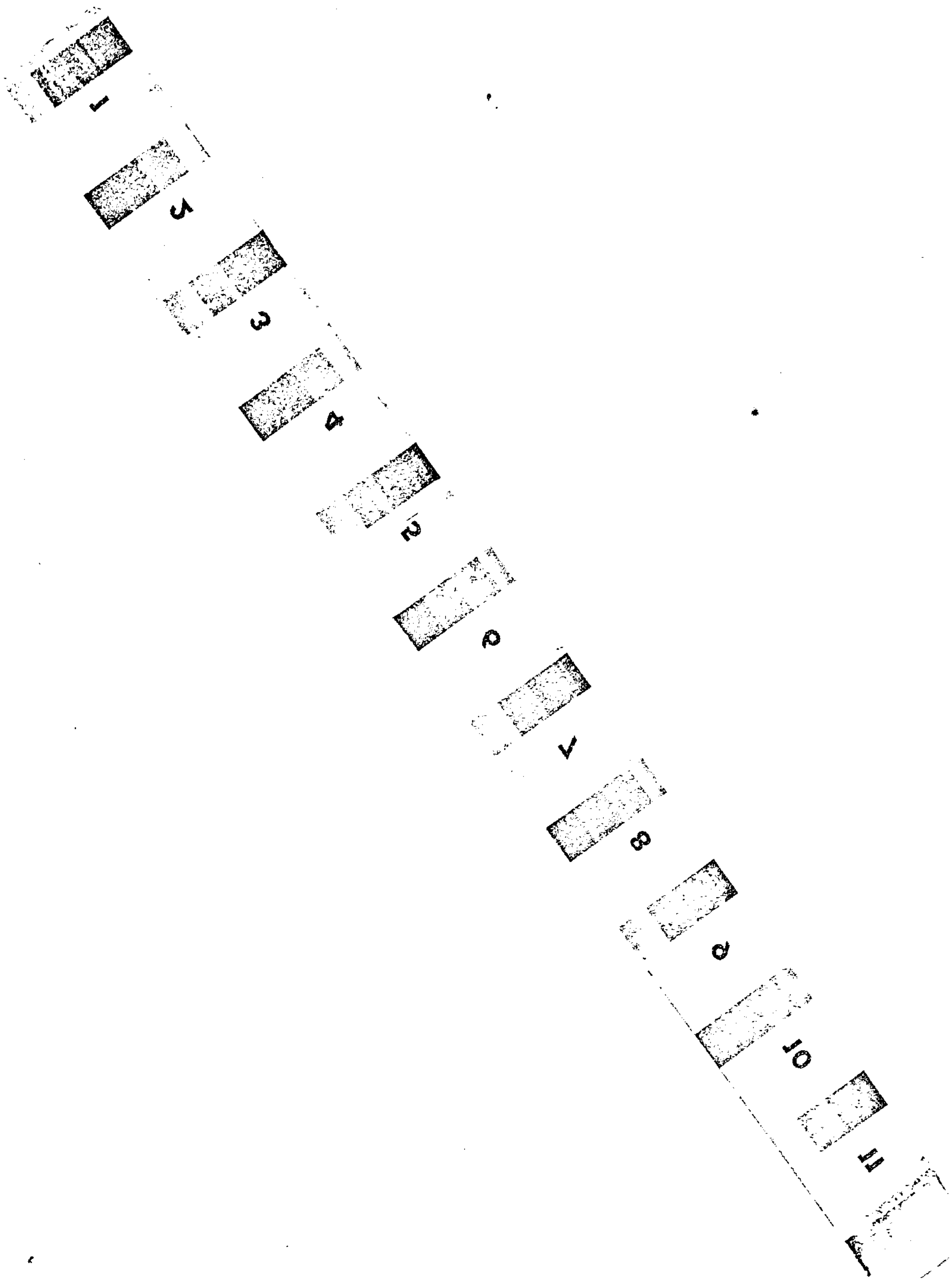


Figure 8

Sample Print From IGT Printability Tester

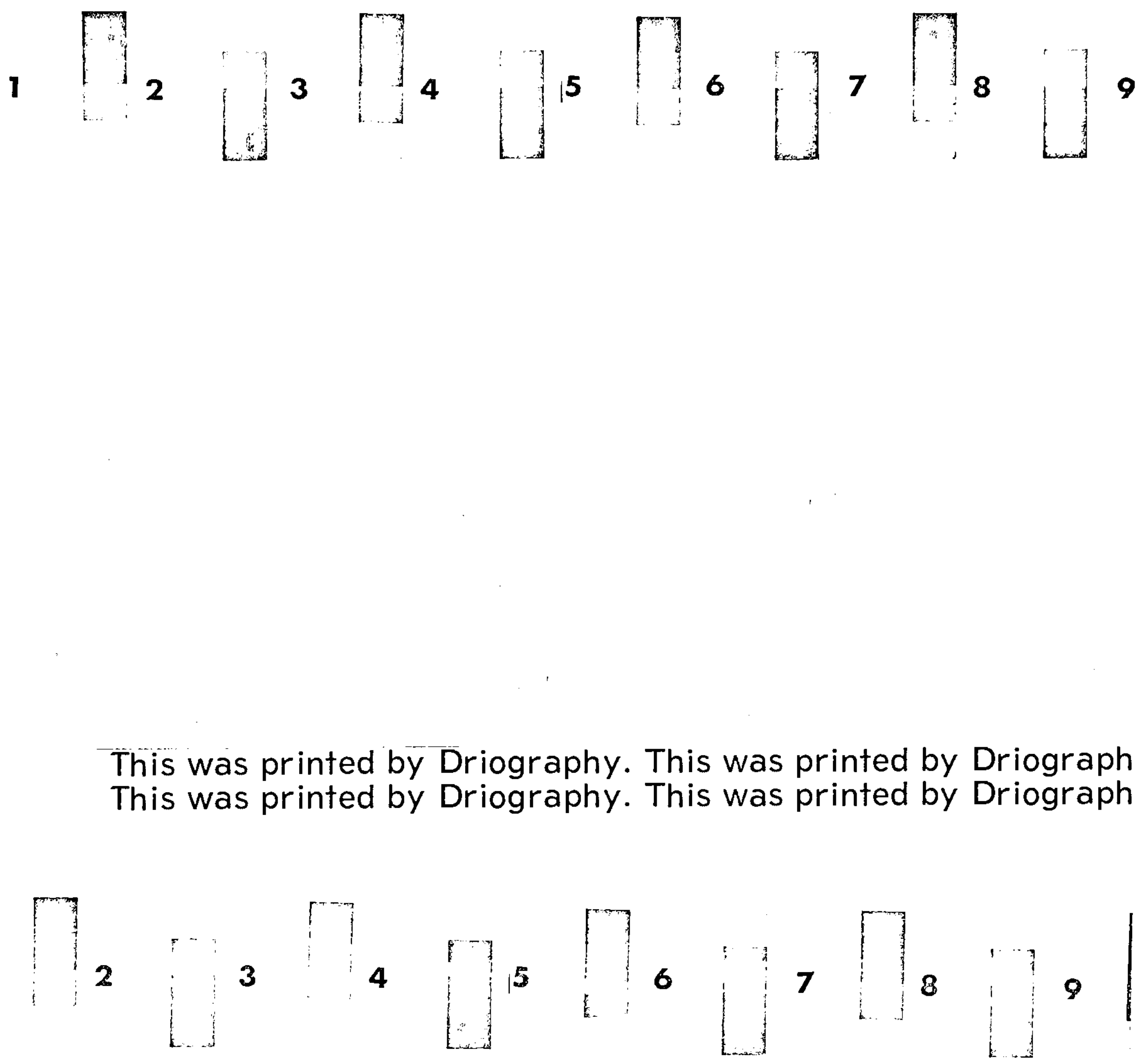


Figure 9

Portion of Sample Print From ATF Chief 15 Press

Controlled Variables

Paper

The paper used in the experiment was a seventy pound offset paper called Mead Moistrite Wove Offset with a regular finish. There were several reasons for this choice of paper. It was recommended by Ron Ink Corporation of Rochester, New York as being a paper suitable for testing high tack inks such as a driographic ink. It has a high pick resistance, an extremely smooth surface, high opacity, and is designed for offset printing. Since they might have an affect on the experiment, the pick resistance and caliper were measured.

The caliper of the paper was found to be quite consistent throughout a single sheet and from sheet to sheet. Its thickness was measured on a Testing Machines Incorporated Model 549 Micrometer. The average caliper measurement was .00454 inches and the standard deviation was .000077 inches. In order to obtain these measurements, five sheets of the paper, 8 1/2 by 11 inch size, were pulled at random from a lift of approximately 500 sheets. A measurement was then made in each of the four corners and the center of the sheet. The location and method of measuring was kept constant from sheet to sheet. The original data for this can be seen in Table 1.

TABLE 1

TEST PAPER CALIPER DATA

Sheet Identification	Caliper Measurement Location				
	Corner #1	Corner #2	Corner #3	Corner #4	Center
A	.0045	.0046	.0047	.0046	.0045
B	.0045	.0045	.0046	.0045	.0046
C	.0044	.0045	.0045	.0045	.0045
D	.0045	.0046	.0046	.0046	.0046
E	.0045	.0045	.0044	.0046	.0046

The pick resistance of the paper was determined by using the IGT Pick Test method. In this method the IGT Printability Tester is utilized along with three specially prepared IGT Pick Test Oils. These oils are identified by their viscosities, which are related to ink tack, and are expressed in units of poise. The low, normal, and high viscosities of these oils are 210, 720, and 1550 poise respectively. In testing, each oil was used individually and at separate times. To perform the test, one cubic centimeter of the particular oil was placed on the distributing roller of the IGT Inking Mechanism and allowed to be distributed for eight minutes. At four minutes, the distributing roller was reversed to give a more even distribution. At the end of the eight minutes, the rubber printing disk was "inked up" for a total of one and one-half minutes.

The printing disk was then placed on the printing mechanism. The pressure was set at thirty kilograms and the appropriate speed range was set. Three ranges of speed are possible with the IGT spring driven device at thirty kilograms pressure. These are A (0 to 500 feet per minute), M (0 to 600 feet per minute), and B (0 to 690 feet per minute).[2]

The pick test was performed with paper cut both grain long and grain short, with the three viscosities of oil, and at the three speeds. No picking was perceived with either the low or normal viscosity oils at any speed. The high viscosity oil did cause picking and tearing at a medium speed with grain short paper, and at a high speed with grain long paper. Figure 10 summarizes some of the variables controlled in the pick test.

Oil viscosity -- 1550 poise (highest)
Oil quantity -- 1 cubic centimeter
Printing Pressure -- 30 kilograms
Speed -- spring device
A 0 to 500 ft/min
M 0 to 600 ft/min
B 0 to 690 ft/min
Inking of mechanism -- total of 8 minutes
Inking of roller -- $1\frac{1}{2}$ minutes
Grain -- long and short

Figure 10

Summary of Pick Test Controlled Variables

Since the paper chosen has an extremely high pick resistance, it is ideal for this experiment. The high pick resistance greatly reduced the possibility of picked fibers entering the experiment as a variable. Table 2 summarizes the results of the pick test.

TABLE 2

PICK TEST RESULTS

Variables	Test								
	1	2	3	4	5	6	7	8	9
Speed	A	M	B	A	M	A	M	B	M
Grain*	L	L	L	S	S	S	L	L	S
Oil added (cc).	0	0	0	0	.65	0	0	0	0
Picking distance (inches)	0	0	3 1/8	0	2 1/2	0	0	3 1/8	3 1/4
Tearing distance (inches)	0	0	4 1/4	0	3 1/4	0	0	4 3/4	4 1/2
Picking velocity (ft/min)	0	0	470	0	360	0	0	470	430
Tearing velocity (ft/min)	0	0	560	0	430	0	0	590	510

* grain long = L grain short = S

The grain direction of the paper was kept constant, but was not considered extremely important in the experiment because of the high pick resistance. For both the IGT and the press the grain of the paper was kept perpendicular to the axis of the printing cylinder. This is considered grain short paper.

Again because of the high pick resistance of the paper, the variations between the felt and wire side of the paper were considered unimportant to the experiment. The wire side was chosen arbitrarily as the printing surface, but variations in the printing side were not considered critical.

