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A Study on doubling in the offset printing process

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A STUDY ON DOUBLING IN THE OFFSET PRINTING PROCESS

by

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's Thesis of

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with a major in Printing Technology has been approved by the Thesis Committee as satisfactory for the thesis requirement for the Master of Science Degree at the convocation of May, 1989.

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ABSTRACT

The purpose of this study was to test the usefulness of the Experimental RIT Doubling Target in identifying directional dot gain in the offset printing process. Doubling, a form of mechanical dot gain, contributes greatly to color variations while printing. Slur, another form of mechanical dot gain, is often confused with doubling. Dot Gain Test Targets currently in use often do not distinguish between the two. A slur test was carried out and the results showed that slur is not a contributor to directional dot gain.

The target proved to be a visual and quantitative measure of Directional and Non-directional dot gain. The concentric circles, one of the main components of the target, were made with the intent of matching non-directional dot gain similar to that of a 50% tint made with a 150 line/inch screen-ruling. A slur test was carried out and the results showed that slur is not a major contributor to directional dot gain. The values for dot gain obtained on the concentric circles were found to be higher in value than the values for dot gain obtained on the 50% tint. Nonetheless, there was a strong correlation between the two values of dot gain on both targets. Direction, another aspect of directional dot gain, was studied in relation to the doubling magnitude. It was found that a definite preferred angle for doubling existed. The Pearson Product Method of Analysis, the t test for statistical significance and graphing were used to analyze the data.

CHAPTER ONE

INTRODUCTION

The offset lithographic method is one of the major printing processes in use. The term offset denotes a process where the ink is not transferred directly from the plate to the paper (as is characteristic of direct lithography) but to another intermediate cylinder covered with a rubber blanket and from there to the substrate. As a printing process, offset lithography is capable of excellent print quality, both in fine line and tone work at a lower cost than other printing processes. This is primarily due to the fact that the rubber blanket can transfer the ink to rough surfaces so that higher quality printing can be done on them. However, offset printing is a delicate process. Inspection of the production run is mandatory to maintain stringent quality requirements. Traditionally, some of the different quality criteria that have been observed are solid ink density, tone reproduction (dot gain), trapping, slur and doubling, register and color balance

To measure and control print quality, it is best to measure and control each separate component which contributes to print quality and its variation. In evaluating a press sheet, we look at the print quality of halftones and that is observed by noticing the feature of how sharp and clear the detail is. One fault that is either unique to halftones or most troublesome when halftones are being printed is dot gain. Dot gain is the increase which takes place in a dot's area during the transfer stages from film to the printed sheet. Dot gain in itself is not regarded as a printing fault since a certain amount of inkspread, when transferring from blanket to paper, is unavoidable.[1] There are, however, different kinds of dot gain with distinct features and causes. Some can be compensated for in the prepress area; others cannot. It is important to distinguish between the various types of dot gain because they call for different remedies. The following is a hierarchy of dot gain classification (figure 1):

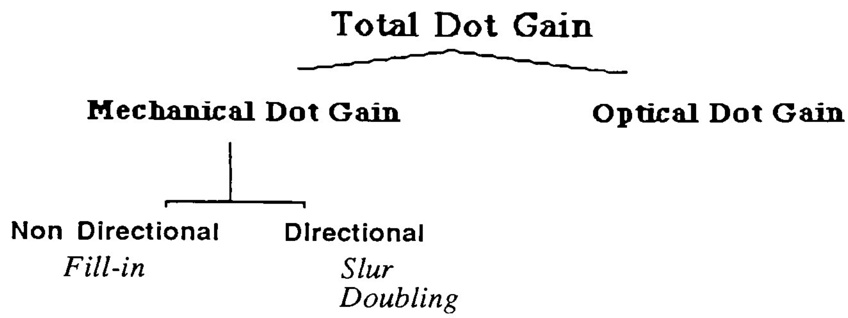


Figure 1. Hierarchy of Dot Gain Classification

Mechanical Dot Gain: There are basically two kinds of mechanical dot gain: non-directional and directional.

Non-Directional Dot Gain is called fill-in (figure 2). The halftone dots suffer a general increase in size in that the dots get uniformly larger due to spreading of ink over the edge of each dot. This can be caused by too much pressure between the blanket and impression cylinder, or by printing with too much ink (also taking into consideration the rheological properties of the ink) and possibly by the characteristics of the blanket (whether conventional or compressible).

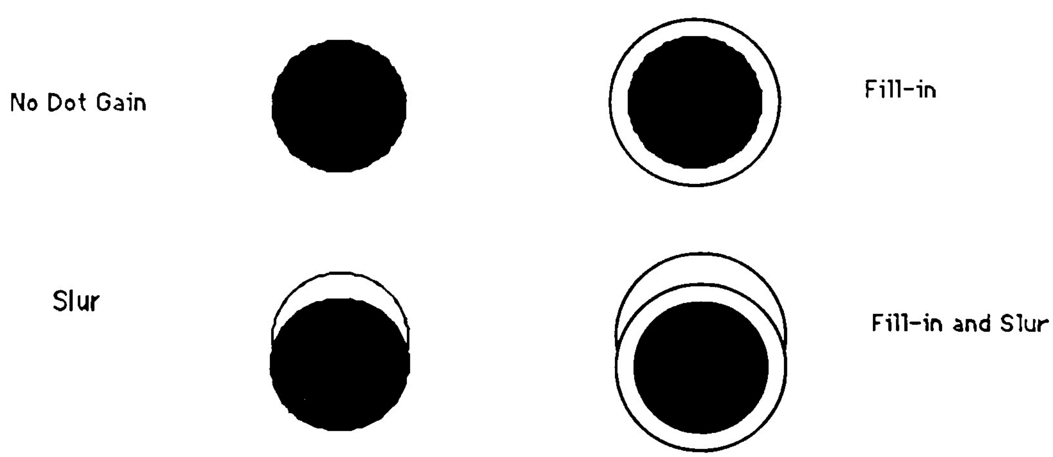


Figure 2. Enlarged Dots Showing the Effects of No Dot Gain, Fill-in, Slur, Fill-in and Slur

Directional Dot Gain occurs as slur and doubling. They are regarded as faults and their occurrence and effect on the print is unpredictable. Slur is a directional increase in dot size noticeable as an elongation or smearing at the trailing edge of a halftone dot. A distinct feature of slur is that it usually occurs in the direction of cylinder rotation on the press (figure 2).

Slur reduces shadow contrast. Halftone highlight areas and fine lettering are usually not affected.[2] A slurred impression will often be uniform from the front to the back of the sheet. Mechanically, the major cause behind slur is attributed to a difference in surface speed between the two printing cylinders (plate-blanket or the blanket-impression). This difference in surface speed is caused by a difference in diameter of the plate, blanket and/or impression cylinder. A slurred impression will show up as a result of excessive impression pressure. It can also be caused by the ink acting as a lubricant in the heavy ink coverage areas permitting the sheet to slip in the impression nip.[3] Other factors that produce other variations of slur in the form of streaks are a loose or slipping blanket, printing with a soft ink (not enough tack); or the use of too much ink especially when printing on coated stock. Defective paper in the form of wrinkled or bulged paper can result in slur. On a single color press, the defective paper will cause slur, but on a multi-color press, it will show up as a double.

Doubling of a halftone dot refers to a weaker, or ghost dot whose position is out of register relative to the full strength true dot.[4] A double impression rarely prints at the same density as the original dot.[5] It does not occur as streaks or elongation like in slur. In multi-color work, the blanket picks up a faint impression from the preceding sheet and fails to transfer it in exact register to the next one being printed. If the transferred dots are not in register with the true, full impression dots, doubling occurs (figure 3). Doubling increases the highlight tone areas and gives muddy reproductions. What results is an increase in the tonal values with an obvious distortion of the dots and a resulting loss of sharpness (of the dots, not of the image).

Doubling is an unpredictable and critical defect in offset printing. It is critical in that it can appear at random and usually can be corrected only by extensive mechanical adjustments on the press. Mechanical inaccuracies such as press and the quality of the paper are its primary causes. It is a problem of register variation between the printing units of a multicolor press but it can conceivably also happen on a single color press due to varying positioning of plate and blanket cylinders. It can also be caused by an unstable automatic register system in the case of a web press.[6] On sheetfed presses, doubling would sometimes occur along the back edge of a sheet of paper due to the paper "slapping" the blanket prematurely. A premature contact of the paper with the blanket unit produces a weak transfer of ink from the blanket of dots that are out of register with the true dots transferred to the paper during impression. Sheets with areas that are not flat (wavy or tight-edged sheets) and static electricity can cause premature contact of the paper and blanket. This premature contact will cause the paper to prematurely touch the surface of the blanket causing a faint impression next to the full impression dot. Paper slippage in the grippers, and excessive wear in the gear train or bearings of the press are other possible causes of doubling.

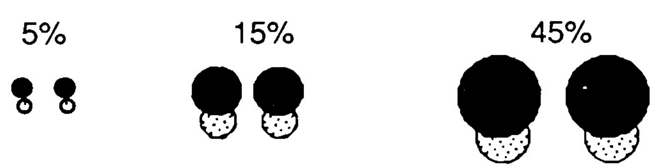


Figure 3. The Appearance of Doubling in Three Tones

Optical Dot Gain is the apparent expansion of the dot when light is reflected from the paper through the ink. The dots behave as if they are larger than they really are. For example a 40% dot pattern does not absorb 40% (reflect 60%) of the incident light. In fact, less than 60% is reflected suggesting that a 40% dot is behaving apparently like a larger dot size. This is basically due to light scattering within the paper. Two factors tend

to enhance this effect: screen-ruling and surface translucency of the substrate printed upon. These two factors exaggerate the effect of light scattering once light enters the substrate. Dots made with fine screen-ruling suffer more light scattering than dots made with coarse screen-ruling.

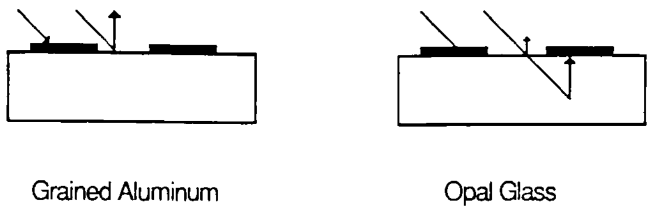


Figure 4. The Effect of Light Scattering on Grained Aluminum and Opal Glass.

Figure (4) shows a comparison of two kinds of surfaces that react differently in terms of light scattering. A dot on an aluminum surface would have a sharp edge with no spreading of light. Aluminum is not a translucent surface, which means light cannot diffuse and scatter within aluminum. A 50% dot would absorb 50% of the light and reflect 50%. A dot on a translucent surface such as opal glass would behave differently. The dot pattern is completely diffused before it emerges from the surface. If actual measurements were taken with a densitometer for this 50% dot pattern, it would read a reflection density of 0.6 instead of 0.3 representing an increase in reflection due to the effect of light scattering.[7]

In this chapter, the different types of dot gain have been defined and briefly described. The following chapter will investigate the problem of doubling and attempt at describing its major causes.

FOOTNOTES

CHAPTER ONE

[1]Southworth, Miles F., Dot Gain Causes and Cures, Quality Control Scanner, Vol.2 No.9 1982 pp.1

[2]Anon., Make the Halftone fit the Paper, Research Progress Report No.15, September - October 1949, Graphic Atrts Technical Foundation, Pittsburgh Pa.

[3]Ibid,

[4]Bureau, William H., What the Printer should know about Paper, Graphic Arts Technical Foundation, pp.190, 215.

[5]Treff, Ernie H., An Engineer's View of Dot Gain on a Web Offset Press, A Presentation made at the PIA Annual Meeting in San Francisco on May 10, 1988, p. 11

[6]Ibid,

[7]J. A. C. Yule and W. J. Nielsen, The Penetration of Light into Paper and its Effect on Halftone Reproduction, TAGA Proceedings 1951, pp. 69-70

CHAPTER TWO

THEORETICAL BASIS OF DIRECTIONAL DOT GAIN

Slur

There are two kinds of directional dot gain: Slur and Doubling. Slur is theoretically caused when the surface speed of the plate, blanket and impression cylinders are not the same. If the diameters should differ either by overpacking or underpacking the plate and blanket, the surface speed of the cylinders will vary and cause blanket slip.[1] A change in packing will be needed in order to correct for this problem. An advantage, if it can be described as such, is that packing has to be quite different before slur is detected and even if it were, it would not be considered much of a problem as long as it was consistent throughout the process.[2] The first hypothesis was formulated in an attempt to investigate the importance of slur (see page 24).

Theoretical Analysis of the Effect of Slur

The effect of packing on slur was theoretically analyzed with the use of an equation that calculates the change in print length as a result of a change in packing. This equation can be used to check for an increase in dot area of a 50% square dot of 150 line screen ruling. The 50% square dot had a side length of 120 microns. The following formula[3] $D = 2P\pi C / 100$ was used for calculating change in print length resulting from a change in packing where D denotes change in print length; C is for % circumference occupied by image; P is for packing change.

Upon obtaining a value for the change in print length, a ratio of increase in print length to the 50% dot side length of 120 microns was used to show the resulting change in size as a result of this change in packing. The overall increase in dot size was less than a micron or approximately .3 microns (see Appendix A for actual calculations). As a rule of thumb, a 1 micron change in diameter of a 50% dot of a 150 line screen causes a change in dot area of almost 1% dot area. Since the slur does not occur all around the dot, the increase in the dot size would be much smaller. This is due to the fact that it is occurring in only one direction. This change was small enough to warrant it being ignored. Even if

there was a chance that slur actually occurred, its effect on the dot is totally negligible. The effect on print length is important because it would ultimately affect register. This, however is not an issue of concern in this study. This only goes to support the contention that slur is not a fault in printing and consequently in directional dot gain. The only problem of directional dot gain that is significant in practical work is doubling.

Doubling

Doubling caused by inaccuracies on the press can best be understood by identifying the types of presses involved. Presses are classified as sheet-fed and web-fed according to the form in which the paper is fed into and through the press. On a sheetfed press, sheets of paper are fed into the press one at a time, the impression is made and each sheet is removed or delivered into a pile. On a web press, the paper is fed from a roll and printing is continuous as the paper passes between the impression cylinder and blanket cylinder. It is important to understand how doubling is caused on each of these presses and to understand the variables that interplay to create the phenomenon.

Primarily, a double exists whenever there is a problem in register (however, this is not a misregister between 2 colors, but between a color and its "ghost" image). Doubling caused by misregister within a single unit can be a result of variation in the relative position of the plate and blanket from impression to impression. There are theories that indicate that sideways play of the plate cylinder in addition to printing with a loose blanket can result in a variation in the relative position of the plate causing doubling.

