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A Comparison of high-end color system halftones and postscript-generated halftones

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A Comparison of High-End Color System Halftones and PostScript-Generated Halftones

by

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Abstract

The purpose of this study was to compare the quality of PostScript-generated four-color halftones to halftones produced by traditional high-end color systems. The quality issue is one that must be addressed before a decision can be made to move magazine production onto a complete desktop publishing platform.

In moving layout and design functions onto a desktop publishing platform, publishers can take advantage of PostScript as a page-description language to electronically create complete pages. Electronic assembly would eliminate the mechanical stripping step, allowing great reductions in prepress manufacturing costs.

There are two routes that can be taken to output these electronic pages.

First, the pages can be output via the traditional high-end color systems, like those marketed by companies such as Dupont Imaging Systems and Scitex. These systems, though expensive to purchase and maintain, are proven in terms of quality for four-color output.

The alternative to the high-end method is to output pages through device-independent PostScript-driven imagesetters, like those marketed by companies such as Agfa and Linotype. These devices are low-cost in comparison to the high-end systems. The quality, however, is the subject of debate.

To highlight the differences in quality, the same continuous-tone data generated from a high resolution scanner was sent for halftone film output through both a high-end imagesetter and a PostScript-driven imagesetter. The images were shown to two groups of viewers: professionals (from the printing and publishing industry) and non-professionals. The viewers were then asked questions pertaining to the sharpness, detail, contrast, tonal range, and overall pleasing color of the two sets of images.

For each group, the responses were analyzed statistically to determine if there was a perceived difference between four-color images generated from a high-end color system and those generated from PostScript-driven output devices. In addition, the responses of the two groups were compared statistically to determine if there was a difference between the way the professionals viewed the two images and the way non-professionals viewed them.

It was determined that within the group of professionals, there was no statistically meaningful difference perceived between the high-end color and the PostScript color. The same was found to be true for the non-professionals. However, when comparing the responses of professionals to non-professionals, it was found that there was a statistically meaningful difference in the pattern of their responses, or in the way they viewed the images--though within each of these two groups, there was no statistically apparent agreement on the preferences.

Chapter 1

Introduction

Stripping text, graphics, and four-color separation film together to form an editorial page remains the single most expensive process in a magazine's prepress production cycle. A weekly news magazine such as Business Week, for example, spends about $1.2 million per year to strip its domestic and international editions. Four-color separations run another $1.1 million, bringing the total prepress costs for the magazine to about $2.3 million.

As the Editorial Production Manager for Business Week, it is my responsibility to look for ways to reduce costs. Reducing or eliminating stripping charges is an obvious target. Technology, in the form of off-the-shelf desktop publishing design packages, can help reduce these costs significantly.

Art directors, working in a Macintosh environment, can use programs such as Quark XPress to design page formats. Using low-resolution scans from a desktop scanner as art, designers size, place, rotate, and crop images on a page. When the design is final, the live text is imported into the page and adjustments are made. Once the placement of the text and graphics is finalized, there are two paths that can be taken. The desktop files can be sent into either a high-end color system, such as the Scitex Assembler workstation, or directly through to a PostScript environment.

In the Scitex Assembler scenario, the application file is sent through a PostScript Raster Image Processor (RIP), where it becomes the actual page geometry for the page. The RIP'ed file is then sent across the Scitex Gateway into an Assembler station. There, scanner-generated high-resolution continuous tone images are brought in to replace the low-resolution versions. The page is then sent to a Scitex Raystar film plotter for generation of four final pieces of film.

Note that in this environment, the four-color images are not sent through any type of PostScript interpreter. The point of this is to take advantage of the screening algorithms offered by the high-end film plotter, rather than those accompanying PostScript-driven output devices. In a sense, it affords a magazine the best of both worlds. The PostScript RIP allows design application files to become page geometry, offering savings in stripping upwards of $1 million per year. At the same time it allows continuous-tone images to be produced using the proven conventional screening algorithms.

In the PostScript environment, the low-resolution images are also replaced with high-resolution versions. However, the entire application file--line art and graphics--is converted to PostScript before going to the image plotter. Therefore, the images are subject to the parameters set forth for dot generation by PostScript, as well as the physical limitations of the PostScript-driven output devices.

There are inherent limitations governing dot placement, screen frequency, and screen angle in PostScript-generated halftones. Whether or not these limitations are enough to rule out this generation of PostScript-generated separations as a challenger to the quality of traditional high-end color equipment is the question that was addressed in this study.

Chapter 2

Theoretical Bases of the Study

Developed by Adobe Systems Inc., PostScript, in simplest terms, is a page description language. As described in Stephen Roth's Real World PostScript, ". . . it is a device-independent imaging model, a way to create images composed of dots."[1]

A PostScript Raster Image Processor (RIP) takes information from a Macintosh application file and converts it into a set of instructions for driving an output device. Devices cover the gamut from the low-resolution 72-dots-per-inch Apple LaserWriter to the high-resolution 2540-dots-per-inch Linotronic imagesetter. Such imagesetters are capable of creating screened four-color halftones, ready for plating. The question remains, however, as to how well PostScript-generated halftones compare to those created from high-end color systems.

Before a comparison can be made between the halftone quality of PostScript-generated and scanner-generated outputs, it would be useful to review the concept of halftoning, give an overview of the principal halftone processes, and define the common parameters used in describing a halftone dot. An analysis can then be made with respect to the quality of the halftones output from the two devices.

By definition, "a halftone process converts a gray-scale image into a binary image in such a way that the rendered image gives the viewer the impression of tonal gradation similar to the original gray-scale image."[2]

In other words, halftoning converts an original continuous-tone image into a series of printable dots. In the case of four-color separations, one set of dots is produced for the cyan, magenta, yellow, and black process colors. These separations are produced in register to each other so that when overprinted, these dots of varying sizes give the viewer the illusion of viewing the original image.