Ink

Three black inks specifically formulated for driography were supplied for the experiment by Ron Ink Company of Rochester, New York. Table 3 summarizes the information about the inks, obtained from their labels.

TABLE 3

INFORMATION ABOUT INKS

Kind	Label Date	Formula Number	Batch Number	Tack at 1 minute 1200 RPM
Low Tack Driographic	4/2/73	EX-203	X20009	10.0
Medium Tack Driographic	4/2/73	A-4543-M	X18092	17.0
High Tack Driographic	4/2/73	EX-202	X20008	19.0

The medium tack ink (17.0) was the one normally supplied to driographic printers; the low and high tack inks were specifically formulated for this experiment. The inks were carefully handled during the experiment period.

They were kept in a cool dry place and were well sealed. During use the ink was kept covered, the ink was scraped off the surface to avoid trapping air, and the skin paper was consistently replaced.

It was decided that it would be appropriate to verify the tack of the inks as listed by the manufacturer. The tack of the inks was therefore determined on the GATF Inkometer located in the GARC laboratories. The readings were taken on two separate days as a double check of the results. On both days the temperature of the laboratory was about 82 degrees Fahrenheit; the relative humidity, however, dropped from 62 per cent on the first day to 47 per cent on the second day.

The readings were taken with the Inkometer temperature at 90 degrees Fahrenheit and the speed set at 1200 revolutions per minute. The readings on the high and medium tack inks were consistent from one day to the next, the low tack ink reading increased. The readings over a ten minute period can be seen in Table 4.

The performance of the medium tack ink was quite surprising, especially since this is Ron Ink's standard driographic ink. On both days, the tack of the ink stayed fairly level for the first seven minutes of the test. At eight or nine minutes the ink started to dry and glaze on the rollers. Since this behavior is quite unusual, it was decided to eliminate the medium tack ink from the experiment. The data from Table 4 has been graphed in Figure 11.

TABLE 4

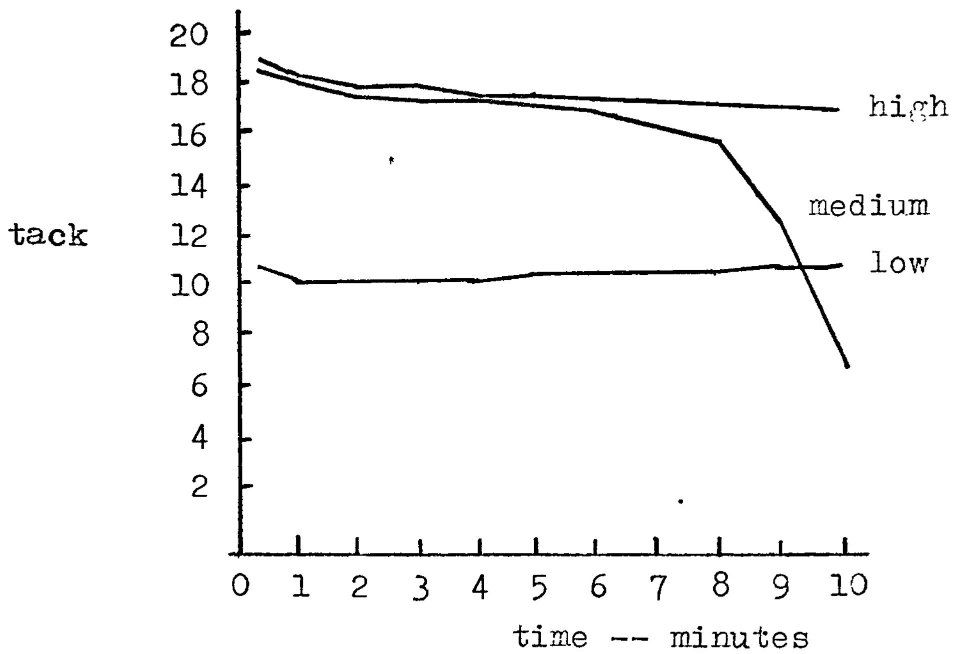
TACK OF TEST INKS
(Grams / Meter)

Time	Low Tack		Medium Tack		High Tack	
	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
20 sec.	10.5	11.8	18.2	18.7	18.4	18.6
1 min.	10.2	11.3	18.0	18.2	18.1	18.3
2 min.	10.2	11.0	17.6	18.0	17.9	18.0
3 min.	10.2	11.0	17.5	18.0	17.9	17.9
4 min.	10.3	11.1	17.5	17.5	17.8	17.8
5 min.	10.5	11.3	17.3	17.2	17.8	17.9
6 min.	10.5	11.3	17.0	17.0	17.8	17.8
7 min.	10.5	11.3	16.5	16.3	17.6	17.8
8 min.	10.6	11.3	15.9	14.0	17.6	17.7
9 min.	10.7	11.4	13.0	6.5	17.6	17.5
10 min.	10.8	11.5	7.0	3.5	17.5	17.6

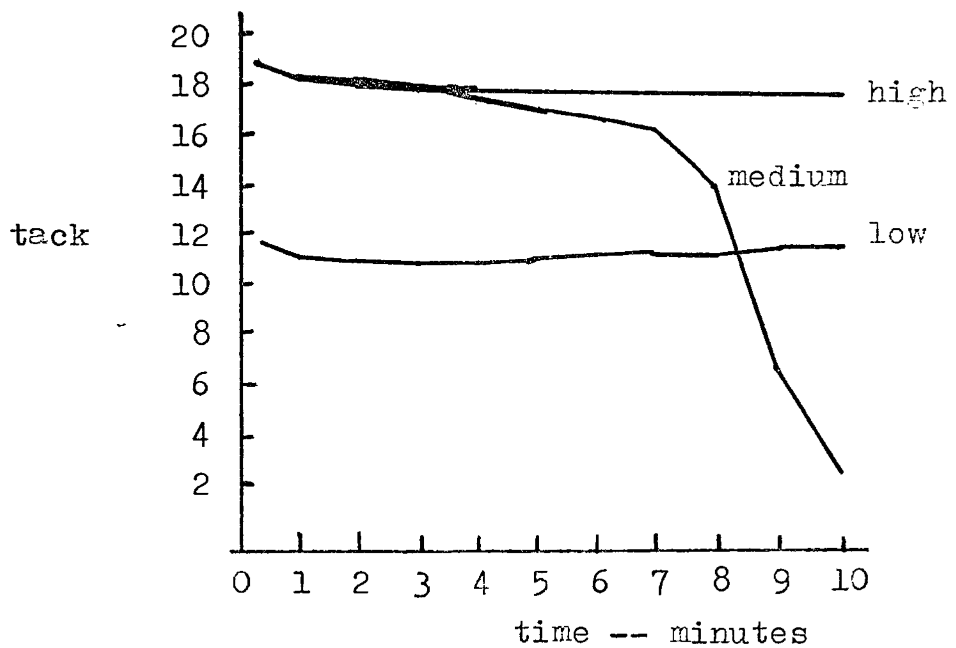
The Plate

The driographic plate used was the Dry Plate manufactured by 3M. A ten inch by fifteen inch plate was used. The package of plates had an expiration date of January, 1974.

During all phases of the experiment, the plate was handled in accordance with the manufacturer's recommendations. It was protected from scratching by using the supplied plastic slipsheet. It was also protected from all extraneous light and from extremes of heat and cold.



Tack Vs. Time -- Day 1



Tack Vs. Time -- Day 2

Figure 11

Tack of Test Inks

To expose the plate, the plastic slipsheet was removed and the surface was sprayed with 3M's Silicone to prevent the negative from sticking to the slightly tacky surface. The plate was placed in the printing frame and covered with the flat containing the negatives. The negative was placed in contact with the plate, emulsion side to plate emulsion. A gray scale was also placed on the plate to check the exposure. The vacuum was drawn out of the frame for a relatively long period to assure good contact.

To make the exposure, a pulsed Xenon light source was used at a distance of forty inches from the plate. After a fifteen second exposure, the image was slightly visible.

A 3M Dry Plate Developing Pad was used for hand development. It was found to work best if it was premoistened with the developer. It was also helpful to use a clean pad for each plate. For the first thirty to sixty seconds of development, light rubbing was all that was required. When the image began to darken, the pressure was increased for the next four minutes, or until the image was completely developed. After development, the plate was rinsed with water and dried. The plate was then slipsheeted with plastic and placed in a dark area. One plate was also cut into strips to fit the IGT.

During the running of the experiment, the plate was handled carefully to prevent scratching. To clean the plate, a soft cloth was used with Dry Plate Image Cleaner.

Temperature and Humidity

The experiment was conducted on two separate days in the GARC laboratories. These laboratories were selected partly because they are temperature and humidity controlled. The climate control equipment was not functioning properly, however, during the period of the experiment. Since these factors could not be controlled, they were measured during the experiment period. This means that the results of the experiment are only valid under these measured conditions. During the IGT section of the experiment, the temperature of the ink was also recorded.

The room temperature was measured with a Taylor Sling Psychrometer. The ink temperature was recorded with a Centigrade thermometer attached to the metal inking drum of the IGT inking mechanism. The measurements were taken at the beginning, middle, and end of the IGT experiment, and at the beginning and end of the press experiment. The results of these measurements are recorded in Table 5.

Speeds

Most driographic printing is done and probably will be done by small sheet fed presses. It was therefore decided that the range of speeds that would be used in the

TABLE 5

TEMPERATURES AND RELATIVE HUMIDITY

	Time*	Room Temperature: Wet bulb	Room Temperature: Dry bulb	Relative humidity of room	Ink temperature
IGT Experiment	b	66°F	73°F	61%	24.5°C 76.0°F
	m	68°F	77°F	60%	26.5°C 79.7°F
	e	69°F	79.5°F	58%	28.0°C 82.0°F
Press Experiment	b	65°F	71°F	73%	
	e	62°F	73°F	53%	

* b -- beginning of experiment
m -- middle of experiment
e -- end of experiment

experiment would be comparable to a small sheet fed press. According to Mr. Daniels of GARC, a small Harris sheet fed press running at a top speed of 8000 impressions per hour would be moving paper at the rate of 250 feet per minute.[3] This speed falls in the range of the IGT with the pendulum drive and the ATF Chief 15.

Table 6 shows the relationship between the targets or step wedges, their distance from the start of printing, and the speed at each point in the IGT experiment. The velocities are based on the use of the pendulum drive and twenty kilograms of printing pressure. They were calculated using a graph supplied by IGT.[4]

TABLE 6

VELOCITY AT EACH TEST TARGET ON IGT STRIPS

Target number	Number of inches from start of print	Velocity in ft/min at 20 kg.
1	1/4	30
2	1	75
3	1 3/4	110
4	2 3/8	130
5	3 1/8	150
6	3 7/8	170
7	4 1/2	195
8	5 1/4	210
9	5 7/8	230
10	6 5/8	250

Four targets on each strip were used as the measured test targets. Specifically, the targets numbered 3, 5, 7, and 9 with respective velocities of 110, 150, 195, and 230 feet per minute.

The speeds on the ATF Chief 15 press are not continuously adjustable between zero and top speed, but are adjustable to ten separate speeds. The speeds are set using a lever, notched at ten separate points, found at the side of the press. In order to set the press at speeds which approximated those used on the IGT, velocity readings were taken at each notched point. A Hasler Foot / Minute Meter was used to make these reading. The speeds chosen were 108, 160, 200, and 248 feet per minute.

Impression Pressures

In the IGT part of the experiment, no blanket was used for printing. The plate transferred its ink directly to the paper. The amount of pressure between the plate and the paper could be directly adjusted on the IGT by means of a small lever on the side of the mechanism. After some informal experimentation, it was decided that a pressure of 20 kilograms generally gave the best print. This was made the standard for the IGT part of the experiment.

The packing under the blanket and plate in the press part of the experiment were maintained at the Chief 15 standards. This also seemed to give satisfactory printed results. With these pressures as standards, it was felt that they could be eliminated as variables in the experiment.

Inking Pressures

The pressure between the ink roller and the plate was considered critical and was one of the variables in the experiment. On the IGT, this pressure was relatively easy to adjust by using the small knobs on the side of the mechanism. It was set at 5, 10, and 15 kilograms for the three pressure levels of the experiment.