The easiest way to depict how doubling occurs is usually on a multi-color press. The actual misregister occurs as follows: The press sheet enters the first unit of the press and the first layer of ink is laid down. The press sheet then moves to the second unit of the press and the still wet ink of the first unit on the paper, transfers to the blanket of the second unit. When it is time for the next sheet to enter the second printing unit, this ink will be transferred back from the second blanket to the second sheet. This secondary transfer of ink is commonly known as print-back. It is important to understand that this problem of misregister of backtrapping is within a single color. If the two sheets are not in perfect register, a double image occurs, a strong one from the first unit and a weaker one

from the second unit: the end result is that the dot increases in size affecting color and contrast.

The Effect of Paper on Doubling

Paper is a major source of variability that is responsible for doubling. Paper-related problems that promote doubling on a sheetfed press are in the form of paper wrinkling. Wrinkled paper is paper that lacks flatness. Paper wrinkling can be caused by an imbalance of moisture in the paper. An example would be that of paper brought into the pressroom from a storage area having a different temperature and/or humidity level than that of the pressroom. Paper is usually susceptible to wrinkling when unwrapped and unprotected. The paper quickly releases or absorbs moisture as it adjusts to the new environment. This moisture adjustment takes place primarily around the edges of the unwrapped paper. This creates internal stress in the sheets that almost guarantees paper wrinkling. Moisture imbalance occurs between the protected areas deep inside the stack of paper and the unprotected outside edges of the sheets. Depending on whether paper is losing or gaining moisture, a tight-edged or wavy-edged condition develops in the sheet.[4] A tight-edged or wavy edged paper does not lie flat on any surface. This affects the way the paper will travel on the press. Sometimes a slight bulge or wave in the paper would cause the paper to touch the blanket prematurely resulting in a faint impression alongside the main impression dot. This is another cause of doubling.

Paper-related problems that promote doubling on a **web press** can best be understood by studying the paper travel. Paper does not flow but is drawn in the case of a web press. This creates a force in the web known as web tension. Controlling tension on a press is actually controlling conditions under which the paper is drawn through the press. This helps to minimize variability in flow behaviour in order to help maintain register.[5] Part of this control takes place at the infeed of a web press. The infeed is a section that extends from the roll of paper to the first printing unit. It contains a roll stand and a series of rollers that lead the web into the first unit. The infeed controls the speed, the tension and lateral position of the web before it reaches the first printing unit. For example, a

poorly set-up roll in the infeed can have consequences along the entire length of the press. Any sideways movement of the web (web weave) can cause a register change from one revolution to the next. This effect is circumferential. Web weave is considered as the source of the largest doubles observed in web-offset machinery.[6] In addition, rollers in the infeed have a tendency to glaze especially with the smooth steel rollers. The urethane rollers suffer the same displacement as that which occurs between the plate-blanket nip resulting in tension variations. Web tension has to be held constant and that can only occur if the steel rollers remain clean. Failure to do so will result in paper dust build-up on both the steel and urethane rollers. This will be seen in color variation on the paper due to the mechanical shifts.

Tension in a web is also affected by temperature fluctuations in the dryer. Tightening and loosening of the web as the temperature varies will consequently change register and cause doubling. Water pick-up by the web is another cause for tension variation between the units. This tension variation can also promote doubling.

Press Characteristics that Affect Doubling

Web and sheetfed presses share certain components in terms of press design. One of these components are bearers. Bearers are hardened steel rings found at the end of printing cylinder bodies, and are used on both sheet and web presses. The bearers of plate and blanket cylinders are in contact and supposedly facilitate smoother rolling between the cylinders. Bearers found on either sheet or web-fed presses are thought by some to be essential for high quality / high speed printing, but it is also true that many presses have been made without them and run quite successfully on similar kinds of work.[7]

External factors that further affect bearer performance can be the presence of a gum coating on the surface of the bearers while printing. Gum coating on bearers is caused by gum build-up as a result of cleaning the plate. The eventual deposit of gum coating on the bearers is hard and can cause enough pressure to cause a bump which forces the cylinders out of parallel and could eventually flatten a spot on the blanket. Doubling and Slur would result, depending on the job layout, and due to the absence of parallelism between the cylinders.[8] Doubling or Slur would probably not show up on all jobs, but

certain jobs would have color variation due to the wear and due to the cylinders being out of parallel.

The plate, blanket, and impression cylinders on an offset press are driven by gears and supported by bearers. Bearers are a common occurrence on web presses but not a common design characteristic on sheetfed presses. Sheetfed presses are mostly gear-driven. Even with the best gear drives, cylinders will vary minutely in speed and as the mesh of the gears move from tooth to tooth. Dot Gain (the percent of growth over original dot size) and directional dot gain (slur and doubling) are caused by actions within the nip areas of the cylinders. The nip areas are between the inking roller and plate, the plate and blanket, and finally between the blanket and paper .

The plate and blanket nip is considered to be the most critical. At the plate-blanket nip, friction between the two cylinders is reduced due to the lubricating action of the ink and water film. As the ink travels from plate to blanket and to paper, this same ink is split in half between the two surfaces. Less ink between the blanket and paper is a cause of more friction in that nip area. The resulting transfer occurring at the printing nip, the point at which the paper is actually taking ink, is so delicate that even a slight variation in speed can cause problems like gear streaking and doubling. The cylinder bearers help prevent these problems by smoothing out the drive through rolling friction. For maximum effect, they are preloaded, that is the cylinder bearers are brought together until there is substantial contact force between the bearers while the blanket is compressed to provide the printing pressure.[9]

The radius of the blanket cylinder is constantly changing as it goes through the plate-blanket nip, because the blanket is soft whereas the radius of the hard plate cylinder remains constant. Because of the change in the radius of the blanket cylinder, we can expect a change or a tendency to change of the surface speed of the blanket. This change in surface speed coupled with constant speed of the surface of the plate cylinder produces a situation in which printing problems such as slurring and doubling are likely to occur.

Such is not the case in the blanket to blanket nip on a perfecting press which prints

both sides of the paper in one pass. The radius of the two blanket cylinders in the printing nip are simultaneously changing in the nip area. This change is expected to produce a change in surface speed of the blankets. Whether the tendency is for the surface speed to increase or decrease is of little significance in that there will be a similar tendency on both sides of the nip. Whatever happens in the way of increasing or decreasing speed on the surface of the blankets, the elasticity of the paper will allow it to track the two blankets accurately by either stretching or contracting. This makes the blanket to blanket nip a very stable operation and printing problems are not expected to to arise there. Instead any problems involving the transfer of the image such as slurring and doubling are expected to occur in the plate to blanket nip.

Dr. A. Ghany Saleh found in his investigation into the causes of dot gain and its effect on color reproduction that the pressure in the NIP area between plate and blanket and blanket and substrate was an important variable. This pressure will result in an ink squash which contributes to the dot growth. Machine geometry or design and press conditions can induce other forms of dot gain or dot defects such as slur and doubling. Dot gain will ultimately be influenced by press configurations, cylinder diameter, number of gears, quality, dimensional stability, finishing and shape of the teeth, ink train, cooling system and the type of bearing in housing.[10]

The inking system on a press can be a major source of printing variations. It is important that ink transfer be consistent in order to ensure consistent color. Consistent ink transfer invariably involves proper roller settings, maintaining ink and water balance and the proper chemical condition of the rollers. Rollers in the inking system are normally set to one another and to the vibrator rollers. The ductor roller setting to the vibrator roller and the receiving drum is most crucial. During tests run by GATF on instrumented presses, where the ductor roller is set too hard against the vibrator, the load created by the acceleration of the ductor was enough to slow the unit down and create vibration and tension variations in the web before and after the printing unit involved. On a sheetfed press, any slight vibration that occurs on a press would automatically affect the plate. Printing problems associated with this problem of ductor shock include doubling and slur and streaks.

Ink and water are two other press variables that must be kept to a minimum to maintain ink and water balance. However, minimum water should be run without promoting piling on the ends of the rollers. Excessive amounts of water tend to be used on longer running jobs; however this can be detrimental to the process. As mentioned earlier, excessive amounts of water means a greater deposit of coating, sizing and fiber from the paper coating. This wetness on the paper can cause piling and manifest itself in a grainy print. In addition this water can accumulate on the inking rollers, vibrators, and distributors and can consequently promote slur and doubling.[11]

Blanket type and quality influence print quality. W. R. Grace & Co. U.S.A., a leading blanket manufacturer carried out tests of performance of blankets under varying packing conditions. Its studies revealed that dot gain and slur can be minimized by proper blanket packing and that compressible blankets can print well under a much wider range of packing than conventional blankets. Compressible blankets also have the added advantage of being compressed greatly at the nip while maintaining relatively light surface pressure resulting in low dot gain and slur.[12]

FOOTNOTES

CHAPTER TWO

[1]Porter, A.S., Lithographic Presswork. First Edition, Graphic Arts and Technical Foundation, 1980, p. 244.

[2]Ibid.

[3]Ibid.

[4]Anon., The Paper, Press or Blanket may Cause Cut Sheets to Wrinkle, American Printer, Vol. 211 No. 5, September 1988, pp. 102.

[5]Crouse, David B. Web Offset Press Operating. Second Edition Graphic Arts and Technical Foundation, 1984, p. 121.

[6]Treff, Ernest H. An Engineer's View of Dot Gain on a Web Offset Press. A Presentation made at the PIA Annual Meeting in San Francisco on May 10, 1988, p. 25.

[7]Tyma Louis S., Ingo Koebler and Herbert Stoeckle. Bearers -- A Necessary Evil? TAGA Annual Proceedings 1982, p. 402.

[8]Printing Industries of America Web Offset Section Meeting Proceedings: 1987 Web Offset Section Annual Meeting, p. 244.

[9]Ibid.

[10]Saleh, Abdel Ghany. The Analysis of the Dot Gain Problem and its Effect on Color Reproduction. TAGA Annual Proceedings 1984, p. 498.

[11]Ibid.

[12]Leslie, Geoffrey. Blankets and the Control of Dot Gain. Australasian Printer Magazine, Vol.38 No.10 November / December 1987, pp. 8.

CHAPTER THREE

REVIEW OF THE LITERATURE

A review of pertinent literature reveals that few studies of mechanical dot gain, particularly doubling have been undertaken. There have been indications in literature that control of mechanical dot gain through various measures has been attempted. However, before control is possible, a method of analysis and measurement of directional dot gain is needed.

Test targets are test images used to determine the quality of printing in the various reproduction stages. Some test targets are sensitive to dot gain and are capable of determining whether an increase in dot area is a result of directional or non-directional gain. Doubling is often confused with slur. Directional dot gain, whether doubling or slur, can cause a regular halftone tint to get darker and it may be hard to assign the real cause to either of the two. However if a test target is used that is sensitive to directional dot gain, it becomes easy to determine by visual means whether directional dot gain has occurred. One of the first papers published where the relation between directional and non-directional dot gain was studied was that by Warren Rhodes.[1] He designed a test pattern consisting of parallel line tints arranged side by side; one with horizontal parallel lines and the other with vertical parallel lines. This pattern allows visual and objective observation of *definition*; a term he used to describe sharpness of printing. He defined the term *resolution* as the ability of a system to resolve or discriminate between closely spaced elements. Resolution test objects perpendicular to the direction of sheet travel were affected by slur more than those oriented parallel to sheet travel. If directional dot gain exists, the two parts of the target will be affected differently and one will print darker than the other. This is a visual indication of slur and/or doubling. Furthermore, his objective method of evaluation was conducted with the use of measurements taken with a densitometer. This method allowed him to distinguish between directional and non-directional dot gain and to further assign numeric values to directional dot gain in

terms of densitometric measurements. The disadvantage of this test target was that it would not indicate a directional dot gain if it should occur at an angle of 45 degrees.

The LTF Star Target (or what is known today as the GATF Star Target) is an adaptation and refinement of a similar target that was developed in 1957 by Robert E. Wood of the Western Printing and Lithographing Company Plant in Racine Wisconsin. The WPL target consisted of a solid one-eighth inch diameter center surrounded by ninety pie shaped solid radial wedges. It is a visual indicator of mechanical dot gain; the center increases in diameter if ink-spread (fill-in) occurs and elongates or stretches at right angles to the slur direction if slur occurs.[2]

GATF designed the Star Target with only 36 wedges which resulted in a much smaller center. It proved to be a quick and effective measure of ink-spread, slur and doubling during a press run. The geometric properties of this arrangement makes its press sheet image sensitive to ink-spread, slur and doubling especially when stripped in the trim areas at each corner of the trailing edge of the press sheet. This is because these areas are usually the most affected by slur or doubling. Doubling will cause a figure 8 to appear in the centre of the star, while slurring will appear as an oval in the centre with elongations at right angles to the direction of sheet travel. The problem with this target is that it cannot be used to make densitometric measurements for dot gain because it is too small. Originally, it was designed for visual evaluation use.[3]

Figure 5. The GATF Star Target

The GATF Dot Gain Scale was another test target designed for inspecting and evaluating halftones visually and without the use of the densitometer. It also was a good indicator of change in dot size at the various reproduction stages whether in the contact printing of negative or positive in platemaking, proofing or in printing. The design of the

dot gain scale is based on the principle that tints made with fine screens are much sensitive to changes in dot area than are coarse screens. It consisted of ten numerical steps, starting from 0 to 9. These numerical numbers were made with a 200-line screen while the background was of a coarser screen of 65 line. During the reproduction stage, if a number has the same density as the background, it would be an indicator of a numeric amount of gain. While these numbers are sensitive to directional and non-directional dot gain, there is also a parallel-line type section which indicates directional dot gain.

This parallel line section is known as the Slur Gauge. It consists of a bar of vertical line background, and a series of horizontal lines which form the word SLUR. The lines have the same value, so the word SLUR is invisible when all lines are printed with equal thickness. But if slur occurs, the horizontal lines thicken and the word SLUR shows up as darker or lighter than the background.

Figure 6. The GATF Dot Gain Scale and Slur Gauge

GATF proceeded to design another test target later to be known as the Ladder Target. The Ladder Target was designed to show gripper-to tail variation in the various reproduction stages. Primarily it was designed to give a qualitative measure by visual inspection, but numerical measures of slur and doubling could be obtained by taking densitometric measurements in certain areas. The target was three-quarters of an inch wide and twenty-five inches long. The center portion consisted of a 50% percent horizontal line screen. The two outer strips are the same except that the lines run vertically. Slur and doubling are measured quantitatively as the difference between the two neighboring areas. The Ladder target is very sensitive to directional dot gain and manifests itself by a perceptible darkening of the center of the target in the direction of printing. Doubling can also cause the center of the target to darken if the doubling was occuring in the printing direction. If the doubling was occurring sideways, the sides of the target will be darkened. This target had the same disadvantage as the parallel line tint target in that it was incapable

of showing any directional image displacement if it should occur at angles of 45 degrees. Therefore a later version of this target also included a bar with lines at a 45° angle.[5]

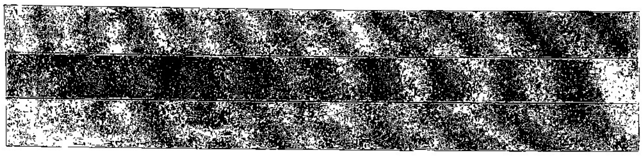


Figure 7. The GATF Ladder Target

The UGRA Plate Wedge is another target that can test for directional dot gain. Since its conception in 1962, the target has under gone some changes. The 1976 version of the UGRA-Scale target consists of five elements namely a continous tone gray scale, a 60 and 120 line, a halftone step wedge, circular patches used as resolution targets, a line patch and a slur target.[6] The slur target is used to test for directional dot gain. It consists of concentric circles whose distance is equivalent to their width (50% area). It is used to observe slur and doubling on the press. This target was an actual refinement of the parallel line tint target because it will show directional dot gain at any angle. Slur would manifest itself as a spreading of lines running across the printing direction; lines running parallel to the printing direction are not affected. Slur is indicated by two dark segments parallel with the printing direction. Doubling also manifests itself visually as dark segments as in the case of slur.[7] However these segments could be in any direction and there can be 2 or more segments depending on the severity of misregister. Neither parallel line tints nor concentric circles can distinguish between slur and doubling though they serve the same purpose of indicating directional dot gain.

Test Targets such as Gretag, RIT Color Control Bars and the Kodak Customized Color Target use a test patch comprised of concentric circles. Generally, their disadvantage lies in the fact that they could only give qualitative or visual indication of directional dot gain and do not lend themselves to numerical analysis because of their small size.

FOOTNOTES

CHAPTER THREE

[1]Rhodes, Warren L., Study of Objective methods for Evaluating Sharpness in Lithography TAGA Proceedings 1955, p.109

[2]Jorgensen, George W., The GATF Star Target for Inkspread and Resolution Measurements, Research Progress Report No. 52, February 1961, Graphic Arts Technical Foundation, Pittsburgh, PA.

[3]Anon., GATF Scales Detect Dot Gain, Canadian Printer and Publisher, April 1986, p. 37

[4]Ibid.

[5]Hull, Harry H., The GATF Ladder Target - A New Test Image, Graphic Arts Technical Foundation Research Progress Report # 99, October 1973

[6]Sigg, Franz. A few things about Microlines that most people do not know, TAGA Proceedings 1988, p. 434

[7]UGRA - GRETAG Plate Control Wedge PCW: Technical Description

CHAPTER FOUR

HYPOTHESES

1. The dot area difference between the dark and light segment on the Experimental RIT Doubling Target is not significant when 12 mil packing is added to the blanket while simultaneously removing the same amount from the plate packing.

2. There is no statistically significant relationship between the direction of doubling and the magnitude of doubling.

3. There is no difference between Dot gain measured on the 50% tint of the Experimental RIT Doubling Target and the average dot gain calculated from the dot gain readings of the light and dark segments on the concentric circles.

CHAPTER FIVE

DESIGN OF THE EXPERIMENTAL RIT DOUBLING TEST TARGET

Design of the Target

The RIT Doubling Target is 1 1/4" inches square in area. The major part of the target is covered by a series of concentric circles. At the corners are located four 5mm square patches that consist of:

1. 3% dot patch used to observe the effect of doubling on small dots
2. Solid patch used to indicate ink-film thickness in order to calculate dot gain
3. 50% tint to correlate between the average of light and dark area values of the concentric circles and the 50% tint
4. A clear patch to zero out the densitometer.

In each half of the circumference of the circle, a scale, indicating angles from 0 to 180 of directional dot gain is available to facilitate labeling the direction of directional dot gain.

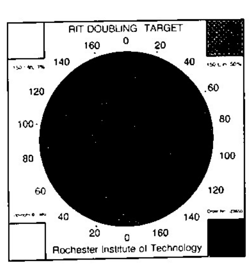


Figure 8. The RIT Experimental Doubling Target

Aspects of new design as compared to the parallel line tint :

It was made into circles allowing it to be sensitive to all directions.

Its large size allows one to take minimum and maximum measurements in the lightest and darkest segments within the patch with a normal densitometer.

Its use of the Murray Davies equation allowing it to obtain values for directional gain as opposed to the use of visual evaluation methods or density measurements.

Small dots may make it easier to differentiate between slur and doubling.

Characteristics of the concentric circles design:

The basic advantage of the new design is the large size of the concentric circles. This enables one to make dot area measurements at the light and dark segments which gives an indication of directional and non-directional dot gain. Moreover the design of the concentric circles is an advantage in that it solves the problem of directional dot gain occurring at 45 degrees which was impossible to take care of with parallel line tints.

The principle of measuring dot gain in this fashion is not in question and using Murray Davies is simply an existing method for this specific application. Where the circle is lightest, there is no directional dot gain because the darkening of the line falls on top of itself indicating no directional dot gain. The actual reading would only indicate fill-in and optical dot-gain. At the darkest spot, we measure the worst possible case of directional dot gain as well as fill-in and optical dot gain. Hence the difference between the light and dark segments is due to the contribution of directional dot gain.

Problems with the method:

If doubling should occur over several printing units, there may be a complex moire pattern that has not only one minimum and maximum section. This may make it impossible to measure. This is, however, a problem for all doubling measurements, and not just only of this method.

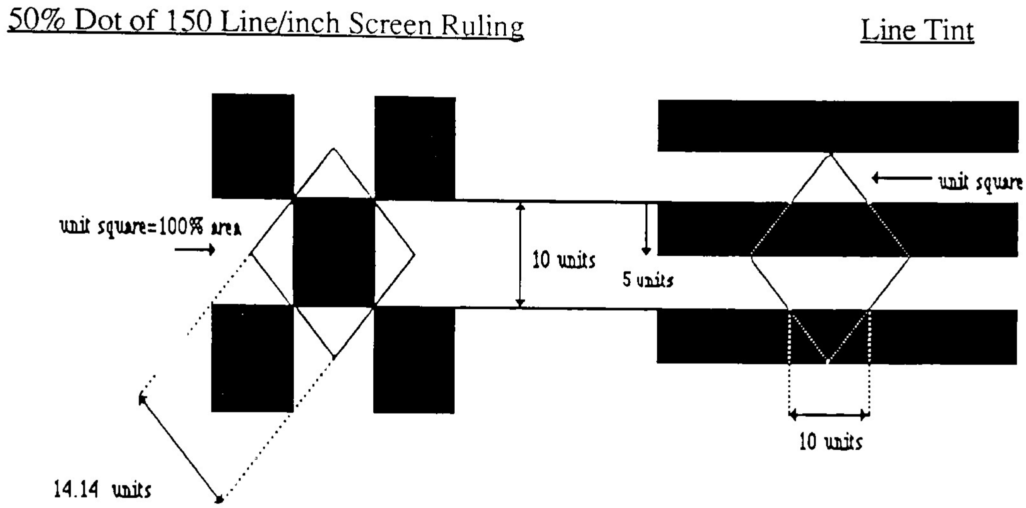
A problem arises in that doubling is a complex phenomenon. It is unpredictable and can not only occur in one direction on one printing unit but in a different direction on another printing unit. Furthermore, the color printed on the last printing unit on a press, normally does not have any doubling of dots, since no more printing units for it to go through, exist.

It was previously stated there is the possibility of having slur on top of doubling and both of them can occur in different directions. In order for this method to work, we therefore need to rely on simplified assumptions which are:

1. Slur is not considered much of a problem; packing has to be off by a sizable amount before slur occurs.
2. Doubling occurs more at the first and second units following the original impression than between the second and third units. The farther away the sheet is from the original impression, the weaker will be the print-back and therefore the doubling and the effect of doubling. The ink at this point is diluted and weak and would not contribute greatly to the problem.

Screen Ruling:

1) What screen ruling should be used for making the concentric circle in order to obtain, on the average, the approximate same value of dot gain as would be obtained on a 150 line/inch 50% dot tint ?
2) How is dot gain a function of the doubling angle for a dot tint and a line tint ?



100% Dot Area = (14.14 units)^2= 200 Units^2 = Unit Square
50% Dot Area = (10.0 units)^2 = 100 Units^2= 50% Dot

Figure 9. 50% Dot and Line Tint

If we chose the geometric relationships between dot and line screens such that both show the same area increase for a double that occurs at 45° angle, then the relationship of figure (9) results. Note that the dot screen is shown at a 45° angle. Under these conditions, the screen ruling for the line tint has to be 1.41 times finer than for the dot tint. In other words the equivalent screen ruling for a 150 lines/inch dot halftone is a line tint with 150 x 1.414 = 212 lines/inch screenruling.

Below is a diagram of two sine functions that indicates the percent area change due to doubling. In other words, if a double is a function of a certain direction (or angle), we can calculate the expected % change in area for both the dot and line tint. Tables 1 and 2 are the calculations that were used to illustrate graphically the sine functions for both the dot and line tint. The average for both sine functions happens to be almost identical.

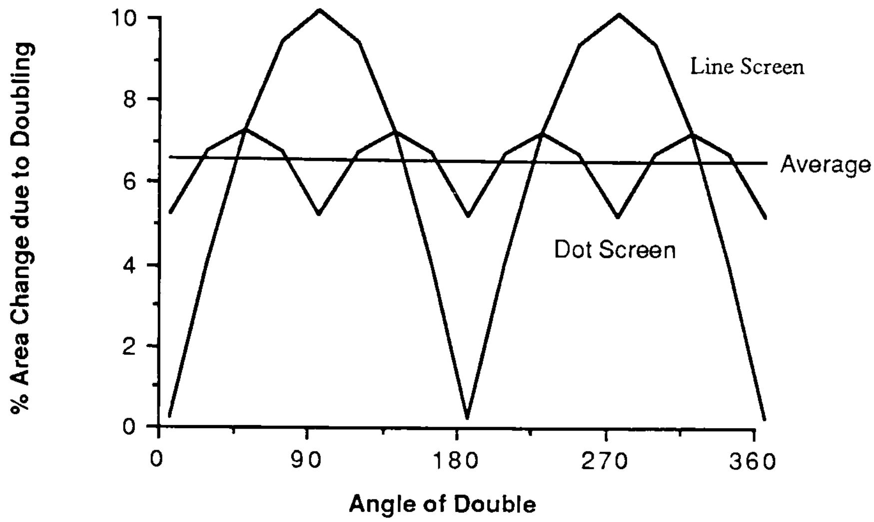


Figure 10. Plot of % Area Change due to Doubling Angle for a 50% Dot and Line Tint

Table 1. Percent Dot Area Increase due to Doubling of 1 Unit at Various Angles

Dot Screen

Percent Increase in Dot Area due to Doubling Angle		Doubling Angle
$1*10*(\sin(0^o) + \cos(0^o)) = 10$ units^2	= 5% area	double 0°
$1*10*(\sin(22.5^o) + \cos(22.5^o)) = 13.06$ units^2	= 6.533%	double 22.5°
$1*10*(\sin(45^o) + \cos(45^o)) = 14.14$ units^2	= 7.07%	double 45°
$1*10*(\sin(67.5^o) + \cos(67.5^o)) = 13.06$ units^2	= 6.533%	double 67.5°
$1*10*(\sin(90^o) + \cos(90^o)) = 10$ units^2	= 5%	double 90°

Line Screen

Percent Increase in Line Area due to Doubling Angle		**Doubling Angle**
2*10*1*sin(0°) = 0 units	= 0% area	double 0°
2*10*1*sin (22.5°) = 7.65 units	= 3.837%	double 22.5°
2*10*1*sin (45°) = 14.14 units	= 7.07%	double 45°
2*10*1*sin (67.5°) = 18.48 units	= 9.24%	double 67.5°
2*10*1*sin(90°) = 20 units	= 10%	double 90°

The average of a half sine curve is defined by the equation: 1/2*π*amplitude

Dot Screen = (2*2.07)/π = 1.317 : 1.317 + 5.00 = 6.317 % which represents the average value of the dot screen
Line Screen = (2*10)/π = 6.366% which is the average value of the line screen

CHAPTER SIX

METHODOLOGY

The analysis procedures utilized in this experiment were chosen to fulfill the following tasks:

1. To show whether slur is a major part of directional dot gain
2. To understand whether the doubling magnitude is a function of the doubling angle
3. To determine whether register variation on the two dimensions of the web (circumferentially and laterally) is related to the problem of doubling.
4. To examine whether a relationship exists between the concentric circles and the 50% tint and determine if the concentric circles can be used to represent a 50% tint in terms of non-directional dot gain.

The First Experiment:

In order to study the effect of slur, we can purposely produce it by removing the packing from the plate and replacing it underneath the blanket. This will result in a change in diameter in both the plate and blanket cylinder. The plate cylinder diameter was reduced by .3mm of packing and the blanket cylinder was reduced by the same amount. A condition as such would theoretically create slur. The Experimental RIT Doubling Test Target was used to visually verify whether slur had occurred.

The Second Experiment:

Since it was suspected that the automatic web alignment mechanism might cause doubling and registration problems, two web press runs were carried out with the following two conditions:

Conditions:

1- Web Aligner and Register Control were on automatic.

2- Web Aligner and Register Control were turned off.

A web-steering device known as the tilt box is found basically at two locations on a press namely at the infeed controls and before the folders. This mechanism is responsible for the sideways placement of the web through the printing units and the folders. Running two tests where the tilt box was activated and deactivated would permit studying its effect on register and doubling. Two test targets sensitive to register variations were used to visually detect and measure any register fluctuations. One was positioned horizontally and the other vertically on the test form.

Several test targets sensitive to dot gain were incorporated in the layout of the test form. They were used as a visual reference for comparison between the new test target and the common ones in use. The color sequence that was run on the press was black, cyan, magenta and yellow. Yellow being the color on the last unit was run with a blank plate because it was felt that it would not throw any light on doubling since the last unit on the press suffers the least or no doubling.

Once makeready was complete and the required density levels were attained, 1000 consecutive sheets were taken off the stacker and numbered in proper sequence. The two press runs were given code numbers 1 and 2 signifying the above mentioned conditions. Magenta and black were the two units studied for doubling since they represent the extreme cases on the press. Black being the first unit is expected to have more doubling than magenta. Cyan was not analysed because it was assumed that its response will be intermediate between black and magenta.

Two visual readings were taken from the RIT Visual Registration Scale target. One reading was for lateral register and the second was for circumferential register. The remainder of readings were taken off the RIT Doubling Target. One was a visual reading of the angle of the double. The densitometric readings were taken with a GRETAG D186 densitometer which was interfaced to a computer where the data was accumulated. The

following patches were read: the solid patch, the 50% patch and the dark and light segments in the concentric circles. It is important to note that the same targets at the same location on the press sheet was used in the collection of data.