The pressure of the inking roller could not be set directly on the Chief 15; therefore, some indirect method was needed. First, at each of the pressures used on the IGT, the ink roller was allowed to drop on a piece of paper. By doing this, a stripe of ink was obtained which varied in width with the pressure. Then the pressure of the ink roller on the plate of the Chief 15 was adjusted to the point at which the ink stripe on the plate matched the IGT ink stripe. It was assumed at this point that the pressures matched.

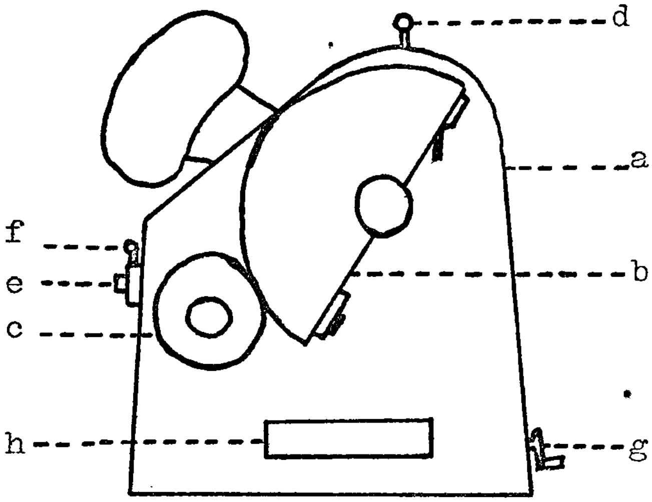
Test Procedure

The experiment was conducted in the laboratories of GARC between June 22 and 26, 1973. The procedure that was followed was based on published literature, advice of qualified personnel, and the researcher's own analysis.

Before, during, and after the experiment, measurements were taken of temperature and humidity. Precautions were also taken to assure that no unforseen event would affect the outcome. The room in which the tests were conducted was relatively free of dust, offset sprays, solvents, and other items which might affect the ink or plate.

The IGT part of the experiment was conducted on one day to prevent day to day variations. To start, 0.6 cubic centimeters of ink was placed on the inking mechanism, using the IGT ink pipette. The rollers were allowed to revolve for eight minutes. The large rubber roller was reversed at four minutes to aid in ink distribution. At eight minutes, the small rubber inking roller was brought into contact to be "inked up" for a period of one and one-half minutes. The small rubber inking roller was immediately removed and placed on the printing mechanism to "ink up" the plate. At this point, the temperature of the ink was recorded.

The printing mechanism used in the test had a pendulum drive and one spindle for the printing wheel. The following discussion refers to Figure 12. The letters in parentheses are indicated in that figure. The printing mechanism had been previously prepared for the test. A plate had been cut into the appropriate length and width to fit on the printing sector (b). It was placed in the



a -- printing mechanism
b -- printing sector
c -- printing wheel and spindle
d -- sector release lever
e -- free stroke adjustment
f -- impression lever
g -- pressure adjustment
h -- pressure indicator

Figure 12

Schematic of the IGT Printability Tester sector so that target one would be one-fourth inch away from the start of printing. It was securely attached and drawn tautly over the sector. The plastic slipsheet was left in place during this period. The free stroke between the wheel and sector was set to ten kilograms (g,h). After removing the slipsheet, the plate was initially inked by a finger tap method, essentially transferring ink from finger tip to plate image area by rapid tapping. Then the inked rubber roller was placed on the printing mechanism (c). The impression lever (f) was placed in the on or forward position and the plate bearing printing sector was rotated by hand at a relatively constant speed for ten revolutions. The purpose of this was to evenly distribute the layer of ink and to remove excess ink from the background of the plate. An impression on paper was then taken to determine whether the ink was evenly distributed. The pressure was re-set at five kilograms. The plate was then re-inked by one turn of the sector against a newly inked wheel. The inking wheel was then returned to the inking mechanism. The impression lever was set at the off position.

The ink pipette was used to add an additional 0.039 cubic centimeters of ink to the mechanism. This amount of ink was added after every two inkings during the experiment. The ink was given sufficient time to be distributed, at least three minutes, and then the inking wheel was placed in position to be re-inked. It was re-inked each time at least one and one-half minutes and not more than four minutes.

A strip of the test paper had been previously attached to a second rubber wheel, of the same diameter as the inking wheel, with a small piece of double backed tape. The paper was attached with the grain running around the wheel, commonly known as grain short. An attempt was made to keep the wire side up, but this was not considered critical.

The pressure on the printing mechanism was then reset at the standard printing pressure of twenty kilograms. The paper wheel was rotated so that the lead edge of the paper lined up with the leading bend in the plate. The impression lever was put in the on position and a print was taken. The impression was released and the paper removed.

The above procedure was followed for each of the pressure settings of 5, 10, and 15 kilograms and for both the low and high tack ink. The plate was not cleaned or otherwise touched during pressure adjustment. When the ink tack was changed, the plate was cleaned with Dry Plate Cleaner and a soft, lint-free cloth. This procedure kept scratching to a minimum on the plate surface.

The part of the experiment which involved the use of a press was also conducted on one day in order to eliminate day to day variations within each part. The press was located in the same laboratory as the IGT equipment. The temperature and humidity readings were taken during the experiment, as indicated in Table 5.

The specifications of the ATF Chief 15 were examined to determine appropriate plate caliper, plate packing, and blanket packing. The speed of the press at various points was then read, using a Hasler Foot / Minute Meter.

The press was "made-ready" to print an eight and one-half by eleven inch sheet of the Mead Moistrite Wove Offset paper. The dampening system was disengaged, the correct packing was placed under the blanket, and a Dry Plate, including its plastic slipsheet, was placed on the plate cylinder with the correct packing.

The ink fountain was then loaded with the lower tack ink and the press was allowed to run so that the ink would be thoroughly distributed in the ink train. The ink form rollers were then adjusted to match the inking pressures used in the IGT experiment. The stripe left by the form roller was made to match the stripe left by the IGT inking roller at various pressures. The adjustment was made by turning the two screws on the ends of the form roller until the stripes matched. The adjustment was made three times in order to match the three levels of pressure.

The press was then started and the form rollers were dropped. The plate "inked up" quickly. Several sheets of paper were printed to complete the "make-ready."

The experiment was then begun, picking the pre-set pressures and speeds at random. In order to avoid constant press "wash-ups," the press runs at each level of ink tack were run together. After the twelve runs at the lower ink tack were completed, the press was "washed-up" and the higher ink tack was substituted. The same plate was used throughout the experiment. It was cleaned with Dry Plate Cleaner when the ink was changed to the higher tack.

The resultant prints from both the IGT and press sections of the experiment were carefully marked, separated, and stored. The readings of density were made in both cases three days after their respective printings.

FOOTNOTES FOR CHAPTER IV

[1]*Gretag -- RIT Color Control System,* Gretag Pamphlet CCS 10 (Switzerland: Gretag Instruments, 1970).

[2]*The IGT Spring Drive Device*, IGT Information Leaflet A7 (Amsterdam, Holland: Research Institute for the Printing and Allied Industries, June, 1965).

[3]Chester Daniels, GARC, Personal Interview, Rochester, N.Y., June, 1973.

[4]*IGT Spring Drive Device*, p 1.

CHAPTER V

ANALYSIS

Several statistical assumptions were made in this experiment. One was that the sample was taken randomly from the population and therefore was representative of it. An assumption was made that the population consisted of all IGT Printability Testers and all ATF Chief 15 presses which can be run under the same conditions of temperature, humidity, speed, pressure, and other variables. It was assumed that the population was normal in the distribution of the results of treatment combinations. Because there was no way to estimate it, error was considered to be independent of the levels at which the experiment was run.

The basic data for all phases of the analysis were the density readings of various targets and non-image areas as described in Figure 7. These densities were read using a Macbeth RD 100 reflection densitometer. The readings were taken holding density reading base, densitometer head orientation, calibration, and ink drying time constant.

The data were arranged in standard order tables, as described in Statistics: An Introduction.[1] The first column in the table identifies the various levels of each factor used in the treatment combination. This identification is a three digit number. The first digit indicates the ink tack level -- low (1), or high (2). The second indicates the inking pressure level -- low (1), medium (2), or high (3). The third digit indicates the printing speed in feet per minute -- 110 (1), 150 (2), 195 (3), or 230 (4). The main columns of the table are the densities or ratios for each replicate of the experiment.

Tables 7 and 8 give the absolute densities of the non-image area in the IGT and press experiments respectively. The ratio of solid to tone area in the IGT experiment is shown in Table 9. This same ratio in the press experiment is found in Table 10. The average density recorded for the non-image area in the IGT experiment was .032 with a standard deviation of .0018. The average in the press experiment was .024 with a standard deviation of .0401. The distributions are, however, quite skewed, which can be shown by the value of the mode. The mode for the IGT densities is zero and for the press densities is .01.

In order to determine which method of recording toning, absolute densities or ratios, gave the greatest similarity between the IGT and the press experiment, a correlation study was made. The correlation method followed that described by Rickmers and Todd.[2] It was decided to accept an alpha (α) risk of 0.05 in the results. Average

TABLE 7

ABSOLUTE DENSITIES IN NON-IMAGE AREA IN IGT EXPERIMENT

Treatment combination	a	b	c	d	e
111	.05	.04	.03	.04	.04
211	.00	.00	.00	.02	.00
121	.09	.07	.07	.06	.06
221	.01	.01	.01	.01	.01
131	.14	.10	.10	.11	.14
231	.02	.00	.01	.01	.01
112	.04	.03	.02	.03	.03
212	.01	.00	.01	.01	.01
122	.07	.06	.07	.06	.07
222	.01	.01	.01	.00	.01
132	.09	.09	.10	.09	.07
232	.01	.00	.01	.00	.02
113	.03	.02	.01	.02	.03
213	.01	.00	.00	.01	.02
123	.04	.05	.05	.05	.06
223	.005	.02	.005	.01	.01
133	.03	.05	.08	.09	.06
233	.02	.00	.01	.01	.01
114	.02	.02	.01	.02	.02
214	.01	.00	.01	.01	.02
124	.04	.03	.04	.04	.05
224	.01	.01	.01	.01	.01
134	.08	.04	.08	.08	.06
234	.02	.00	.01	.01	.01

TABLE 8

ABSOLUTE DENSITIES IN NON-IMAGE AREA IN PRESS EXPERIMENT

Treatment combination	a	b	c	d	e
111	.12	.10	.10	.10	.09
211	.00	.00	.00	.00	.00
121	.10	.08	.09	.08	.08
221	.00	.00	.00	.00	.01
131	.03	.04	.04	.01	.04
231	.00	.00	.01	.02	.02
112	.19	.20	.22	.18	.13
212	.02	.00	.04	.03	.02
122	.01	.02	.04	.02	.00
222	.00	.00	.00	.01	.00
132	.01	.01	.02	.01	.01
232	.00	.00	.00	.00	.00
113	.04	.03	.04	.04	.03
213	.00	.00	.00	.00	.00
123	.01	.00	.01	.01	.00
223	.00	.00	.00	.00	.00
133	.02	.02	.02	.02	.01
233	.00	.01	.00	.01	.01
114	.05	.03	.04	.04	.05
214	.00	.00	.00	.00	.00
124	.00	.00	.00	.00	.00
224	.00	.00	.00	.00	.00
134	.00	.00	.00	.00	.00
234	.00	.00	.00	.00	.00

TABLE 9

RATIO OF SOLID TO TONE AREA IN IGT EXPERIMENT

Treatment combination	a	b	c	d	e
111	.78	.95	.84	.87	.81
211	.71	.62	.75	.76	.70
121	.81	.82	1.00	.92	.87
221	.70	.65	.64	.83	.80
131	.80	.80	.94	.91	.95
231	.61	.63	.69	.70	.82
112	.81	1.00	.73	.90	.89
212	.77	.79	.91	.81	.85
122	.86	.87	.88	.94	1.02
222	.82	.87	.77	.88	.68
132	.94	.98	.98	1.02	.82
232	.71	.96	.91	.88	.78
113	.84	.93	.99	.96	.95
213	.64	.85	.83	1.00	1.03
123	.85	.96	.99	.94	1.00
223	.75	.89	.84	.91	.79
133	.97	.92	1.07	.99	.97
233	.77	.89	.86	.82	.96
114	.89	.88	.86	.96	.95
214	.73	.96	.91	1.02	.94
124	.89	1.00	.86	.97	.89
224	.79	1.00	.81	.91	.92
134	.84	.94	.88	1.01	.95
234	.71	1.00	.86	.93	.84