Measurement of Vertical and Horizontal Register

The terms vertical and horizontal register signify circumferential and lateral register variations on the two dimensions on the web. Sideways movement of the web caused by the web alignment and the automatic register system can result in register variations. Two RIT Visual Registration Scale targets were incorporated into the design of the test form to relate these two variables magnitude of doubling. One target was positioned in the direction of web travel in order to indicate any circumferential variation that might occur, and the other was positioned perpendicular to web travel to show any lateral or sideways change in register. Another additional variable was calculated from the values obtained from circumferential and lateral measurement and was indicated as Magnitude of Misregistration. This variable is defined by the equation:

$$\text{Magnitude of Misregister} = \sqrt{(V_{reg} - V_{ave})^2 + (H_{reg} - H_{ave})^2}$$

V_{reg}: Vertical or Circumferential Register Variation

Vave: Average or mean value of Vertical or Circumferential Register Variation

H_{reg}: Horizontal or Lateral Register Variation

H_{ave}: Average or mean value of Horizontal or Lateral Register Variation

Hypothesis 2 was an attempt at relating the magnitude of Doubling to the corresponding doubling angle simultaneously taken from the same target. However, the process of trying to relate these two variables did not end at this point. It was felt that relating magnitude of doubling to vertical and horizontal register changes would provide some additional information that could be of noteworthy interest. Furthermore the register

angle derived from the two coordinates, vertical and horizontal register can also be studied in relation to magnitude of misregister. The value for magnitude of misregister can be calculated from the two variables vertical and horiontal register variation. The register angle and magnitude of misregister would define the two coordinates on a polar system of coordinates.

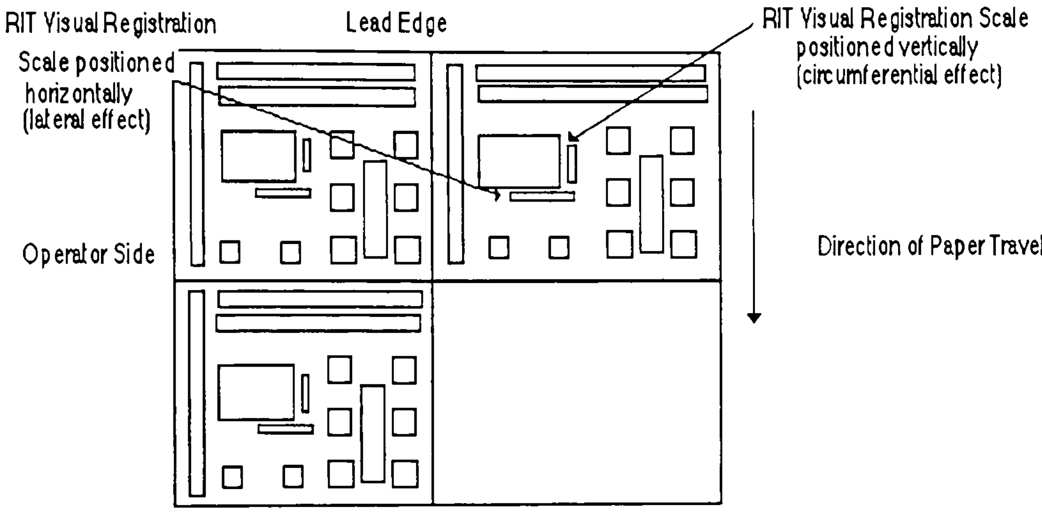


Figure 11. Layout of Test Form used on Web-Press Run

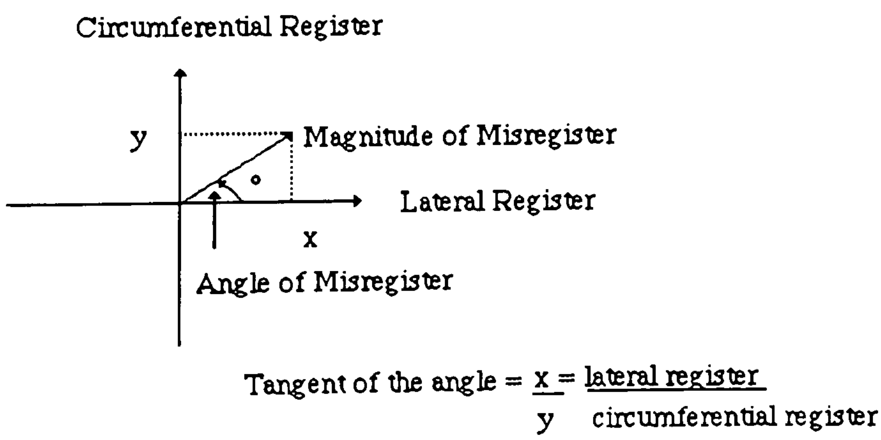


Figure 12. Plot of Vertical and Horizontal Register on a Cartesian System of Coordinates

Determination of doubling angle

A degree of uncertainty was noted when trying to read the value for doubling angle off the doubling target:

1. It was felt that reading the doubling angle off the target did not need to exceed an accuracy of ± 5 10° degrees.
2. Because there are two segments, there is a symmetry of 180° rather than 360°. Therefore an angle of 0° degrees corresponds or is the same as an angle of 180°.
3. In addition, if there was no moire or specifically no directional dot gain that was evident on the target, it was impossible to assign a doubling angle. We chose in such a situation to give it a value of zero.

Analysis:

A special program written in BASIC language was used to collect the numeric data that was taken visually and densitometrically. The Statistical Method of Analysis used to test Hypotheses 2 and 3 were:

1) Regression and Correlation Analysis in order to develop a linear equation relating the two variables, namely Doubling and Doubling Angle and 50% Dot Tint and 50% Line Tint (concentric circle). It is important to point out that this method of analysis does not imply the establishment of a cause-and-effect relationship between the two variables.

2) The Pearson Product Moment Correlation Coefficient r was used to investigate the nature of the relationship between the two variables. Values for r were defined between -1 and +1. A value of +1 indicates that x and y are perfectly related in a positive linear sense meaning that all the points in the scatter diagram lie on a straight line with a positive slope. A value of -1 indicates that the two variables are perfectly related in a negative sense. An r value close to zero indicates that x and y are not linearly related.

3) A t test was used to test for a significant relationship between the dependent variable and the independent variables. The critical value for a two-tailed t distribution for a sample size of 500 and a confidence level of 99% equals 2.58. Any t-value in the experiment above 2.58 was considered a statistically significant relationship.

4) Graphical Representation was carried out using the Macintosh Cricket Graph software. All calculations and computations were done using the Minitab Statistical Computing System.

Test for Significance:

In the statistical analysis of this study, the regression equation relating any two variables that were studied was obtained. The regression equation is

$E(y) = \beta_0 + \beta_1 x$ where $E(y)$ = mean value of y for a given value of x; β_o =y-intercept of the regression line and β_1 = slope of the regression line.

The estimated regression equation was obtained and it is represented by the following equation: $y = b_0 + b_1 x$

If a relationship exists between x and y, the coefficient $\beta_1 x$ should differ from zero.

A conclusion regarding the significance of the regression relationship can be tested using the following hypothesis:

$H_0: \beta_1 = 0$

$H_1: \beta_1 \neq 0$

One of the properties for the sampling distribution for b_1 is that

Mean: $E(b_1) = \beta_1$[1]

The **t test** regarding $\beta_1 = b_1 - \beta_1 / s_{b1}$ has a t distribution with n-1 degrees of freedom (n representing the sample size and n-1 representing the degrees of freedom).

By looking under a t distribution table, a value for t corresponding to a level of confidence of 99% and (n - 1) degrees of freedom is obtained. If this t value is less than the calculated value $\beta_1 = b_1 \;\; \beta_1 / s_{b1}$, then the null hypothesis will be rejected and one can conclude that there is a significant relationship between the two variables. (s_{b1} is the standard deviation of the coefficient x)

FOOTNOTES

CHAPTER SIX

[1]David R. Anderson, Dennis J. Sweeney, Thomas A. Williams. Statistics Concepts and Applications, Second Edition. West Publishing Company: St. Paul, 1986. pp.525-527

CHAPTER SEVEN

RESULTS

First Hypothesis

Visual examination of the target revealed that no slur or doubling had occurred. There was no moire indicative of the phenomenon, however there was the expected change in the print length of the image as a result of the shift in packing from the plate to the blanket (Refer to chapter 2 under slur). The image printed longer because of the decrease in plate diameter. What is of importance in a situation like this is that a change in print length is expected to happen but not that of slur. The Null Hypothesis was accepted due to the obtained results.

Second Hypothesis

There was no strong correlation between magnitude of doubling and doubling angle. This was obvious from the low values for the correlation coefficient for both black and magenta. The values obtained from the **t test** however signified that there was a significant relationship between the two variables. This significant relationship is an indication that we are 99% sure that the variables involved for the test for the correlation did not occur by chance.

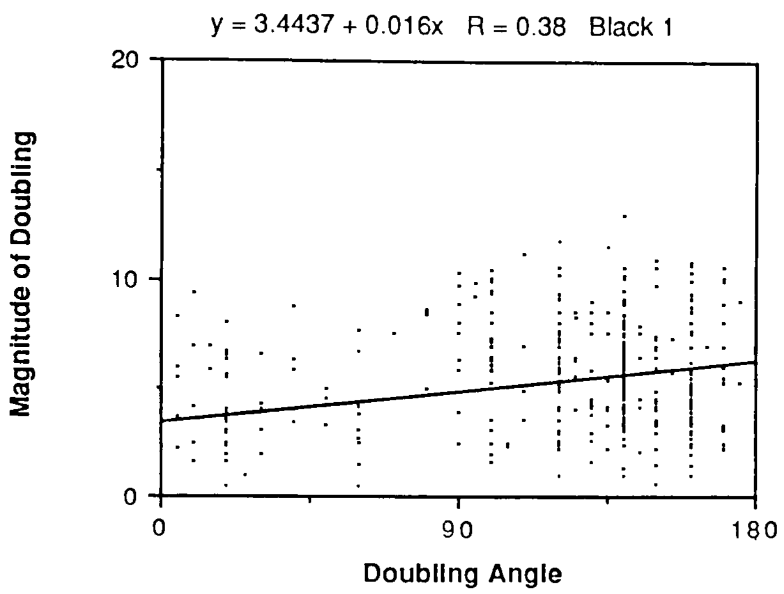
Table 2. Table of **r** and **t** values for Magnitude of Doubling versus Doubling Angle

	Magnitude of Doubling			
	Black 1	**Magenta 1**	**Black 2**	**Magenta 2**
r Doubling Angle	.38	.46	.43	.49
t Doubling Angle	9.17	11.65	10.59	12.58
significance at alpha level of	.99	.99	.99	.99

What was interesting to note in the graphical analysis, was that a relationship can be shown to exist between the two variables magnitude of doubling and doubling angle by simple observation of the polar plots. One of the features of the scatter and polar plots as shown in figures (13 and 14) and (15) was the orientation of the points. There appeared to be a preferred angle for both colors black and magenta. In the case of black for conditions 1 and 2, the preferred angle was within the range of 120 - 160 degrees. Magenta for conditions 1 and 2 had a preferred angle between 60 and 120 degrees. Magenta had a distinct feature in that the preferred doubling angle was in the orientation of paper travel. This probably indicates that sideways lateral register variation (sideways lateral paper movement) does not effect the problem of doubling as much as the vertical or circumferential register variation on the web. A probable explanation can be the affect of web tension, that can ultimately affect paper performance thereby exaggerating the doubling problem. The t test also provided further information that 99% of the variables involved for the test of correlation did not occur by chance. Based on the graphical representation and the results of the t test, one can arrive at the conclusion that there exists a relationship between magnitude of doubling and doubling angle. The results allow us in turn to reject the null hypothesis.

Third Hypothesis

There was a strong correlation between dot gain measured on the 50% tint made with a 150 line screen-ruling and dot gain measured on the concentric circles. This was indicated by the values for the correlation coefficient **r** for conditions (1) and (2) on the press for both colors black and magenta (refer to figures (16 and 17). The values were .84 and .79 for black and magenta in condition (1) and .91 and .88 for conditon (2). Furthermore, the t test indicated that a significant relationship exists between the two values for dot gain in that 99% of the variables involved for the test for the correlation did not occur by chance. Hence the null hypothesis was rejected.



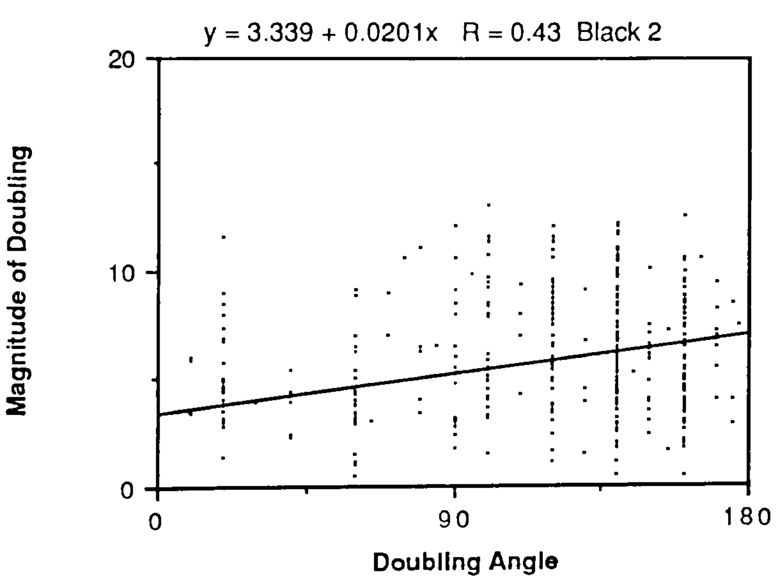
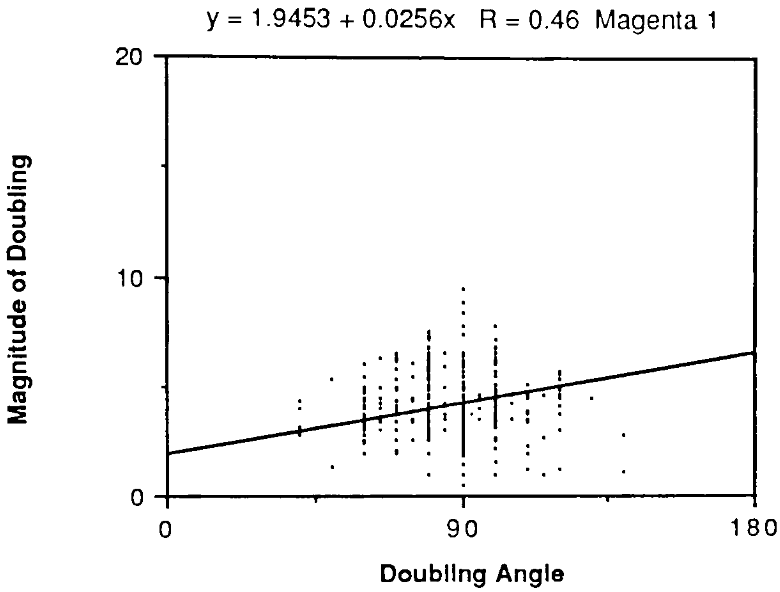


Figure 13. Scatter Diagram and Straight Line Approximation between Magnitude of Doubling and Doubling Angle for Black 1 and 2



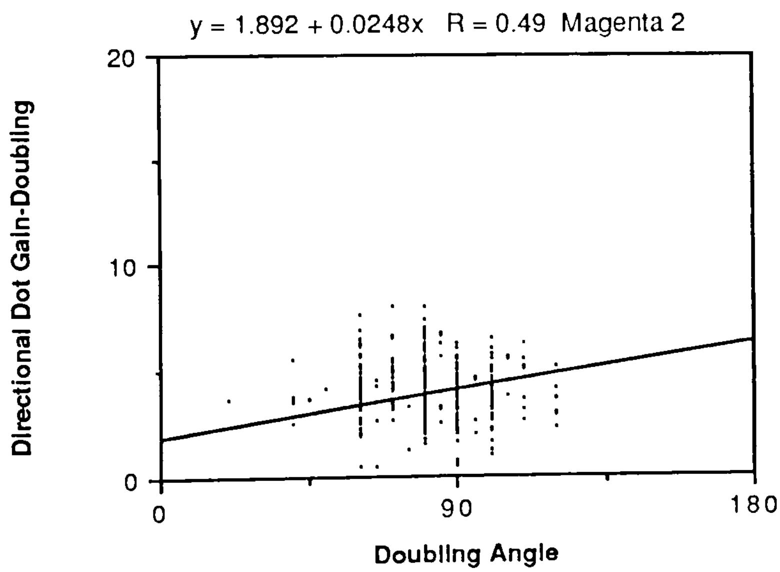
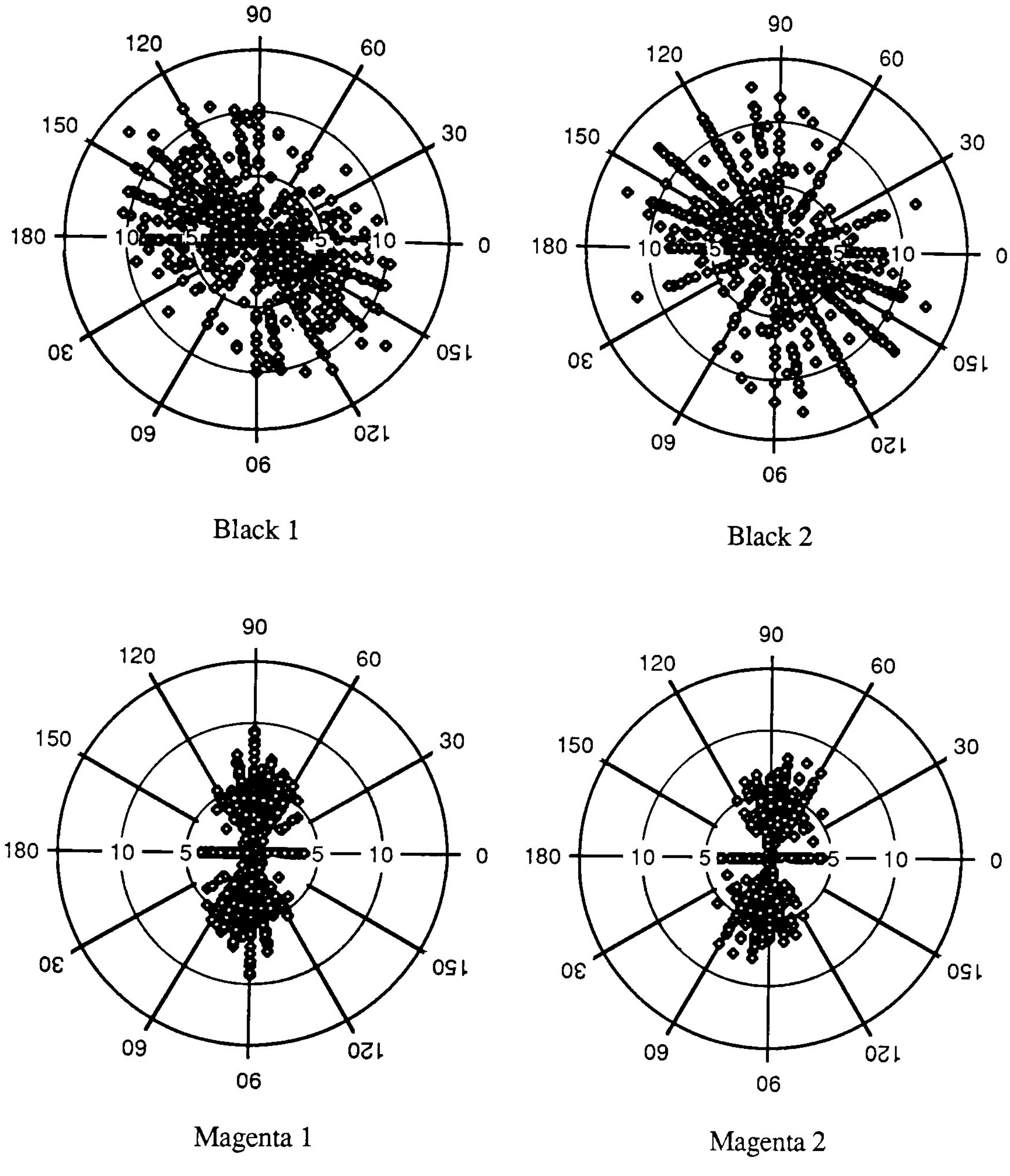
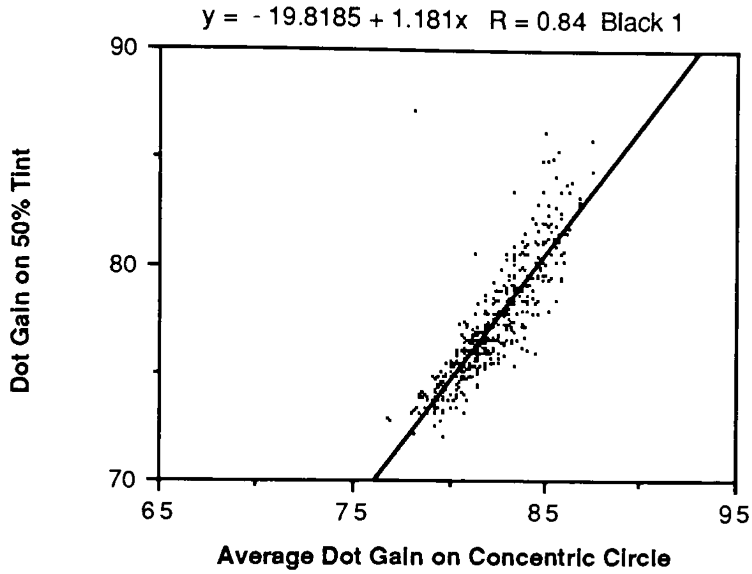


Figure 14. Scatter Diagram and Straight Line Approximation between Magnitude of Doubling and Doubling Angle for Magenta 1 and 2



The distance from the center indicates the magnitude of doubling in % dot area.
Direction of paper travel is at 90 degrees.

Figure 15. Polar Graphs of Doubling for Black and Magenta 1 and 2



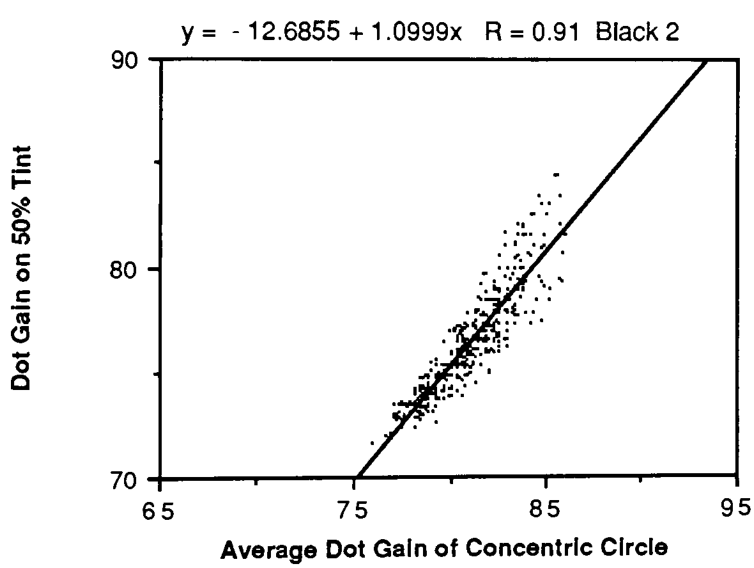
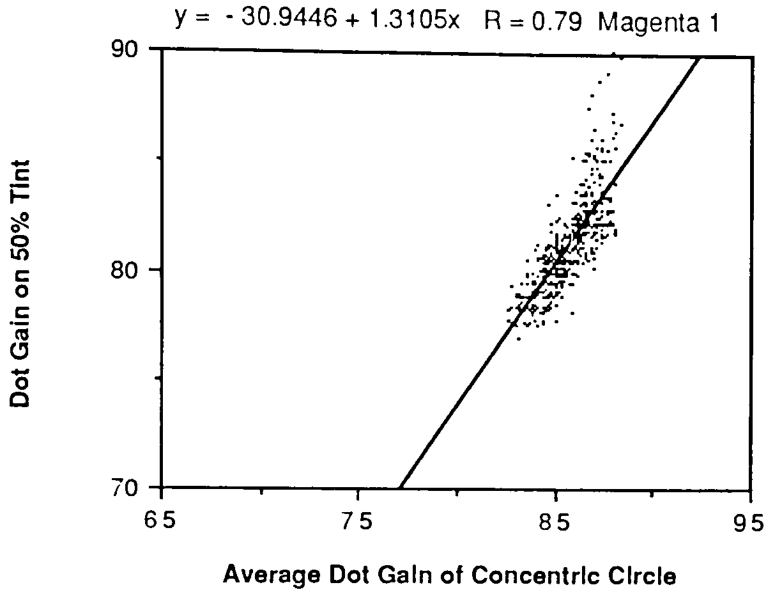


Figure 16. Scatter Diagram and Straight Line Approximation between Dot Gain on 50% Tint and Average Dot Gain on Concentric Circles for Black 1 and 2



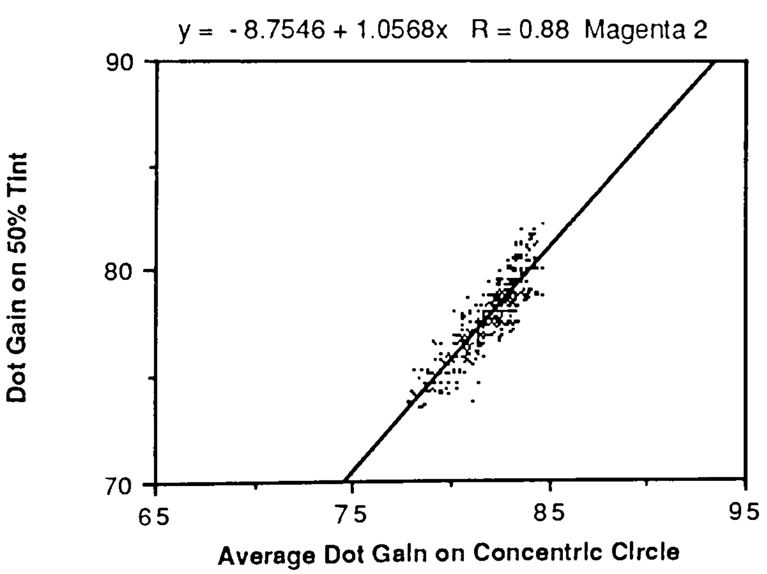


Figure 17. Scatter Diagram and Straight Line Approximation between Dot Gain on 50% Tint and Average Dot Gain on Concentric Circles for Magenta 1 and 2

Table 3. Table of **r** and **t** values for Dot Gain on 50% tint versus Average Dot Gain on Concentric Circles

	Dot Gain on 50% Tint			
	Black 1	**Magenta 1**	**Black 2**	**Magenta 2**
r Ave. Dot Gain on Concentric Circles	.84	.79	.91	.88
t Ave. Dot Gain on Concentric Circles	34.28	28.83	47.48	40.78
significance at alpha level of	.99	.99	.99	.99

Further Observations

The Black unit had a higher value for doubling than Magenta under both conditions (1) and (2). Black being the first unit is expected to double more than Magenta. Magenta being the last unit printed on had a lower value for doubling. This was observed from the mean values for Magenta and Black in the analysis.

Table 4. Mean Value and Standard Deviation for Magnitude of Doubling and 50% Tint

	Doubling		**50% Tint**				
	Mean	St.Dev	Mean	St.Dev.	Min.	Max.	Dot Gain
Black 1	4.93	2.68	77.27	2.82	61.7	92.9	27.3
Magenta 1	3.86	1.70	81.08	2.13	76.9	90.1	31.1
Black 2	5.13	2.95	76.39	2.39	71.5	84.4	26.4
Magenta 2	3.63	1.62	77.91	1.72	73.5	82.2	27.9

The test run under both conditions where the web alignment and automatic register system was activated and deactivated did result in a statistically significant difference in magnitude of doubling and the mean value for dot gain on the 50% tint for both conditions. The mean value of the magnitude of doubling for black was slightly higher under condition 2 than it was for condition 1, while the reverse was true for the mean value of dot gain for the 50% tint. In the case of magenta, the mean values obtained for magnitude of doubling and dot gain were slightly less under condition 2 than under condition 1. Even though these differences are statistically significant, a 0.2% area difference due to doubling has simply no practical significance.

All tests showed average dot gain within the SWOP specifications of 24 $\pm$ 4% except Magenta 2 which had an average dot gain of 31%.

Table 5. Table of **r** and **t** values between Magnitude of Doubling and Lateral-Circumferential Register

		Magnitude of Doubling			
		Black 1	**Magenta 1**	**Black 2**	**Magenta 2**
r	Lateral Register	.04	.19	.04	-.03
	Circumferential Register	-.02	.16	-.14	.17
t	Lateral Register	.89	4.54	.88	-.73
	Circumferential Register	-.45	3.71	-3.10	3.95
significance at alpha level of		no	.99	no	no
		no	.99	no	.99

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND OBSERVATIONS

Two main hypotheses were tested in this experiment. The first hypothesis was if doubling occurs, does it necessarily occur in a preferred direction. After analyzing the data to try and indicate whether a relationship exists between the two variables, the results obtained from the correlation coefficient r showed that doubling angle showed no correlation to the magnitude of doubling. This means that generally, smaller values of doubling are not associated with different angles than larger values of doubling. However the scatter and polar plots indicated that for both black and magenta, there was a preferred range of doubling angles. Reading the doubling angle off the target was not an accurate procedure and an element of uncertainty was evident in the readings.