TABLE 10

RATIO OF SOLID TO TONE AREA IN PRESS EXPERIMENT

Treatment combination	a	b	c	d	e
111	.93	.92	.89	.93	.90
211	.71	.81	.83	.77	.83
121	.87	.89	.85	.88	.88
221	.72	.84	.73	.72	.87
131	.91	.90	.91	.85	.86
231	.69	.73	.68	.71	.81
112	.94	.96	.96	.98	.99
212	.76	.78	.73	.79	.84
122	.83	.81	.82	.80	.77
222	.78	.75	.82	.82	.91
132	.89	.92	.87	.92	.88
232	.68	.71	.69	.75	.85
113	.87	.91	.87	.90	.88
213	.88	.72	.71	.70	.81
123	.85	.83	.79	.84	.78
223	.76	.72	.73	.72	.79
133	.85	.84	.84	.83	.91
233	.82	.74	.73	.78	.79
114	.84	.86	.80	.81	.95
214	.67	.67	.67	.70	.70
124	.80	.82	.78	.91	.84
224	.75	.69	.79	.72	.72
134	.76	.71	.76	.75	.86
234	.78	.69	.68	.70	.73

values from each experiment level were used, which meant that there were twenty-four pairs of averages for each correlation study. The coefficient of correlation (r) was calculated using the following formula:[3]

$$r = \frac{\sum(x - \overline{x})(y - \overline{y})}{\sqrt{\sum(x - \overline{x})^2 \sum(y - \overline{y})^2}}$$

Using twenty-four pairs as the sample size, the value of r had to exceed .4227 in each correlation calculation in order for that correlation to be significant.[4] The values of r are shown in Table 11 for the various comparisons made.

TABLE 11

COEFFICIENTS OF CORRELATION (r)

Comparison	r
IGT ratio vs. press ratio	.314
IGT absolute vs. press absolute	.175
Press ratio vs. press absolute	.737
IGT ratio vs. IGT absolute	.533

The correlations are significant when comparing different measuring techniques on the same printing mechanism. They are insignificant when comparing the two different printing mechanisms. It should be considered, however, that the twenty-four averages used as the sample represent 120 toning densities. Therefore, a lower correlation might be accepted as being significant.

In order to get a general idea of how the speeds, tacks, and pressures used in the experiment affected the amount of toning, the relationships were graphically plotted using absolute data. In order to plot the effects of two of the three variables on a graph, the amount of toning connected with the third variable, either speed, tack, or pressure, was summed for each treatment combination of the two variables being plotted.

Generally, it was found that the amount of toning decreased as tack increased for each of the levels of speed and pressure. This is shown in Figures 13 through 16.

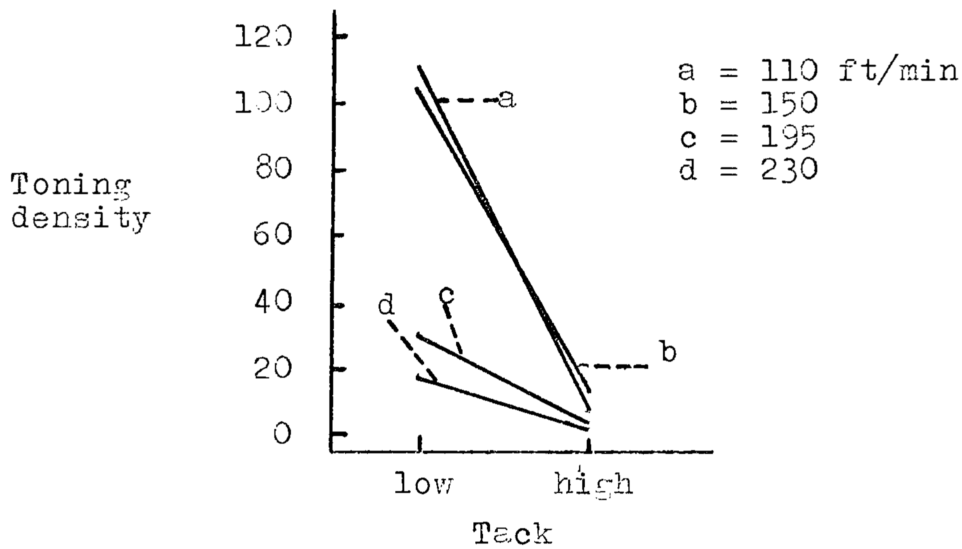


Figure 13

Absolute Values of Toning as a Function of Tack at Various Levels of Speed on the Press

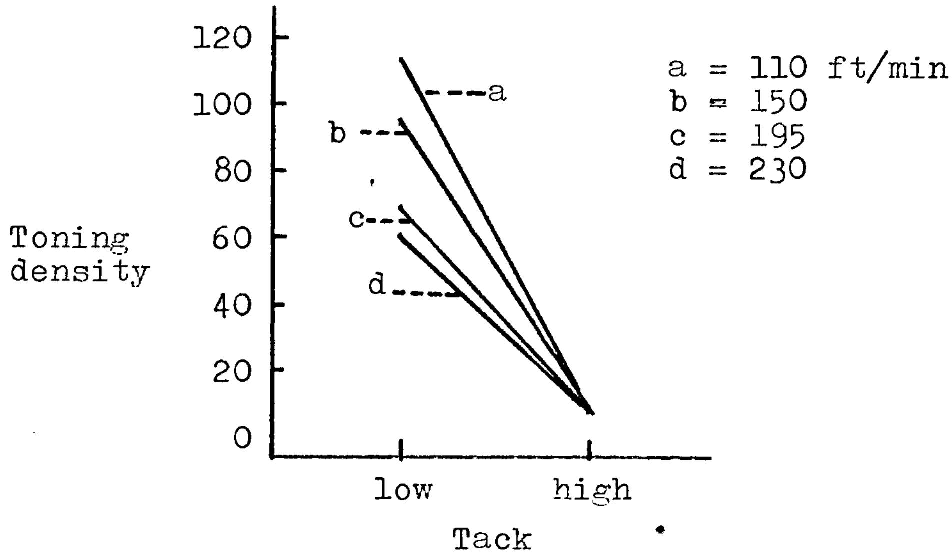


Figure 14

Absolute Values of Toning as a Function of Tack at Various Levels of Speed on the IGT

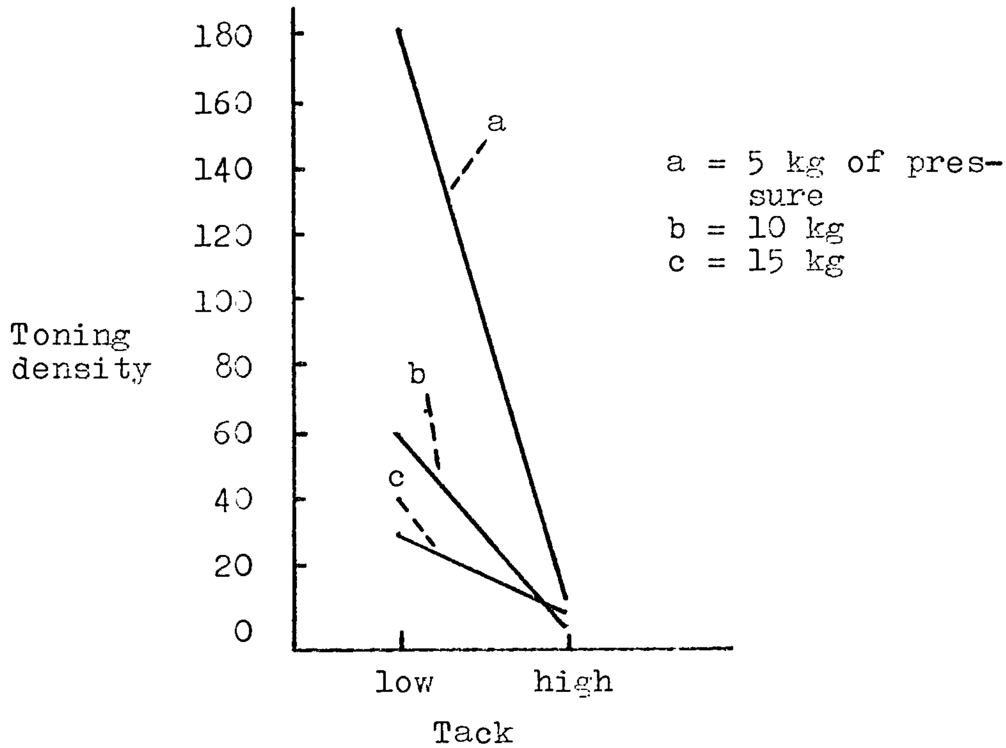


Figure 15

Absolute Values of Toning as a Function of Tack at Various Levels of Pressure on the Press

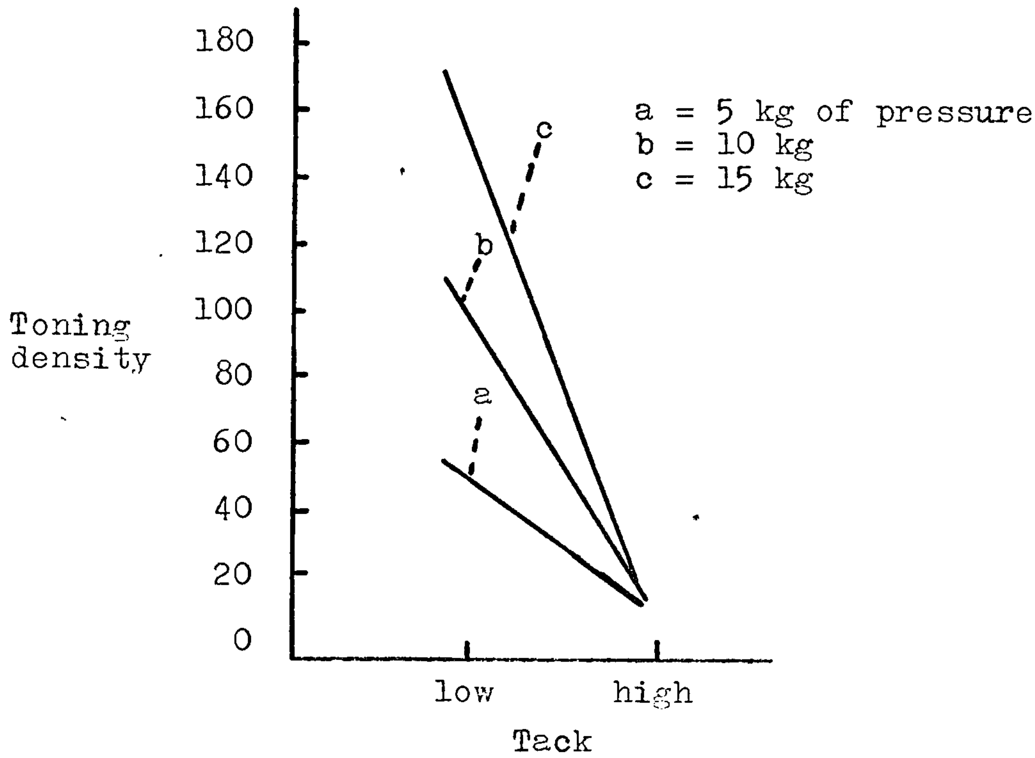


Figure 16

Absolute Values of Toning as a Function of Tack at Various Levels of Pressure on the IGT

The amount of toning was found to be relatively unaffected by speed or pressure changes when using the high tack ink. When using the low tack ink, increases in speed lowered the amount of toning on both the press and the IGT. Increases in pressure, using the low tack ink, had opposite effects on the press and IGT. This result was not expected and can perhaps be explained by the dynamic rolling conditions on a press as opposed to the IGT. The results are shown graphically in Figures 17 and 18.