The second hypothesis was a test of the target's usefulness and to further determine whether the target is capable of representing a 50% tint in terms of dot gain. The original intent in the design of the concentric circles was that it should indicate non-directional dot gain similar to what happens on a 50% dot pattern. The target permits separate measurement of directional and non-directional dot gain. The reading is important in that it throws light on what total portion of total dot gain is due to the directional part of the overall dot gain value. One of the drawbacks of this method and of the target in general, is that one can only take measurements manually and not with a scanning densitometer. One has to visually determine the light and dark segment on the concentric circles before attempting to take actual readings with the densitometer. A smart densitometer could overcome this problem if it was programmed to take readings at specified locations on the concentric circle. The resulting values can be calculated to provide the numeric values for directional and non-directional dot gain. Targets similar in design to the Kodak Customized Color target make it easier to use a scanning densitometer for long press runs where many readings are required.

The concentric circles were made with the intent of simulating a 50% tint of 150 line screen-ruling as far as non-directional dot gain is concerned. The values for dot gain on the concentric circles and the 50% tint did not however match. A strong and significant correlation was indicated in the values obtained for the correlation coefficient **r**. However the value for dot gain on the concentric circles was higher than that of the tint. Further studies are still needed to account for this discrepancy especially if the error cannot be attributed to screen-ruling.

Other observations drawn from this experiment:

The Experimental RIT Doubling Target was found to be a sensitive target in its configuration and design to directional dot gain. The components of the target lend themselves to visual and numerical evaluations of dot gain. Primarily, it was designed to test for all the aspects of mechanical dot gain, directional and non-directional. Numerical values for the latter and the former are possible through the use of densitometric readings from the dark and light segments of the concentric circles. The original intent of having a 3% tint was for visual identification of the particular kind of directional dot gain, be it slur or doubling. The 3% highlight dot was probably not the best size to visually identify directional dot gain. This is due, in part, because these small size dots tend to get lost in the roughness of the paper. It takes more than a loop of 10x magnification to observe it. During the press run of the second experiment, it was evident on some of the press sheets that a double dot exists. An improvement on the target that could aid in visuallizing directional dot gain more distinctively would be having several highlight dots made preferably within a range of 2% to 6% in order to visually distinguish a double dot when it occurs.

An observation was noted in the value obtained for magnitude of doubling on the press sheets. As mentioned earlier the magnitude of doubling was calculated as a difference in dot area of the two segments on the concentric circles. This was carried out

with the use of the Murray-Davies Equation. The value for doubling on every second revolution of the plate for the impression of the blanket, was found to be significantly higher than the value obtained on the first revolution of the plate. This variation is possibly due to the slack that paper undergoes at the second impression of the plate and the blanket because of the plate-gap blanket nip. The blanket could experience a slackness as it goes through the gap area of the plate, which might result in a momentary decrease in web tension. This slackness in paper tensioning potentially could cause register variation, or doubling.

The RIT Doubling Target can be used as a visual and quantitative measure of the two aspects of Mechanical Dot Gain namely Directional and Non-Directional Dot Gain. Applications of the target can be directed towards press checks before they are placed in operation or routine checks on older presses. This applies to production sheet-fed presses and web-presses. It can also be used to detect any slur or doubling on proof sheets, before the actual production sheets are run.

In conclusion, even though there are some weaknesses to the target, it is a useful tool to quantitatively and qualitatively determine directional and non-directional dot gain.

CHAPTER NINE

RECOMMENDATIONS FOR FURTHER STUDY

The following is a list of recommendations that would prove useful in understanding the target's capabilities, that were not covered in this study.

1. The test runs that were carried out in this study were done on presses that did not necessarily represent the conditions of presses out in industry. Doubling was studied in relation to paper and register effect. It needs to be added that equipment wear is also a major contributor to the problem of doubling. The presses that were used are in good condition and therefore tended to minimize the problem. Implementing the slur and doubling experiment on industry presses to test whether equipment wear is a contributor could prove to be a useful study.

2. The data for Cyan (being the second unit on the press) could also be studied in order to test its relevance to the problem of doubling.

3. The web press run actually included two other conditions in addition to the two outlined in this study. The third and fourth conditions were situations where the web aligner was on manual while the register control system was on automatic and the fourth condition was the opposite. A study of these conditions and their effect on doubling could throw additional light on the problem of doubling.

4. The second experiment that was carried out in this study should be carried out on another web press in order to determine whether the preferred angle for black (being the first unit) and magenta (being the third unit) would match the results

for the preferred angle found in in this study. Furthermore, it would be interesting to find out why the preferred doubling angle differs from one unit to another.

5. The relationship between magnitude of misregister and misregister angle was not analyzed in this study. The magnitude of misregister and misregister angle are two values that can be derived from the values of vertical and horizontal register variation. This relationship could be studied and compared with that relationship of magnitude of doubling and doubling angle. (Please refer to chapter 5.)

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APPENDIX A

CALCULATION OF THE CHANGE IN PRINT LENGTH CAUSED BY A CHANGE IN PACKING

Notations:

1 micron = 10^{-6}m = .001mm

120 microns is the side length of a 50% square dot of 150 line screen-ruling

120 microns = .12 mm

Diameter of plate and blanket = 220 mm (Heidelberg specifications)

Change in packing = .012" = .3mm

Sheet size = 17 1/2 x 22 inches

$$\text{Circumference of a Cylinder} = \pi \times \text{Diameter} = \pi \times 220 \text{ mm} = 691.15 \text{ mm}$$

Sheet dimension around the cylinder = 17 1/2 inches x 25.4mm/inch = 444.5 mm

$$\% \text{ of circumference occupied by image} = \text{Ratio of } \frac{\text{length of paper}}{\text{circumference of cylinder}} \times 100$$

$$\text{Percentage} = \frac{444.5}{691.2} \times 100 = 64\ \%$$

To calculate the change in print length, the formula $D= 2P\pi C / 100$ was used where D denotes change in print length; C represents the percentage of the circumference occupied by the image and P is for packing change.

D= 2 x .3mm x 3.1415 x 64% = 1.206 mm

The percent of change in print length is then calculated as
1.206/444.5 x 100 = .27%

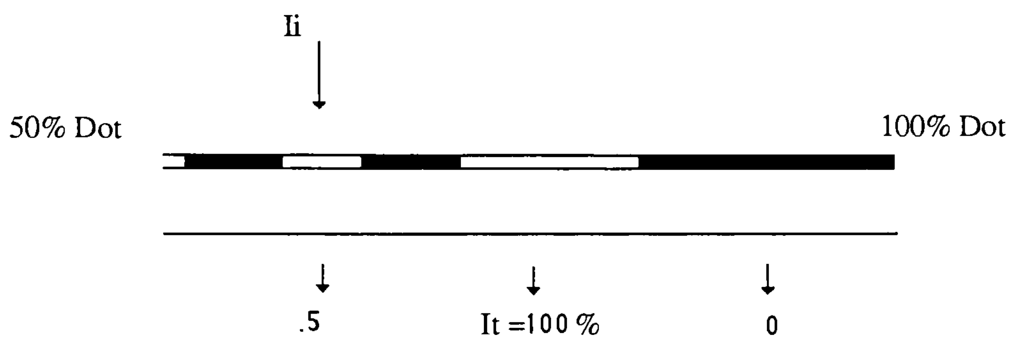
A dot would change by the same % length. An example is that of a 50% dot made with a 150 lines/ inch screenruling having a side length of 120 microns.
.12mm x .0027 = .0003 mm.
.1203 .12 = .0003 meaning the change in size of a 120 micron dot is approximately .3 microns.

Since Slur is usually in the cylinder rotation direction, the overall increase in dot size is going to be in one direction only and not all the way around the dot. Therefore dot area is affected by a very insignificant amount.

APPENDIX B

DERIVATION OF THE MURRAY-DAVIES EQUATION

The Murray-Davies Equation is used to represent the relationship of dot area to the reflection or trasmittance characteristics (density) of a halftone dot.



I_i= Intensity of Incident Light

I_t=Intensity of Transmitted Light

Transmittance = $\frac{I_t}{I_i}$

Opacity = $\frac{1}{T} = \frac{I_i}{I_t}$

Density = D = $\log_{10}$ Opacity = $\log_{10} \frac{1}{T}$

a = dot area ; a = 1 T

Transmittance of Solid Black = 0% :

Transmittance of a Clear Film = 100%=1:

50% Dot = 1/2 black and 1/2 clear = .5 Transmittance

Question: What is the density of a 50% dot ?

$D = \log_{10} 1/.5 = \log_{10} 2 = .301$

for a 75% dot T=25%; Density = $\log_{10} 1/.25 = \log 4 = .602$

for a 87.5% dot T=12.5%; Density = $\log_{10} 1/.125 = \log 8 = .9$

for a 90% dot T=10%; Density = $\log_{10} 1/.1 = \log 10 = 1$

Murray Davies equation permits calculation of dot area when the density of the dots is not infinite.

Transmittance of a 90% dot = 10% = .1

$T_{tint} = (a \times T_{dot}) + ((1 \quad a) \times T_{clear})$

$T_{tint} = aT_{dot} + T_{clear} - aT_{clear}$

$T_{tint} = a(T_{dot} - 1) + 1$

$1 \quad T_{tint} = a(1 - T_{dot})$

$a = \frac{1 - T_{tint}}{1 \quad T_{dot}}$ Since the transmittance of the dot equals the transmittance of a solid, the equation becomes $\mathbf{a = \frac{1 - T_{tint}}{1 - T_{solid}} = \frac{1 - 10^{-Dt}}{1 - 10^{-Ds}}}$

Example:

90% dot where transmittance of dot area = 10% = .1

$T_{90\%\ tint} = ((1-a) \times T_{10\%clear}) + (a \times T_{90\%tint})$

$(.1 \times 100\%) + (.9 \times 10\%)$

$.1 + .09 = .19$

$Density_{tint} = \log_{10} 1/.19 = \log 5.263 = .72$

APPENDIX C

Table of Regression Equations and Analysis of Variance for the variables in Data of Black (1)

The data that was accumulated was stored on a floppy disc and was not printed with this thesis. Access to the data is possible by contacting Mr. Franz Sigg.

Computer Analysis Using Minitab:

C1	C2	C3	C4	C5	C6	C7	C8
1	0.18	0.08	110	79.4	83.4	6.9	0.004107
2	0.18	0.06	120	75.4	82.5	0.0	0.015952
3	0.20	0.08	90	78.7	83.0	6.3	0.019801
4	0.18	0.07	120	75.2	81.5	2.6	0.005973
5	0.18	0.08	95	80.4	83.3	9.3	0.004107
6	0.18	0.06	100	74.7	80.6	1.6	0.015952
7	0.18	0.07	130	76.9	81.4	4.1	0.005973
8	0.18	0.08	120	80.9	83.4	9.4	0.004107
9	0.19	0.06	125	76.8	81.2	6.3	0.018495
10	0.20	0.08	120	80.6	83.6	11.8	0.019801
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.

C2: Circumferential Register
C3: Lateral Register
C4: Doubling Angle
C5: Dot Gain on 50% Tint
C6: Average Dot Gain on Concentric Circles
C7: Magnitude of Doubling
C8: Magnitude of Misregister

Correlation C2-C8

	C2	C3	C4	C5	C6	C7
C3	0.096					
C4	0.010	-0.086				
C5	0.113	0.213	0.175			
C6	0.113	0.175	0.126	**0.838**		
C7	**0.040**	**-0.020**	**0.380**	**0.595**	**0.552**	
C8	-0.116	-0.497	**0.026**	-0.092	-0.118	**0.061**

Analysis of Variance and Estimation of the Population Regression Line with the Data from Black 1

The Regression Equation is: C7 = 3.31 + 9.0 C2

Predictor	Coef	Stdev	t-ratio	p
Constant	3.307	1.838	1.80	0.073
C2	9.02	10.15	**0.89**	0.375

s = 2.680 R-sq = 0.2% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	5.672	5.672	0.79	0.375
Error	498	3577.543	7.184		
Total	499	3583.215			

C2: Horizontal Register
C7: Magnitude of Doubling

The Regression Equation is: C7 = 5.05 - 1.44 C3

Predictor	Coef	Stdev	t-ratio	p
Constant	5.0459	0.2708	18.63	0.000
C3	-1.445	3.197	**-0.45**	0.652

s = 2.682 R-sq = 0.0% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1.468	1.468	0.20	0.652
Error	498	3581.746	7.192		
Total	499	3583.215			

C3: Vertical Register
C7: Magnitude of Doubling

The Regression Equation is: C7 = 3.44 + 0.0160 C4

Predictor	Coef	Stdev	t-ratio	p
Constant	3.4437	0.1970	17.48	0.000
C4	0.015968	0.001742	**9.17**	0.000

s = 2.481 R-sq = 14.4% R-sq(adj) = 14.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	517.35	517.35	84.04	0.000
Error	498	3065.86	6.16		
Total	499	3583.21			

C4: Doubling Angle
C7: Magnitude of Doubling

The Regression Equation is: C7 = - 38.8 + 0.566 C5

Predictor	Coef	Stdev	t-ratio	p
Constant	-38.761	2.646	-14.65	0.000
C5	0.56555	0.03422	**16.53**	0.000

s = 2.156 R-sq = 35.4% R-sq(adj) = 35.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1269.1	1269.1	273.12	0.000
Error	498	2314.1	4.6		
Total	499	3583.2			

C5: Dot Gain on 50% Tint
C7: Magnitude of Doubling

The Regression Equation is: C7 = - 55.8 + 0.739 C6

Predictor	Coef	Stdev	t-ratio	p
Constant	-55.828	4.115	-13.57	0.000
C6	0.73917	0.05004	**14.77**	0.000

s = 2.237 R-sq = 30.5% R-sq(adj) = 30.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1091.7	1091.7	218.19	0.000
Error	498	2491.6	5.0		
Total	499	3583.2			

C6: Average Dot Gain on Concentric Circles
C7: Magnitude of Doubling

The Regression Equation is: C7 = 4.76 + 6.19 C8

Predictor	Coef	Stdev	t-ratio	p
Constant	4.7560	0.1780	26.72	0.000
C8	6.192	4.526	**1.37**	0.172

s = 2.677 R-sq = 0.4% R-sq(adj) = 0.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	13.417	13.417	1.87	0.172
Error	498	3569.798	7.168		
Total	499	3583.215			

C7: Magnitude of Doubling
C8: Magnitude of Misregister

The Regression Equation is: C5 = - 19.8 + 1.18 C6

Predictor	Coef	Stdev	t-ratio	p
Constant	-19.818	2.833	-6.99	0.000
C6	1.18099	0.03446	**34.28**	0.000

s = 1.540 R-sq = 70.2% R-sq(adj) = 70.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	2786.7	2786.7	1174.82	0.000
Error	498	1181.3	2.4		
Total	499	3967.9			

C5: Dot Gain on 50% Tint
C6: Average Dot Gain on Concentric Circles

The Regression Equation is: C4 = 91.6 + 63 C8

Predictor	Coef	Stdev	t-ratio	p
Constant	91.627	4.242	21.60	0.000
C8	63.3	107.9	**0.59**	0.557

s = 63.81 R-sq = 0.1% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1404	1404	0.34	0.557
Error	498	2027651	4072		
Total	499	2029055			

C4: Doubling Angle
C8: Magnitude of Misregister

Table of Regression Equations and Analysis of Variance for the variables in Data of Magenta (1)

Computer Analysis Using Minitab:

C1	C2	C3	C4	C5	C6	C7	C8
1	0.08	-0.04	70	78.5	85.1	3.9	0.041445
2	0.08	-0.02	120	80.6	84.7	4.5	0.022111
3	0.08	-0.03	60	79.4	84.9	4.0	0.031675
4	0.08	0.00	85	83.1	84.7	6.5	0.007754
5	0.08	-0.02	50	79.8	85.0	1.3	0.022111
6	0.08	0.00	80	80.9	84.8	5.5	0.007754
7	0.08	-0.01	90	79.1	85.2	3.0	0.013211
8	0.08	-0.02	75	79.9	84.9	5.5	0.022111
9	0.10	0.00	80	78.0	83.8	4.2	0.027729
10	0.08	-0.01	80	81.1	84.9	6.4	0.013211
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.

C2: Circumferential Register
C3: Lateral Register
C4: Doubling Angle
C5: Dot Gain on 50% Tint
C6: Average Dot Gain on Concentric Circles
C7: Magnitude of Doubling
C8: Magnitude of Misregister

Correlation C2-C8

	C2	C3	C4	C5	C6	C7
C3	0.357					
C4	0.251	0.012				
C5	-0.099	0.450	0.115			
C6	-0.330	0.369	-0.149	**0.791**		
C7	**0.199**	**0.164**	**0.463**	**0.463**	**0.150**	
C8	-0.018	0.501	**-0.041**	0.295	0.277	**0.041**

Analysis of Variance and Estimation of the Population Regression Line with the Data from Magenta 1

The Regression Equation is: C7 = 2.76 + 15.4 C2

Predictor	Coef	Stdev	t-ratio	p
Constant	2.7557	0.2560	10.77	0.000
C2	15.375	3.388	**4.54**	0.000

s = 1.666 R-sq = 4.0% R-sq(adj) = 3.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	57.157	57.157	20.59	0.000
Error	498	1382.408	2.776		
Total	499	1439.565			

C2: Horizontal Register
C7: Magnitude of Doubling

The Regression Equation is: C7 = 3.86 + 5.26 C3

Predictor	Coef	Stdev	t-ratio	p
Constant	3.86321	0.07501	51.50	0.000
C3	5.264	1.420	**3.71**	0.000

s = 1.677 R-sq = 2.7% R-sq(adj) = 2.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	38.677	38.677	13.75	0.000
Error	498	1400.888	2.813		
Total	499	1439.565			

C3: Vertical Register
C7: Magnitude of Doubling

The Regression Equation is: C7 = 1.95 + 0.0256 C4

Predictor	Coef	Stdev	t-ratio	p
Constant	1.9453	0.1781	10.92	0.000
C4	0.025631	0.002199	**11.65**	0.000

s = 1.507 R-sq = 21.4% R-sq(adj) = 21.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	308.51	308.51	135.84	0.000
Error	498	1131.05	2.27		
Total	499	1439.57			

C4: Doubling Angle
C7: Magnitude of Misregister

The Regression Equation is: C7 = - 26.1 + 0.370 C5

Predictor	Coef	Stdev	t-ratio	p
Constant	-26.141	2.574	-10.15	0.000
C5	0.37009	0.03174	**11.66**	0.000

s = 1.507 R-sq = 21.4% R-sq(adj) = 21.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	308.75	308.75	135.97	0.000
Error	498	1130.82	2.27		
Total	499	1439.57			

C5: Dot Gain on 50% Tint
C7: Magnitude of Doubling

The Regression Equation is: C7 = - 13.1 + 0.198 C6

Predictor	Coef	Stdev	t-ratio	p
Constant	-13.061	5.017	-2.60	0.010
C6	0.19802	0.05868	**3.37**	0.001

s = 1.681 R-sq = 2.2% R-sq(adj) = 2.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	32.184	32.184	11.39	0.001
Error	498	1407.381	2.826		
Total	499	1439.565			

C6: Average Dot Gain on Concentric Circles
C7: Magnitude of Doubling

The Regression Equation is: C7 = 3.77 + 2.09 C8

Predictor	Coef	Stdev	t-ratio	p
Constant	3.7692	0.1315	28.66	0.000
C8	2.094	2.298	**0.91**	0.363

s = 1.699 R-sq = 0.2% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	2.396	2.396	0.83	0.363
Error	498	1437.169	2.886		
Total	499	1439.566			

C7: Magnitude of Doubling
C8: Magnitude of Misregister

The Regression Equation is: C5 = - 30.9 + 1.31 C6

Predictor	Coef	Stdev	t-ratio	p
Constant	-30.945	3.886	-7.96	0.000
C6	1.31050	0.04545	**28.83**	0.000

s = 1.302 R-sq = 62.5% R-sq(adj) = 62.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1409.7	1409.7	831.23	0.000
Error	498	844.5	1.7		
Total	499	2254.2			

C5: Dot Gain on 50% Tint
C6: Average Dot Gain on Concentric Circles

The Regression Equation is: C4 = 76.8 38.3 C8

Predictor	Coef	Stdev	t-ratio	p
Constant	76.763	2.375	32.32	0.000
C8	-38.26	41.50	**-0.92**	0.357

s = 30.68 R-sq = 0.2% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	800.3	800.3	0.85	0.357
Error	498	468823.4	941.4		
Total	499	469623.7			

C4: Doubling Angle
C8: Magnitude of Misregister

Table of Regression Equations and Analysis of Variance for the variables in Data of Black (2)

Computer Analysis Using Minitab:

C1	C2	C3	C4	C5	C6	C7	C8
1	0.21	-0.01	60	77.3	82.5	9.1	0.018170
2	0.21	-0.03	20	73.9	80.6	3.1	0.008565
3	0.21	-0.02	60	76.1	81.8	6.5	0.010087
4	0.21	-0.02	65	74.0	79.0	0.0	0.010087
5	0.21	-0.01	80	75.7	81.3	11.1	0.018170
6	0.21	-0.03	40	73.9	80.0	4.3	0.008565
7	0.20	-0.03	70	76.0	80.1	7.0	0.004212
8	0.21	-0.02	20	72.6	79.3	4.0	0.010087
9	0.20	-0.02	140	79.6	84.6	5.6	0.006793
10	0.21	-0.03	155	78.7	82.9	7.2	0.008565
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.

C2: Circumferential Register
C3: Lateral Register
C4: Doubling Angle
C5: Dot Gain on 50% Tint
C6: Average Dot Gain on Concentric Circles
C7: Magnitude of Doubling
C8: Magnitude of Misregister

Correlation C2-C8

	C2	C3	C4	C5	C6	C7
C3	0.272					
C4	-0.018	-0.002				
C5	-0.087	-0.330	0.310			
C6	-0.048	-0.273	0.194	**0.905**		
C7	**0.039**	**-0.138**	**0.429**	**0.748**	**0.613**	
C8	-0.067	0.091	**0.157**	0.004	-0.041	**0.172**

Analysis of Variance and Estimation of the Population Regression Line with the Data from Black 2

The Regression Equation is: C7 = 1.92 + 15.8 C2

Predictor	Coef	Stdev	t-ratio	p
Constant	1.922	3.644	0.53	0.598
C2	15.84	18.01	**0.88**	0.379

s = 2.950 R-sq = 0.2% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	6.735	6.735	0.77	0.379
Error	498	4333.347	8.701		
Total	499	4340.082			

C2: Horizontal Register
C7: Magnitude of Doubling

The Regression Equation is: C7 = 4.06 - 40.3 C3

Predictor	Coef	Stdev	t-ratio	p
Constant	4.0604	0.3678	11.04	0.000
C3	-40.33	13.01	**-3.10**	0.002

s = 2.924 R-sq = 1.9% R-sq(adj) = 1.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	82.142	82.142	9.61	0.002
Error	498	4257.940	8.550		
Total	499	4340.082			

C3: Vertical Register
C7: Magnitude of Doubling

The Regression Equation is: C7 = 3.34 + 0.0201 C4

Predictor	Coef	Stdev	t-ratio	p
Constant	3.3390	0.2067	16.15	0.000
C4	0.020121	0.001901	**10.59**	0.000

s = 2.667 R-sq = 18.4% R-sq(adj) = 18.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	797.23	797.23	112.06	0.000
Error	498	3542.85	7.11		
Total	499	4340.08			

C4: Doubling Angle
C7: Magnitude of Doubling

The Regression Equation is: C7 = - 65.4 + 0.924 C5

Predictor	Coef	Stdev	t-ratio	p
Constant	-65.428	2.804	-23.33	0.000
C5	0.92361	0.03669	**25.17**	0.000

s = 1.958 R-sq = 56.0% R-sq(adj) = 55.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	2430.0	2430.0	633.53	0.000
Error	498	1910.1	3.8		
Total	499	4340.1			

C5: Dot Gain on 50% Tint
C7: Average Dot Gain on Concentric Circles

The Regression Equation is: C7 = - 69.4 + 0.920 C6

Predictor	Coef	Stdev	t-ratio	p
Constant	-69.352	4.302	-16.12	0.000
C6	0.91965	0.05311	**17.32**	0.000

s = 2.332 R-sq = 37.6% R-sq(adj) = 37.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1631.0	1631.0	299.83	0.000
Error	498	2709.0	5.4		
Total	499	4340.1			

C6: Average Dot Gain on Concentric Circles
C7: Magnitude of Doubling

The Regression Equation is: C7 = 4.39 + 72.1 C8

Predictor	Coef	Stdev	t-ratio	p
Constant	4.3858	0.2303	19.04	0.000
C8	72.12	18.52	**3.89**	0.000

s = 2.908 R-sq = 3.0% R-sq(adj) = 2.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	128.24	128.24	15.16	0.000
Error	498	4211.85	8.46		
Total	499	4340.08			

C7: Magnitude of Doubling
C8: Magnitude of Misregister

The Regression Equation is: C5 = - 12.7 + 1.10 C6

Predictor	Coef	Stdev	t-ratio	p
Constant	-12.685	1.877	-6.76	0.000
C6	1.09990	0.02317	**47.48**	0.000

s = 1.017 R-sq = 81.9% R-sq(adj) = 81.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	2333.1	2333.1	2253.95	0.000
Error	498	515.5	1.0		
Total	499	2848.6			

C5: Dot Gain on 50% Tint
C6: Average Dot Gain on Concentric Circles

The Regression Equation is: C4 = 74.5 + 1399 C8

Predictor	Coef	Stdev	t-ratio	p
Constant	74.454	4.919	15.14	0.000
C8	1399.1	395.5	**3.54**	0.000

s = 62.11 R-sq = 2.5% R-sq(adj) = 2.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	48261	48261	12.51	0.000
Error	498	1920954	3857		
Total	499	1969216			

C4: Doubling Angle
C8: Magnitude of Misregister

Table of Regression Equations and Analysis of Variance for the variables in Data of Magenta (2)

Computer Analysis Using Minitab:

C1	C2	C3	C4	C5	C6	C7	C8
1	0.12	-0.03	100	75.3	78.8	1.3	0.0207019
2	0.11	-0.03	65	75.5	79.9	4.5	0.0123194
3	0.11	-0.03	80	74.7	78.7	2.0	0.0123194
4	0.11	-0.03	85	76.1	80.9	6.8	0.0123194
5	0.11	-0.04	75	74.7	79.0	1.2	0.0089534
6	0.11	-0.04	80	76.1	79.4	5.1	0.0089534
7	0.11	-0.04	90	74.1	79.9	0.7	0.0089534
8	0.10	-0.02	90	77.7	80.6	4.4	0.0186163
9	0.11	-0.03	0	75.3	80.4	3.0	0.0123194
10	0.10	-0.03	110	77.8	81.6	3.6	0.0086582

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C2: Circumferential Register
C3: Lateral Register
C4: Doubling Angle
C5: Dot Gain on 50% Tint
C6: Average Dot Gain on Concentric Circles
C7: Magnitude of Doubling
C8: Magnitude of Misregister

Correlation C2-C8

	C2	C3	C4	C5	C6	C7
C3	0.039					
C4	0.025	0.194				
C5	-0.179	-0.365	0.097			
C6	-0.165	-0.414	-0.125	**0.877**		
C7	**-0.033**	**0.174**	**0.491**	**0.315**	**0.165**	
C8	0.111	0.015	**0.053**	-0.131	-0.186	**-0.081**

<u>Analysis of Variance and Estimation of the Population Regression Line with the Data from Magenta 2</u>

The Regression Equation is: C7 = 4.19 5.56 C2

Predictor	Coef	Stdev	t-ratio	p
Constant	4.1899	0.7784	5.38	0.000
C2	-5.562	7.661	**-0.73**	0.468

s = 1.620 R-sq = 0.1% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1.384	1.384	0.53	0.468
Error	498	1307.306	2.625		
Total	499	1308.690			

C2: Horizontal Register
C7: Magnitude of Doubling

The Regression Equation is: C7 = 4.26 + 16.3 C3

Predictor	Coef	Stdev	t-ratio	p
Constant	4.2557	0.1743	24.41	0.000
C3	16.290	4.123	**3.95**	0.000

s = 1.596 R-sq = 3.0% R-sq(adj) = 2.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	39.774	39.774	15.61	0.000
Error	498	1268.916	2.548		
Total	499	1308.690			

C3: Vertical Register Variation
C7: Magnitude of Doubling

The Regression Equation is: C7 = 1.89 + 0.0248 C4

Predictor	Coef	Stdev	t-ratio	p
Constant	1.8920	0.1517	12.48	0.000
C4	0.024810	0.001971	**12.58**	0.000

s = 1.412 R-sq = 24.1% R-sq(adj) = 24.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	315.76	315.76	158.37	0.000
Error	498	992.93	1.99		
Total	499	1308.69			