As speed was increased, the amount of toning generally decreased. This can be seen in Figure 15 and in

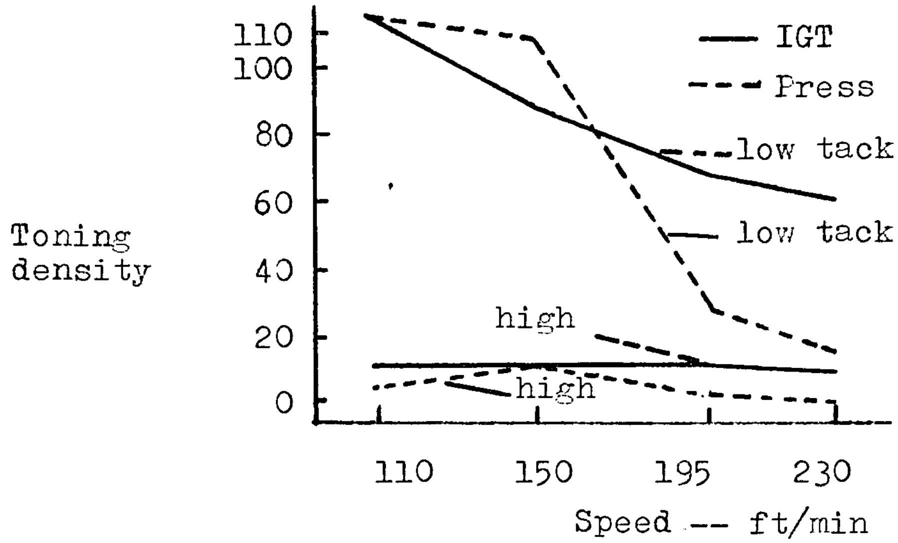


Figure 17

Absolute Values of Toning as a Function of Speed at Various Levels of Tack on Both the IGT and the Press

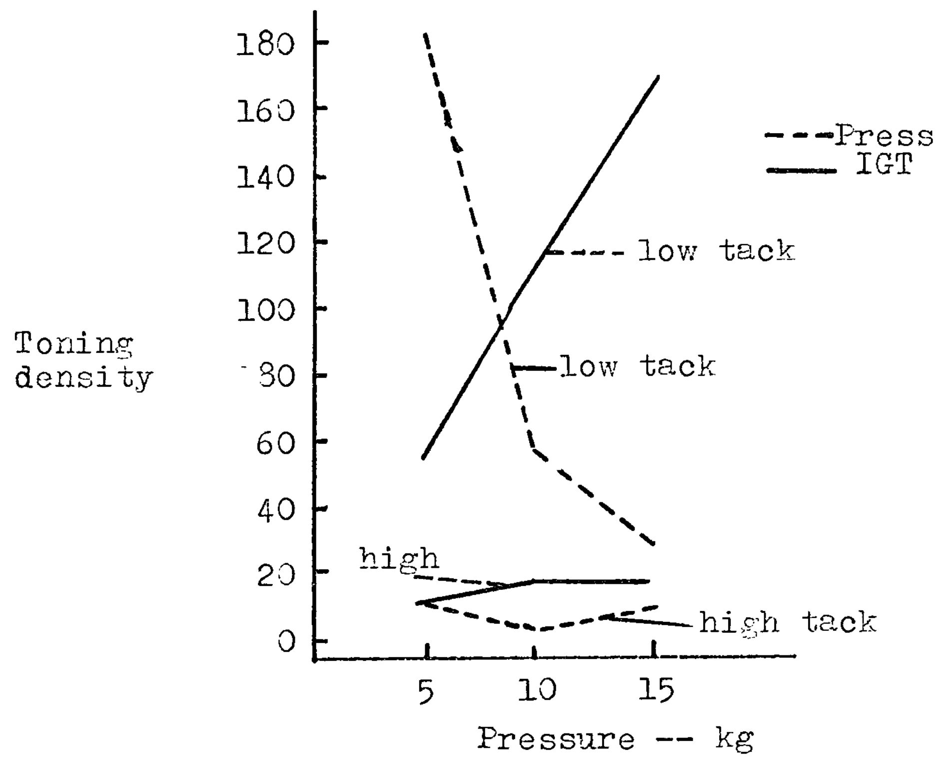


Figure 18

Absolute Values of Toning as a Function of Pressure at Various Levels of Tack on Both the IGT and The Press

Figures 19 and 20 below.

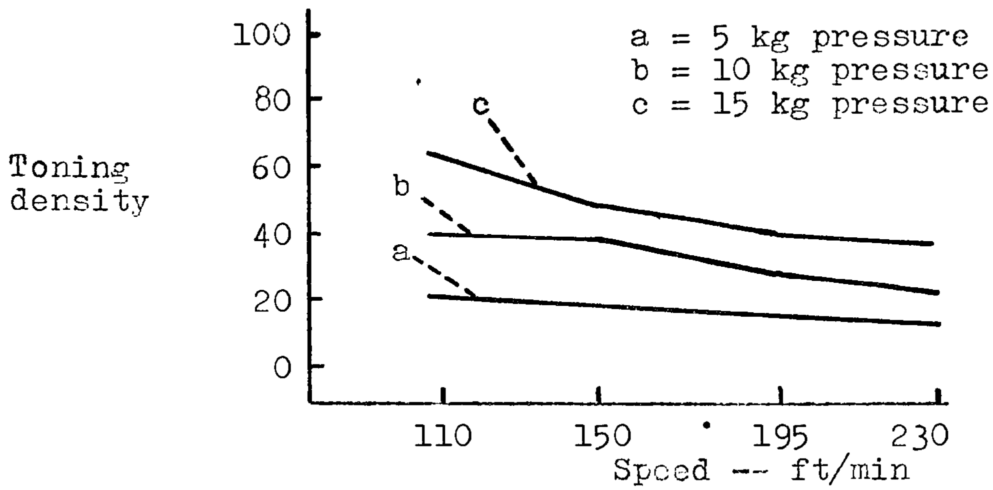


Figure 19

Absolute Values of Toning as a Function of Speed at Various Levels of Pressure on the IGT

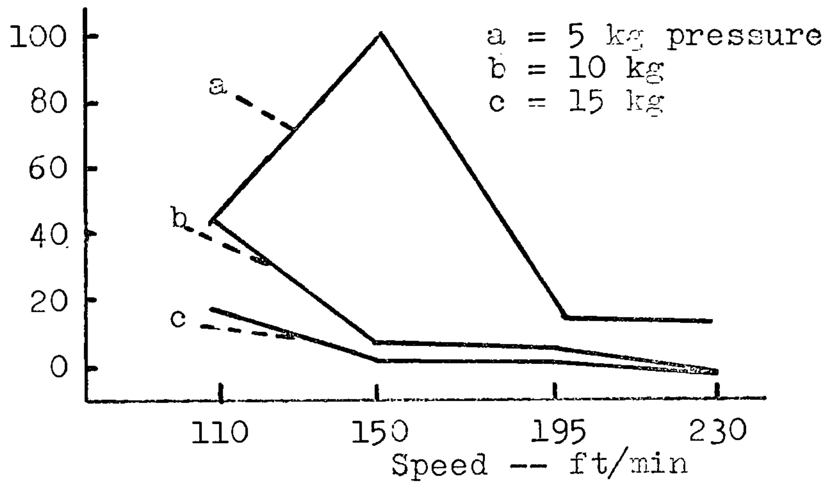


Figure 20

Absolute Values of Toning as a Function of Speed at Various Levels of Pressure on the Press

As pressure was increased, the amount of toning decreases on the press but increased on the IGT. This relationship is shown in Figures 16, 21, and 22.

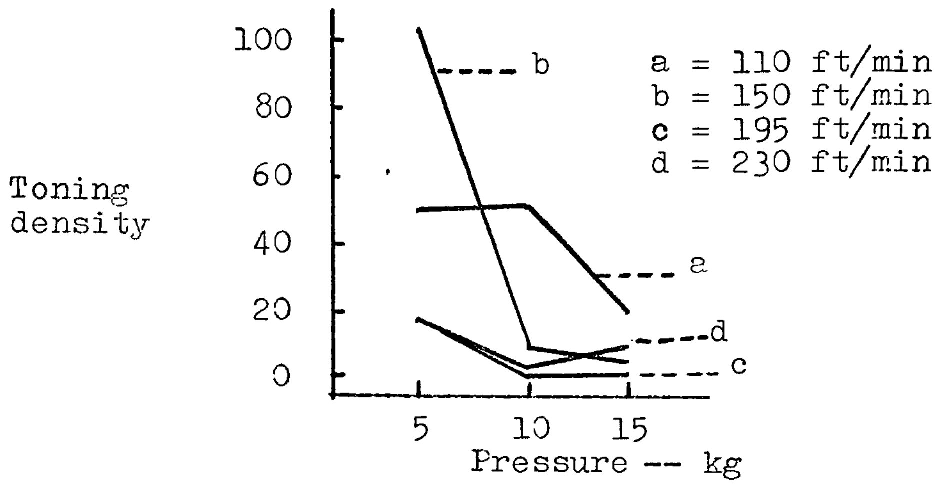


Figure 21

Absolute Values of Toning as a Function of Pressure at Various Levels of Speed on the Press

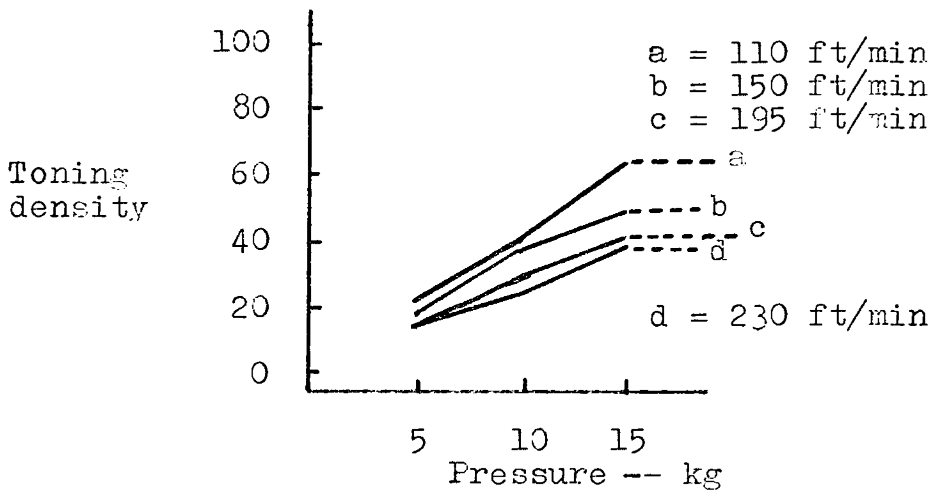


Figure 22

Absolute Values of Toning as a Function of Pressure at Various Levels of Speed on the IGT

In order to determine if there was a statistically significant difference between the various levels of different factors, a paired comparison test was performed. This test followed the outline given by Rickmers and Todd.[5] Using the five replicates of the experiment for each level being compared, the following test statistic was computed:

$$t_v = \frac{\bar{d}}{s_d / \sqrt{n}}$$

In the above equation, d represents the average difference between the levels. The standard deviation of the differences is represented by s_d. The number of pairs of data is represented by n.

Since in all cases there were five pairs of arbitrarily chosen data involved, the value of t_v had to exceed the critical value of 2.78.[6] Table 12 shows the calculated t_v value and its significance for each of the paired comparisons. Absolute density readings were used in these calculations. In most cases, the paired comparison tests confirmed what was shown in the graphical analysis of the absolute data.

A graphical analysis of the ratio values was made in order to compare them with the absolute values. These graphs are shown in Figures 23 through 32.

To determine if any particular factor or combination of factors had a significant affect on the amount of toning, an analysis of variance (ANOVA) was performed. An analysis was performed for the absolute and ratio data for both the press and the IGT. The results are presented in Tables 13 through 16. All calculations were made using the Yates method of analysis.[7] The critical values of F

TABLE 12

FINAL RESULTS OF PAIRED COMPARISON TESTS USING ABSOLUTE DENSITY VALUES

Paired Comparison		Results			
Compared levels	Controlled levels	IGT		Press	
		t_v	Analysis	t_v	Analysis
110 vs 195 ft/min	lo tack lo pre	0.004	toning ↑ as speed ↓	16.500	toning ↑ as speed ↓
110 vs 195 ft/min	lo tack med pre	2.390	n.d.	25.810	toning ↑ as speed ↓
110 vs 195 ft/min	lo tack hi pre	3.940	toning ↑ as speed ↓	2.220	n.d.
110 vs 195 ft/min	hi tack lo pre	- 0.780	n.d.	0.000	n.d.
110 vs 195 ft/min	hi tack med pre	0.000	n.d.	1.000	n.d.
110 vs 195 ft/min	hi tack hi pre	0.000	n.d.	1.000	n.d.
hi vs lo tack	150 ft/min lo pre	5.880	toning ↑ as tack ↓	10.520	toning ↑ as tack ↓
hi vs lo tack	150 ft/min med pre	29.080	toning ↑ as tack ↓	2.350	n.d.
hi vs lo tack	150 ft/min hi pre	9.940	toning ↑ as tack ↓	6.000	toning ↑ as tack ↓

TABLE 12 -- Continued

Paired Comparison		Results			
		IGT		Press	
Compared levels	Controlled levels	t_v	Analysis	t_v	Analysis
hi vs lo tack	230 ft/min lo pre	2.140	n.d.	11.350	toning ↑ as tack ↓
hi vs lo tack	230 ft/min med pre	8.710	toning ↑ as tack ↓	0.000	n.d.
hi vs lo tack	230 ft/min hi pre	9.980	toning ↑ as tack ↓	0.000	n.d.
hi vs lo pre	150 ft/min lo tack	- 8.750	toning ↑ as pre ↑	12.370	toning ↑ as pre ↓
hi vs lo pre	150 ft/min hi tack	0.000	n.d.	3.270	toning ↑ as pre ↓
hi vs lo pre	230 ft/min lo tack	- 3.350	toning ↑ as pre ↑	11.350	toning ↑ as pre ↓
hi vs lo pre	230 ft/min hi tack	0.000	n.d.	0.000	n.d.

Key:
lo -- low
hi -- high
med -- medium
pre -- pressure
↑ -- increases
↓ -- decreases
n.d. -- no significant difference between compared levels

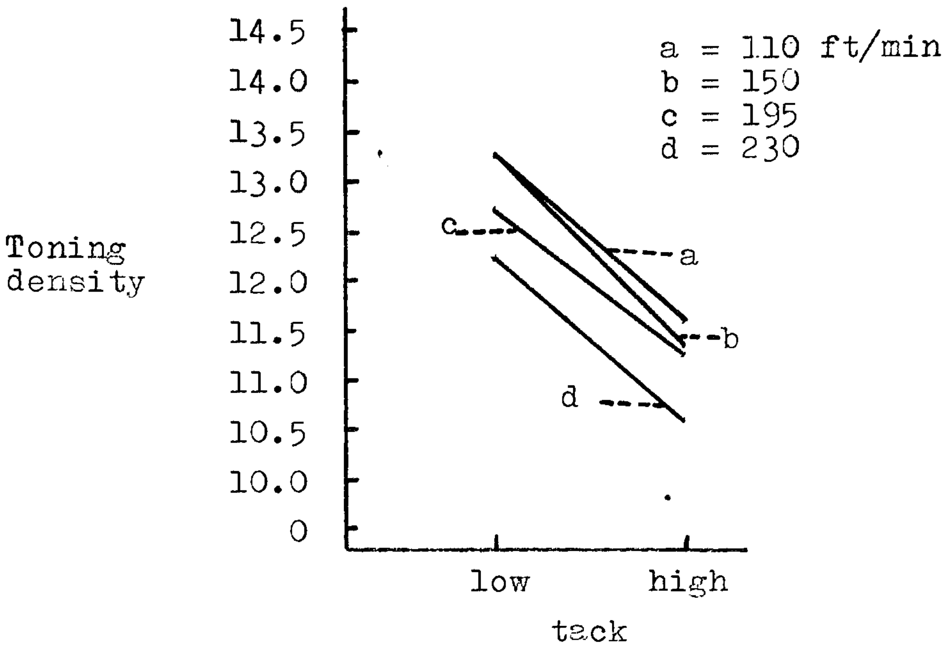


Figure 23

Ratio Values of Toning as a Function of Tack at Various Levels of Speed on the Press

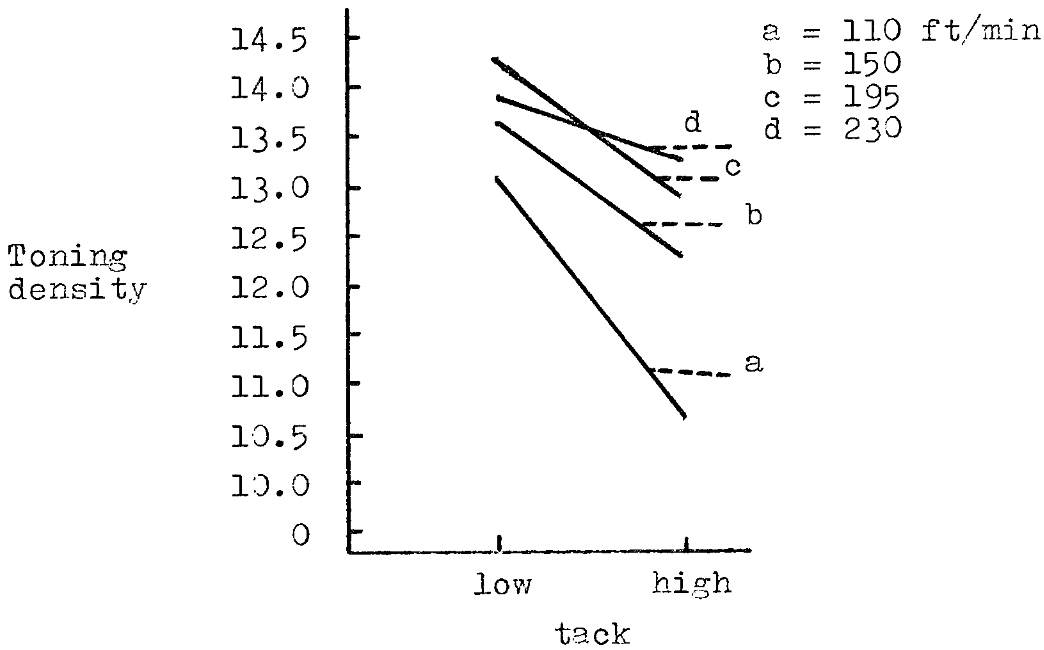


Figure 24

Ratio Values of Toning as a Function of Tack at Various Levels of Speed on the IGT

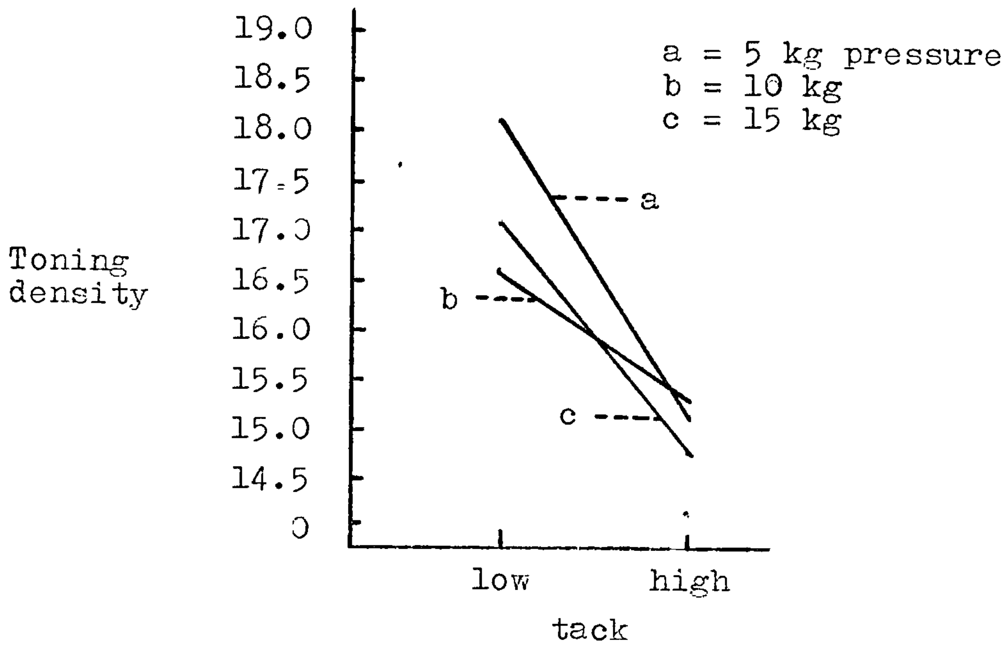


Figure 25

Ratio Values of Toning as a Function of Tack at Various Levels of Pressure on the Press

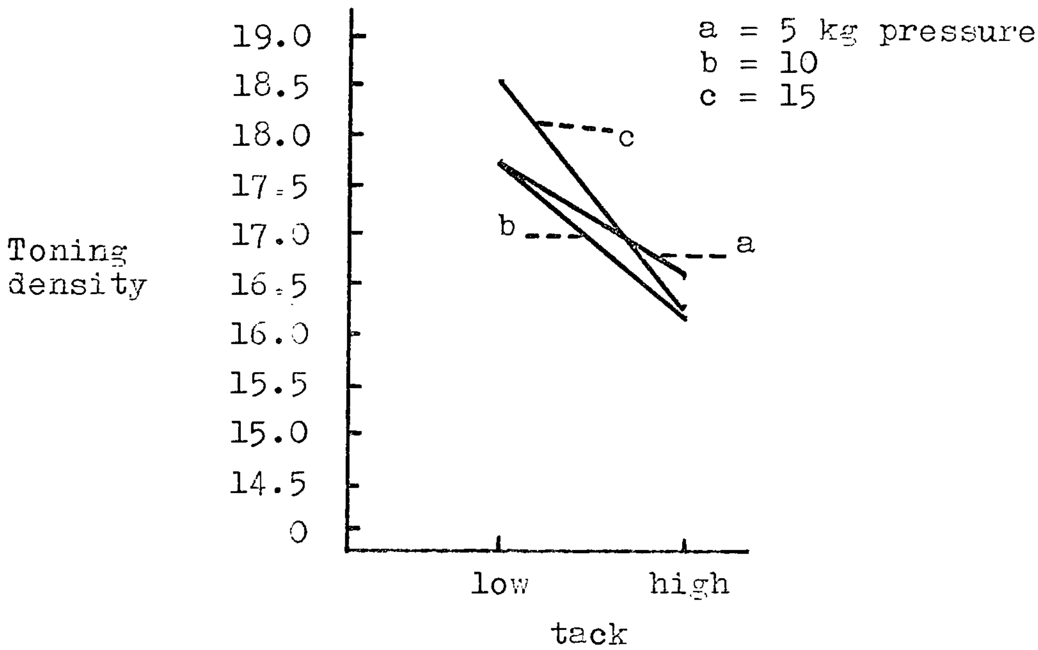


Figure 26

Ratio Values of Toning as a Function of Tack at Various Levels of Pressure on the IGT

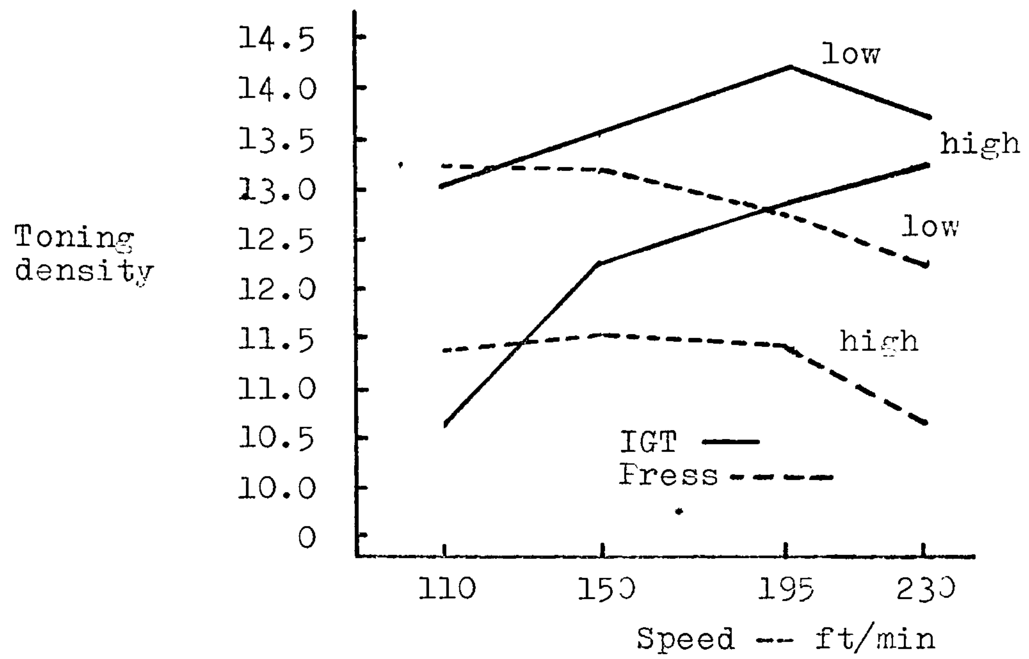


Figure 27

Ratio Values of Toning as a Function of Speed at Different Levels of Tack on Both the IGT and the Press