C4: Doubling Angle
C7: Magnitude of Misregister

The Regression Equation is: C7 = - 19.5 + 0.296 C5

Predictor	Coef	Stdev	t-ratio	p
Constant	-19.468	3.118	-6.24	0.000
C5	0.29645	0.04002	**7.41**	0.000

s = 1.539 R-sq = 9.9% R-sq(adj) = 9.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	129.90	129.90	54.88	0.000
Error	498	1178.79	2.37		
Total	499	1308.69			

C5: Dot Gain of 50% Tint
C7: Magnitude of Misregister

The Regression Equation is: C7 = - 11.7 + 0.187 C6

Predictor	Coef	Stdev	t-ratio	p
Constant	-11.677	4.109	-2.84	0.005
C6	0.18663	0.05010	**3.72**	0.000

s = 1.599 R-sq = 2.7% R-sq(adj) = 2.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	35.475	35.475	13.88	0.000
Error	498	1273.216	2.557		
Total	499	1308.690			

C6: Average Dot Gain on Concentric Circles
C7: Magnitude Of Misregister

The Regression Equation is: C7 = 3.86 - 13.5 C8

Predictor	Coef	Stdev	t-ratio	p
Constant	3.8594	0.1476	26.15	0.000
C8	-13.497	7.480	**-1.80**	0.072

s = 1.616 R-sq = 0.6% R-sq(adj) = 0.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	8.500	8.500	3.26	0.072
Error	498	1300.190	2.611		
Total	499	1308.690			

C7: Magnitude of Doubling
C8: Magnitude of Misregister

The Regression Equation is: C5 = - 8.75 + 1.06 C6

Predictor	Coef	Stdev	t-ratio	p
Constant	-8.755	2.126	-4.12	0.000
C6	1.05678	0.02592	**40.78**	0.000

s = 0.8271 R-sq = 77.0% R-sq(adj) = 76.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1137.4	1137.4	1662.64	0.000
Error	498	340.7	0.7		
Total	499	1478.1			

C5: Dot Gain on 50% Tint
C6: Average Dot Gain on Concentric Circles

The Regression Equation is: C4 = 66.9 + 176 C8

Predictor	Coef	Stdev	t-ratio	p
Constant	66.911	2.927	22.86	0.000
C8	176.1	148.4	**1.19**	0.236

s = 32.05 R-sq = 0.3% R-sq(adj) = 0.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1447	1447	1.41	0.236
Error	498	511551	1027		
Total	499	512998			

C4: Doubling Angle
C8: Magnitude of Misregister

APPENDIX D

PRESS RUN DOCUMENTATION

Specifications of Web Test Run:

Set-up: Makeready plus Actual Run

Press: Harris M-1000 - Blanket to Blanket, Duotrol Dampening System, TEC 2 Zone Dryer

Paper: Great Northern Paper

Color: Blue White

Basis Weight: 38.8

Size: 35"

Finish: Gloss

Roll #: 7 U40504

Goundwood

Plates: 3M Viking

Fountain Solution: ROSOS KSP 500 M4 AS 6 1/2 ounces to a gallon of H_20 pH 3.8, Conductivity 2450

Blanket: Reeves 718's 3 ply Compressible Blanket

Ink: GPI , Black-Magenta-Cyan

Final trim size of signature: 8 1/2 x 11

Densities: Tolerance of + or - .05

M: 1.35

C: 1.35

K: 1.6

Y: Blank plate with the dampening system turned off at this unit only

Press Conditions: 1200 feet / min (Equivalent to 37613 impressions per hour)

Infeed Tension: 133 pounds

Conditions:

1- Web Aligner and Register Control were on automatic

2- Web Aligner and Register Control were turned off

Sheetfed Test for SLUR

Press: Heidelberg MO 19 x 25 1/2 Single Color Sheetfed, Bearer to Bearer

- Ink: Black Offset Sheetfed Super Ultraset / 1/D Dense Black manufactured by Morrison Printing Ink

Lithographic Fountain Solution: 2 ounces Seamist Fountain mixed with one gallon water with additional Fungus Arrester. Manufactured by Anchor / Lithkemko

Paper: Dull-coated
Size: 17 1/2 x 22 1/2 Weight: 70 - 58M
Color: White Grain: Long Caliper: .004" or .10 mm

- Plate: 3M Viking G1 exposed for 40 units and machine processed

Blanket: Compressible

Speed: 5500 impressions / hr

Normal Set-up: Pressure between the plate and blanket cylinder is .07 to .10 mm (.0028-.004")

Best printing result as recommended by Heidelberg is achieved with the rubber blanket packed to .05 mm (.002") under bearer height.

Impression Pressure between blanket and impression cylinder should be .10 mm (0.004"). Normally this is taken care of with the thickness of the paper.

Plate + Underlay = .65mm (.026") which brings it to .15mm (.006") above bearers. The squeeze pressure would be .10mm (.004").

Phase I: The above normal set-up was used, however the scale setting on the impression cylinder was increased from 0 to .1 mm (.004") and gradually increased to .12 mm (.0048")

Solid Ink Density was in the range of 1.3 1.4

Blanket + Underlay = .03 mm (.0012") under bearer height instead of .05 mm (.002")

Phase II: .2mm (.008") of plate packing was removed and added to the blanket packing.

This meant that the plate was now .05mm (.002") below bearers.

Blanket is now packed above bearers by .17mm (.0065")

No adjustment of impression pressure even though it was excessive due to the increased blanket packing.

Phase III: An additional .075mm (.003") was removed from the plate and added to the blanket.

Plate = .13mm (.005") under bearer.

Blanket = .24mm (.0095").

Impression pressure was decreased at one point. While moving or adjusting the impression pressure, directional dot gain was noticed on the sheets because of the movement of cylinders. However once the impression pressure was stabilised, there was no sign of directional gain on the targets.

Mottle was noticed on the printed sheets.

Phase IV: Decreased impression pressure to .08 mm (.0035") then increased back to .1 mm.

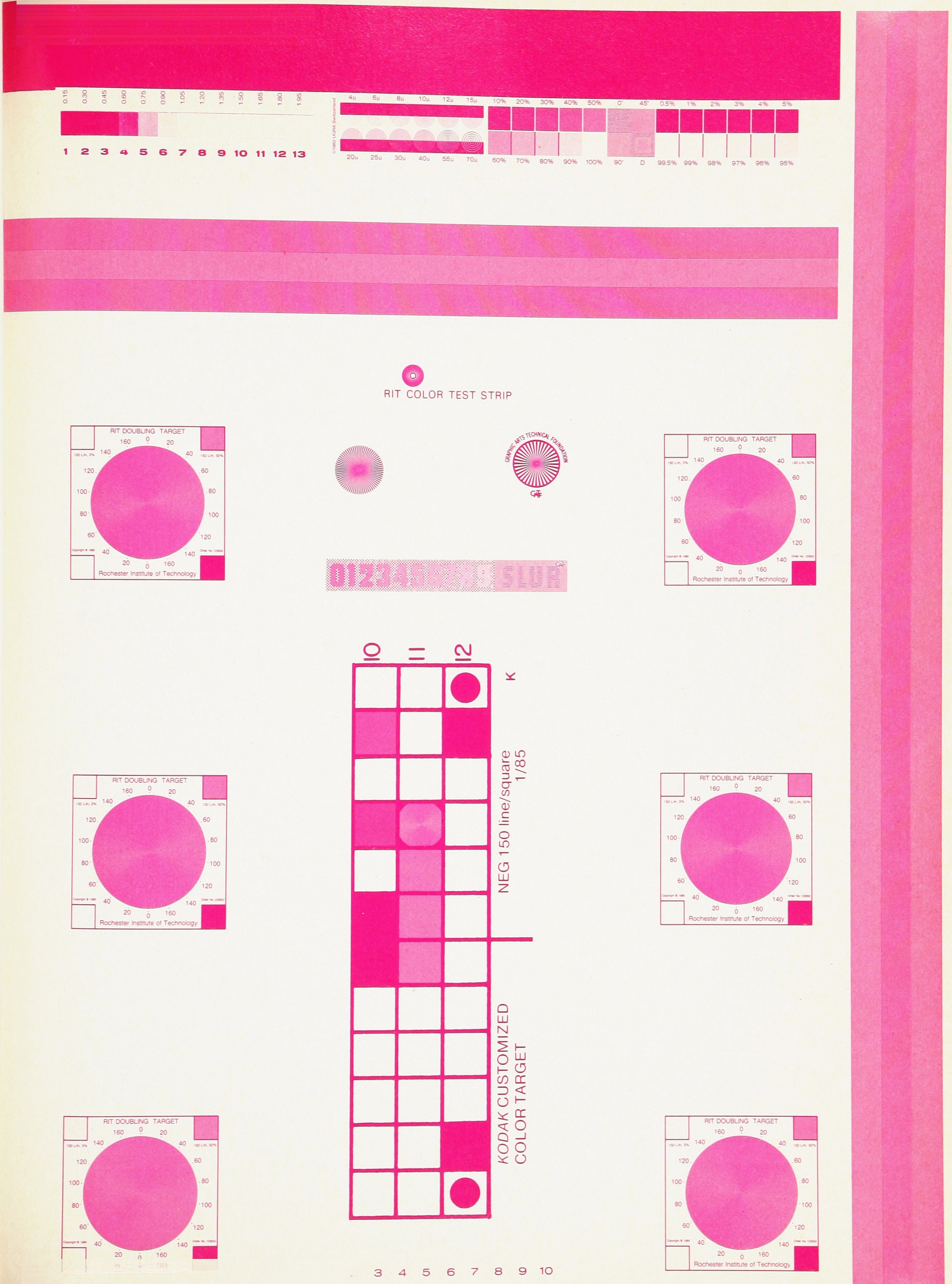
Mottle was present. A most probable cause would have been a lack of sufficient squeeze pressure.

A noticeable change or increase in image length due to decreasing plate packing.

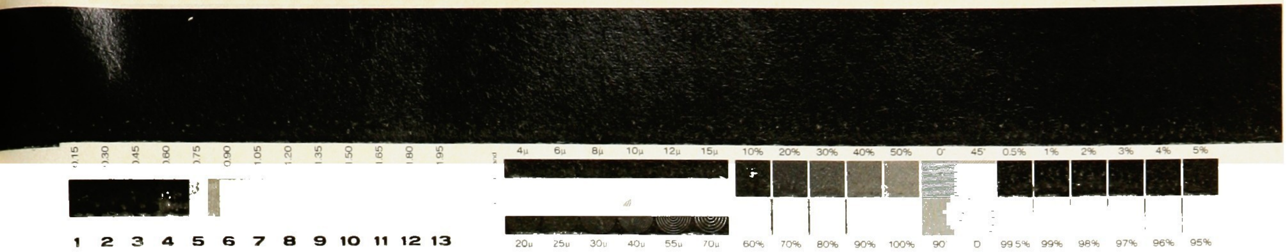
APPENDIX E

FILMS FOR LAYOUT

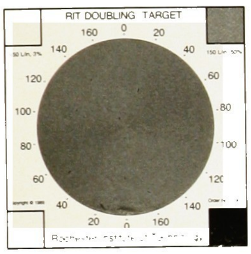
1-	GATF Star Target 36 wedge RIT Star Target 72 wedge	Size: .75 x .75"
2-	GATF Dot Gain Scale and Slur Gauge	Size: .5 x 2.5"
3-	Kodak Customized Color Analysis	Size: 1.5 x 4.75"
4-	GATF Ladder Target	Size: width of 1.25"
5-	RIT Experimental Doubling Target	Size: 1.4 x 1.4"
6-	Image	Size: 5 1/2" x 4 1/8"
7-	RIT Visual Registration Target	Size: 3 x 1/2"
8-	RIT Registration Target	Size: 1.75 x 1.75"
9-	Parallel Line Tints	Size: 8 x 24 mm

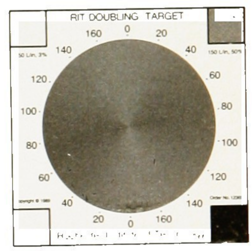


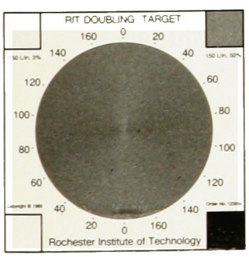
0.15 030 0.45 0.60 0.75 0.90 105 120 135 150 165 180 195
1 2 3 4 5 6 7 8 9 10 11 12 13
4µ 6µ 8µ 10µ 12µ 15µ
20µ 25µ 30µ 40µ 55µ 70µ
10% 20% 30% 40% 50% 0° 45° 0.5% 1% 2% 3% 4% 5%
60% 70% 80% 90% 100% 90° D 99.5% 99% 98% 97% 96% 95%
RIT COLOR TEST STRIP
RIT DOUBLING TARGET
Rochester Institute of Technology
GRAPHIC ARTS TECHNICAL FOUNDATION
0123456789 SLUR
10 11 12
K
NEG 150 line/square
1/85
KODAK CUSTOMIZED
COLOR TARGET
3 4 5 6 7 8 9 10

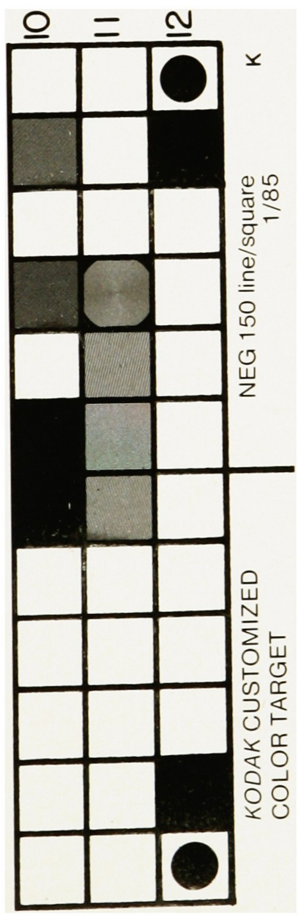


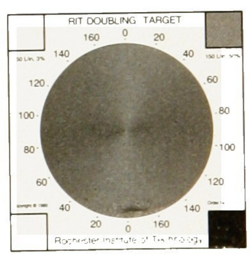
RIT COLOR TEST STRIP

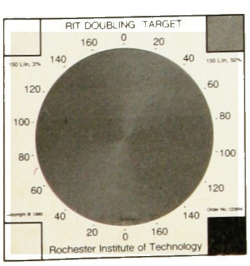


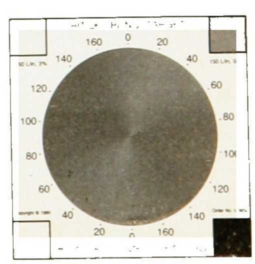












3 4 5 6 7 8 9 10