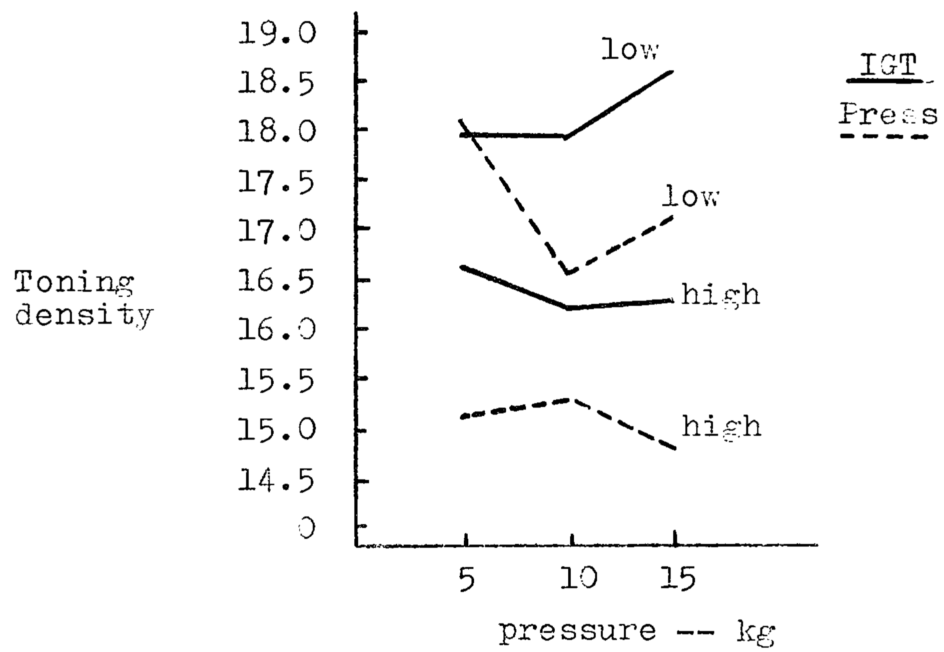


Figure 28

Ratio Values of Toning as a Function of Pressure at Different Levels of Tack on Both the IGT and The Press

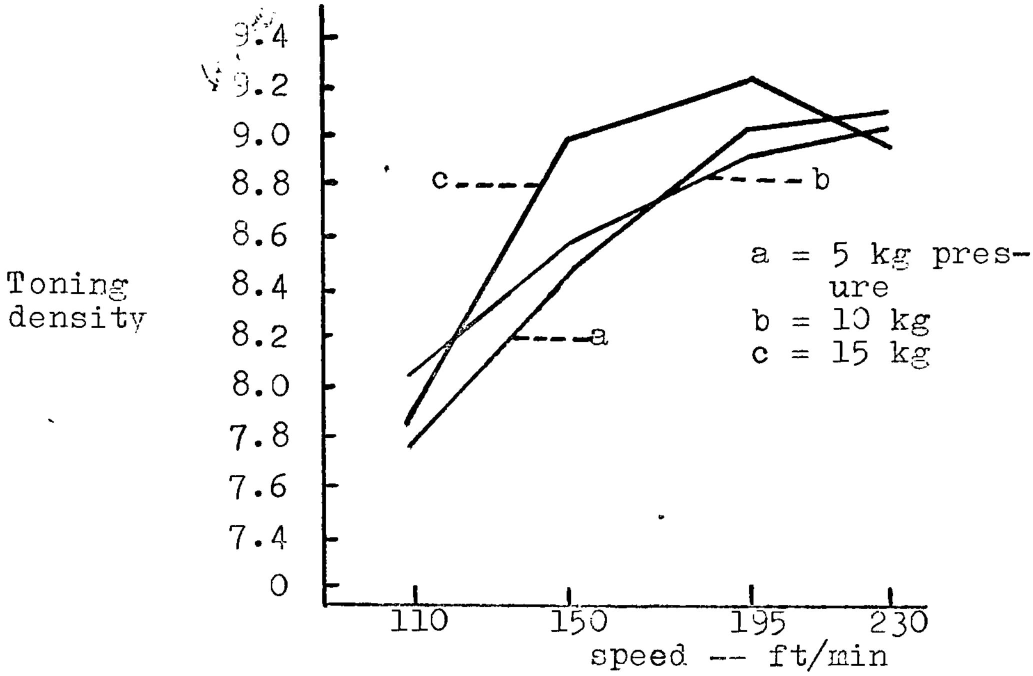


Figure 29

Ratio Values of Toning as a Function of Speed at Various Levels of Pressure on the IGT

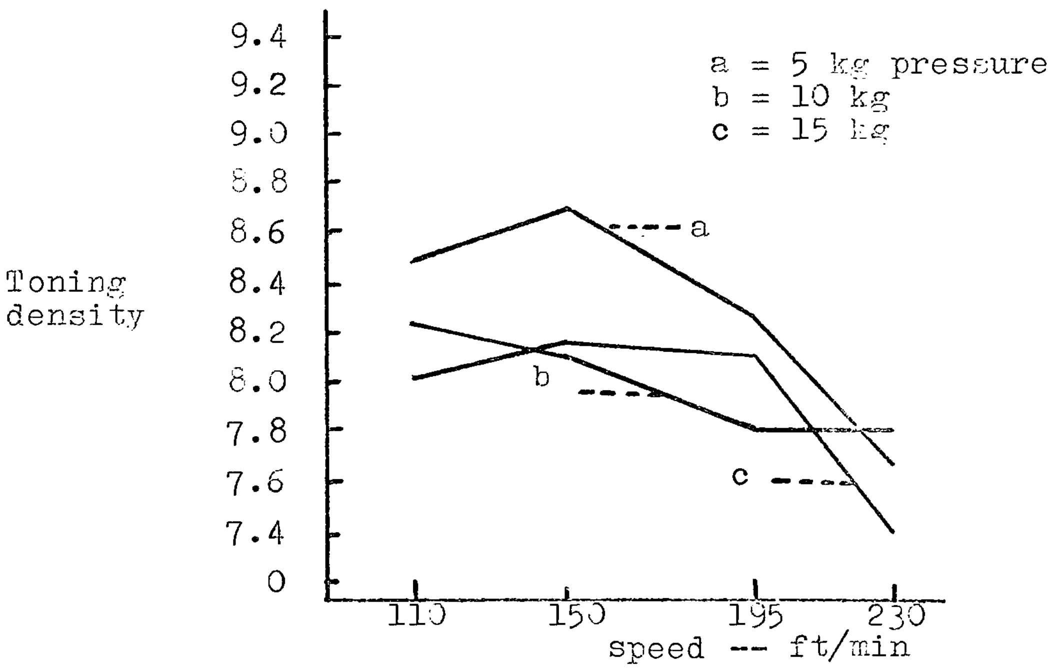


Figure 30

Ratio Values of Toning as a Function of Speed at Various Levels of Pressure on the Press

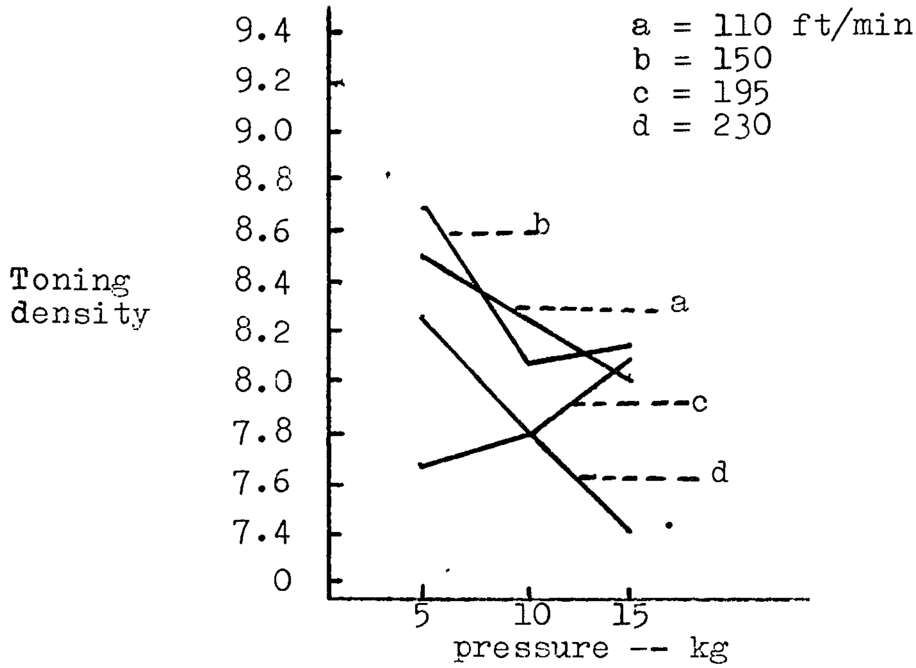


Figure 31

Ratio Values of Toning as a Function of Pressure at Various Levels of Speed on the Press

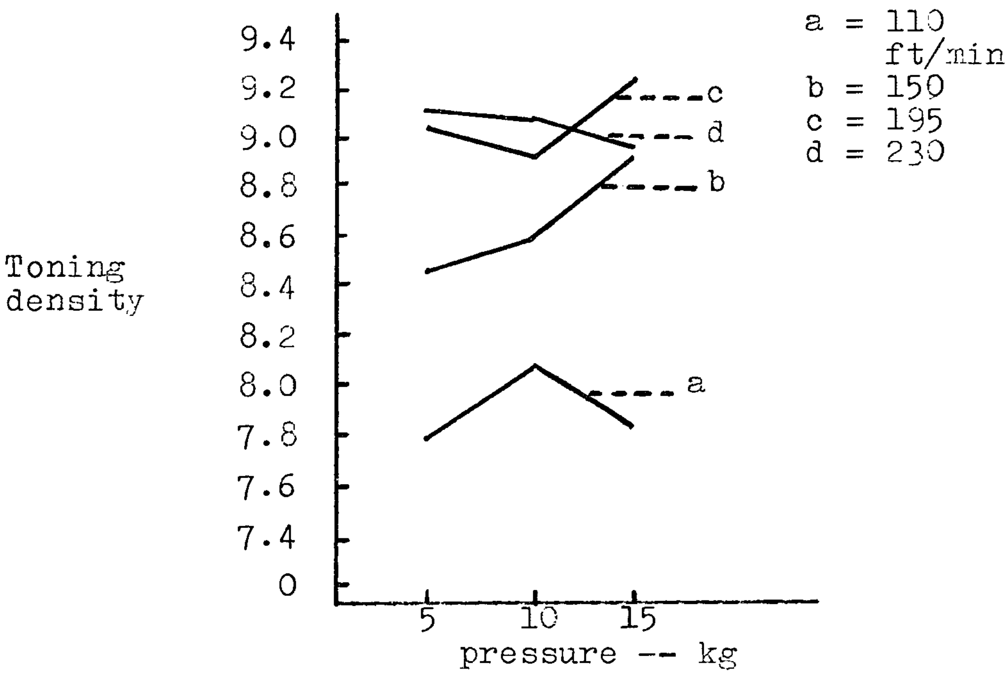


Figure 32

Ratio Values of Toning As a Function of Pressure at Various Levels of Speed on the IGT

TABLE 13

ANOVA
IGT ABSOLUTE DENSITY READINGS

Source	SS	ν	MS	F
Main effects				
A Linear	.0691	1	.0691	691* F_{1} 119 .05 = 3.92
B Linear Quadratic	.0186 .0000 } .0186	1 1 } 2	.0186 .0000 } .0093	93* F_{2} 119 .05 = 3.07
C Linear Quadratic Cubic	.0043 .0001 .0000 } .0044	1 1 1 } 3	.0043 .0001 .0000 } .0014	14* F_{3} 119 .05 = 2.68
Two-factor interactions				
AB [A_1B_1 A_1B_2]	.0162 .0000 } .0162	1 1 } 2	.0162 .0000 } .0081	81* F_{2} 119 .05 = 3.07
AC [A_1C_1 A_1C_2 A_1C_3]	.0056 .0001 .0000 } .0057	1 1 1 } 3	.0056 .0001 .0000 } .0019	19* F_{3} 119 .05 = 2.68
BC [B_1C_1 B_2C_1 B_1C_2 B_2C_2 B_1C_3 B_2C_3]	.0007 .0000 .0001 .0001 .0000 .0000 } .0009	1 1 1 1 1 1 } 6	.0007 .0000 .0001 .0001 .0000 .0000 } .0001	1 NS F_{6} 119 .05 = 2.17
Three-factor interaction Error	.0007 .0090 } .0097	6 96 } 102	.0001 .0001 } .0001	
Total	.1246	119		

TABLE 13 -- Continued

Key (to be used for Tables 13, 14, 15, and 16):

Source = source of variance

Types of sources:
- A = effects of tack
- B = effects of pressure
- C = effects of speed
- The subscript to each source letter indicates the type of interaction --
  - 1 = linear relationship
  - 2 = quadratic relationship
  - 3 = cubic relationship

SS = sums of squares

ν = degrees of freedom

MS = mean square

F = F test
- The first number in this column is the calculated value.
- The second number indicates the table value of F.
- The subscripts to the F incicate the number of degrees of freedom for a two tailed test and the alpha risk involved.
- The symbols next to the calculated F value mean --
  - * = significant
  - NS = not significant

TABLE 14

ANOVA
PRESS ABSOLUTE DENSITY READINGS

Source	SS	SS (pooled)	ν	ν (pooled)	MS	MS (pooled)	F
Main effects							
A Linear		.0520		1		.0691	345.5* $F_{1\ 119\ .05} = 3.92$
B Linear	.0288	.0334	1	2	.0288	.0167	83.5* $F_{2\ 119\ .05} = 3.07$
Quadratic	.0046		1		.0046		
C Linear	.0256	.0297	1	3	.0256	.0099	49.5* $F_{3\ 119\ .05} = 2.68$
Quadratic	.0001		1		.0001		
Cubic	.0040		1		.0040		
Two-factor interactions							
AB A_1B_1	.0266	.0290	1	2	.0266	.0145	72.5* $F_{2\ 119\ .05} = 3.07$
A_1B_2	.0024		1		.0024		
AC A_1C_1	.0190	.0211	1	3	.0190	.0070	35.0* $F_{3\ 119\ .05} = 2.68$
A_1C_2	.0000		1		.0000		
A_1C_3	.0021		1		.0021		
BC B_1C_1	.0038	.0357	1	6	.0038	.0059	29.5* $F_{6\ 110\ .05} = 2.17$
B_2C_1	.0004		1		.0004		
B_1C_2	.0036		1		.0036		
B_2C_2	.0060		1		.0060		
B_1C_3	.0171		1		.0171		
B_2C_3	.0048		1		.0048		
Three-factor interaction	.0205	.0256	6	102	.0034	.0002	
Error	.0051		96		.0000		
Total		.2265		119			

TABLE 15

ANOVA
IGT RATIO VALUES

Source	SS		ν		MS		F
Main effects							
A Linear		.2660		1		.2660	42.9* F_1 119 .05 = 3.92
B Linear	.0051	.0052	1	2	.0051	.0026	.42 NS F_2 119 .05 = 3.07
Quadratic	.0001		1		.0001		
C Linear	.2162	.2646	1	3	.2162	.0882	14.23* F_3 119 .05 = 2.68
Quadratic	.0484		1		.0484		
Cubic	.0000		1		.0000		
Two-factor interactions							
AB A_1B_1	.0162	.0178	1	2	.0162	.0089	1.43 NS F_2 119 .05 = 3.07
A_1B_2	.0016		1		.0016		
AC A_1C_1	.0562	.0690	1	3	.0562	.0230	3.71* F_3 119 .05 = 2.68
A_1C_2	.0001		1		.0001		
A_1C_3	.0127		1		.0127		
BC B_1C_1	.0021	.0193	1	6	.0021	.0032	.52 NS F_6 119 .05 = 2.17
B_2C_1	.0016		1		.0016		
B_1C_2	.0080		1		.0080		
B_2C_2	.0062		1		.0062		
B_1C_3	.0014		1		.0014		
B_2C_3	.0000		1		.0000		
Three-factor interaction	.0019	.6371	6	102	.0003	.0062	
Error	.6352		96		.0066		
Total		1.2790		119			

TABLE 16

ANOVA
PRESS RATIO VALUES

Source	SS	SS (pooled)	ν	ν (pooled)	MS	MS (pooled)	F
Main effects							
A Linear		.3608		1		.3608	186.94* F_1 119 .05 = 3.92
B Linear	.0248	.0293	1	2	.0248	.0146	7.56* F_2 119 .05 = 3.07
Quadratic	.0045		1		.0045		
C Linear	.0511	.1117	1	3	.0511	.0372	19.27* F_3 119 .05 = 2.68
Quadratic	.0505		1		.0504		
Cubic	.0102		1		.0102		
Two-factor interactions							
AB A_1B_1	.0066	.0372	1	2	.0066	.0186	9.64* F_2 119 .05 = 3.07
A_1B_2	.0306		1		.0306		
AC A_1C_1	.0027	.0047	1	3	.0027	.0016	.81 NS F_3 119 .05 = 2.68
A_1C_2	.0016		1		.0016		
A_1C_3	.0004		1		.0004		
BC B_1C_1	.0030	.0396	1	6	.0030	.0066	3.47* F_6 119 .05 = 2.17
B_2C_1	.0118		1		.0118		
B_1C_2	.0000		1		.0000		
B_2C_2	.0000		1		.0000		
B_1C_3	.0031		1		.0031		
B_2C_3	.0217		1		.0217		
Three-factor interaction	.0455	.1977	6	102	.0076	.0019	
Error	.1522		96		.0016		
Total		.7810		119			

were determined using an alpha (α) risk of .05 and a sample size of 120.

The ANOVA for the press absolute densities shows that the individual factors and the two-factor interactions are significant. A summary of the results of the four ANOVAs can be seen in Table 17.

TABLE 17

SIGNIFICANCE OF FACTORS AND INTERACTIONS AS SHOWN IN THE ANOVAS

Factors and Interactions	Press Absolute	IGT Absolute	Press Ratio	IGT Ratio
A	*	*	*	*
B	*	*	*	NS
C	*	*	*	*
AB	*	*	*	NS
AC	*	*	NS	*
BC	*	NS	*	NS

* Significant NS Not Significant

In three of the ANOVAs, all of the factors were significant and two out of the three interactions were significant. This means that the results being observed were significantly affected by the factors being varied and their interactions. This was not a fractional factorial experiment to find all the significant factors affecting toning, but, it is felt, that some of those factors not studied were controlled. This means that the error associated with the untested factors was kept to a minimum.

FOOTNOTES FOR CHAPTER V

[1]Albert D. Rickmers and Hollis N. Todd, Statistics: An Introduction, (New York: McGraw-Hill Book Company, 1967) p321.

[2]Ibid. pp 264 - 270.

[3]Ibid. p 266.

[4]Ibid. p 563.

[5]Ibid. pp 87, 88.

[6]Ibid. p 553.

[7]Ibid. pp 523 - 525.

CHAPTER VI

CONCLUSION

One of the first conclusions reached in this study was that making an analysis of toning based on ratio values was not satisfactory. Much thought had gone into the design of the ratio analysis. It was felt that the ratios would help to mathematically eliminate some of the extraneous variables which might have an affect on the amount of toning. These extraneous variables include such things as misting, slur, humidity, ink flow properties, solvents used, ink chemistry, penetration problems, etc. Recording the effects of toning in a tint area should show the density variations caused by toning in various tint blocks. The density value of a tint is very critical in quality printing. It seems, however, in analyzing the data that the ratios have recorded the pure effects of toning plus the effects of the extraneous variables.

The analysis of variance (ANOVA) of IGT ratio values showed that half of the six factors and their interactions were not significant. This did not compare well with the results of the ANOVAs performed for the other experiments. The ANOVA of press ratio values and the ANOVAs of press and IGT absolute density readings showed that most of the factors and their interactions were significant. These results can be seen in Table 17.

A visual comparison between the graphical plots of toning for each treatment combination was made. Particular attention was paid to the comparison between ratio and absolute methods of recording. After studying the graphs, it was decided that unrelated results were being compared. In several cases, the results in absolute values plotted opposite to that of ratio values. This dissimilarity can be seen in the comparison of Figures 17 and 27, 18 and 28, 19 and 29, 20 and 30, 21 and 31, and 22 and 32. The paired comparison tests of ratio and absolute values showed a similar relationship.

The correlation between the press and IGT ratio values was higher than the correlations of absolute values. This can be seen in Table 11. Neither correlation was significant and therefore little weight should be placed on their importance. However, a partial explanation of the higher correlation with the ratio values might be the greater reproducibility of other factors affecting the densities of the blocks measured.

The IGT gives control over many of the factors that affect toning, such as pressures, speeds, ink film thickness, etc. A printing press, however, adds other factors to the equation for toning. Such things as constantly moving ink train, faster moving ink train, higher and faster heat build-up in ink train, greater surface areas covered, less precise ink film thickness control, less precise pressure control, etc. all have an effect on toning. Since neither the IGT nor the press allows the experimenter to control these factors, the IGT cannot be considered the perfect predictor of toning on a press.

The first hypothesis in this study was that as ink tack decreases, the amount of background toning on a driographic plate increases. This hypothesis was demonstrated to be true in the graphical analysis of Figure 13, 14, 15, and 16. Since the relationship was so clear in the graphical analysis, it was decided that a statistical proof was not needed.

Another hypothesis was that as ink roller to plate pressure increases, the amount of toning increases. The experimental results of this relationship were plotted in Figures 18, 21, and 22. These results were not conclusive in either proving or disproving the hypothesis. It appeared that the level of toning, when pressure was varied, was quite dependent on the ink tack level. Pressure changes had little effect on toning when a high tack ink was used. When a low ink tack was used, however, there were great changes in toning when the pressure was varied. These changes went in opposite directions on the press and the IGT.

The amount of toning increased with pressure at various speed levels on the IGT (Figure 21). On the press, the amount of toning decreased as pressure was increased at various levels of speed (Figure 22). This difference in relationships was one of the factors which made it clear that the IGT and the press were being affected by more factors than tack, pressure, and speed.

The final hypothesis was that as printing speed increases, the amount of toning increases. Figures 17, 19, and 20 illustrate the actual experimental results of this relationship. In all cases, the results are directly opposed to the hypotheses, which should therefore be considered false. An interesting phenomenon shown by the graph of the relationship between speed and toning at various tack levels is that when a high tack ink was used, speed changes had little affect on the amount of toning. A low tack ink produced decreases in toning as the speed in - creased. At various levels of pressure, speed increases also caused decreases in toning.

If a measurement of toning is desired, that measurement should be made directly in the non-image area. Attempting to measure toning in a tint area or making a ratio of tint to solid densities to measure toning is inaccurate. Other factors which cannot be controlled enter the equation when this is done and blur the effect of toning.

The experiment was not completely successful in all of its original objectives, as has already been pointed out. The experiment has shown, however, that ink tack, inking pressure, and printing speed are all significant factors when dealing with toning in driography. Their interactions are also significant. It has been shown that it is possible to print driographically on an IGT Printability Tester. Further work must be done with the IGT to make it a reliable predictor of press results in driography. At present, however, the IGT might be useful in testing various ink - paper combinations when printing driographically.

Toning remains a major problem in driography. As more studies are done in this area, and as the amount of toning is decreased, the use of driography should increase.

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