All halftones are governed by three parameters: dot shape, screen ruling (or frequency), and screen angle. It is against these parameters that output comparisons will be made among different halftoning devices. To review:

1. Dot shape, simply put, is the physical structure of the dot. Examples of traditional shapes include elliptical, square, and round dots.

2. Screen ruling, or frequency, refers to the resolution or dots-per-inch employed in breaking down a continuous tone image. The higher the screen ruling, the more information carried by the halftone and, therefore, the better the resolution.

3. Screen angle defines the physical orientation of the dots on a page. In four-color separation work, each process colors' dots must be offset slightly from the others so that overprinting dots do not create distracting patterns. For conventional camera separations, the ideal angles have been recognized to be 90 degrees for yellow, 45 for magenta, 105 for cyan, and 75 for black.

The following graphic illustrates how the properties of dot shape, screen angle, and screen ruling work together to create a four-color halftone. The dot shape is round, the screen ruling 20 lines-per-inch, and the screen angles the traditional values of 90 degrees yellow, 45 degrees magenta, 105 degrees cyan, and 75 degrees black.

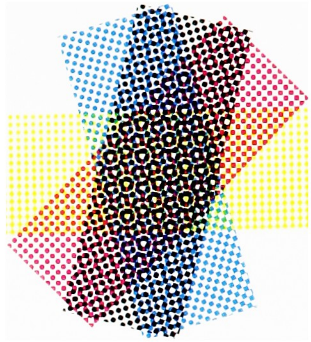

Figure 1. Graphic illustration of four-color screens overprinting at traditional angles.

Notice that the overprinting of dots of all four colors causes a pattern, called a "rosette," to form. This is a desirable pattern. When angles are not properly aligned, a different type of pattern, called a "moire," can form. A moire pattern is an objectionable, wavelike pattern which destroys the desired effect of the reproduction. This pattern degrades the overall quality of an image and is therefore an undesirable trait in a four-color halftone. The ability to position a dot in exactly the right place at a non-interfering angle is a feature that is vital to any halftone-dot generating device.

There are two basic methods for creating four-color halftone separations: photographic halftoning and digital halftoning.

Generally speaking, photographic halftoning is an analog process whereby for each separation color, the original negative is exposed through a series of masks and a contact screen for the purpose of generating a screened negative, ready for plating. To this end, there are two ways to photographically screen an original. Though digital halftoning is the standard for color separation work today, an overview of photographic halftoning will give insight into the basic characteristics of all halftone dots.

The first photographic method is the direct screening method. Each screened color is created in one step by exposing the original negative with a

mask and an angled contact screen. Though relatively quick and easy to produce, direct separations often suffer from poor quality. Miles Southworth, in his book Color Separation Techniques, states that "the direct-screen method of color separation is difficult to control"[3] due to the nature of the highly sensitive film used to create the separation negatives. Variations in development or exposure will cause variations in the quality of the halftones.

Indirect separation screening is the second photographic halftone method. Using the indirect process, continuous-tone negatives are made first. These negatives are then exposed through an angled contact screen, producing screen positives for each separation color. These screened positives are, in turn, contacted into screened negatives for plating.[4]

In both methods of photographic halftoning, the output dots are symmetrical in shape, with the sizes and shapes varying according to the intensity of light incident on the film. The screen angles are dictated by the actual angles of the manufactured contact screens. These screen angles align at the traditional values of yellow 90 degrees, magenta 45 degrees, cyan 105 degrees, and black 75 degrees.

A major disadvantage to photographic halftoning concerns the turn-around time. It is true that direct-separating is a quick, though often unreliable, process, but if exposure or development time is off, the resulting halftone may be unacceptable for quality, and the process must start over. With indirect separation, color is more controllable, but the extra film step makes it time intensive.

Digital halftoning, or electronic scanning, goes a long way toward solving the problems inherent in photographic halftoning. Hou notes in his 1983 book Digital Document Processing that "the digital method has started to

replace the traditional photographic halftone process, not only because most document processing is done by digital electronics, which is binary in nature, but also because the digital technique offers many advantages."[5]

Faster turn-around is a major advantage. While images are being scanned and output, other images can be mounted and previewed on another drum, ready to be loaded once the current images are finished being scanned.

Register is a practical benefit of digital halftoning. Since the plotting of halftone dots is a precise mathematical process, the propensity for digitally-created halftones to be out of register is less than for conventional camera separation halftones.

Moreover, digital images also lend themselves easily to image manipulation and retouching. Using Scitex or Dupont Imaging Systems imaging stations, an image can be called up and altered more accurately and in less time than photo retouching or conventional etching methods are able to do it.

From a publisher's standpoint, digital halftoning holds additional advantages. Information stored digitally can be transmitted to multiple printing sites, eliminating the task of duping and shipping film to each site. It also allows printers to work with first generation film. Perhaps most important, digital transmission gives magazines the power to extend their deadlines in order to cover late-breaking news events.

Generally speaking, "digital halftoning . . . refers to any algorithmic process which creates the illusion of continuous-tone images from the judicious arrangement of binary picture elements."[6]

In a digital environment, a continuous tone image is mounted on a clear scanner drum. As a beam of light from the scanner is focused on the art, the

light is either reflected from the original, in the case of illustrations or color prints, or, in the case of transparencies, transmitted through the original. This reflected or transmitted light is gathered by the scanner's input optics and is used to generate two types of information.

The first is the color information. The transmitted color is passed through various color filters resident in the input optics. The strength of this signal is analyzed against preset thresholds and customized tone curve set-ups. It is then translated into the appropriate amount of yellow, magenta, and cyan process colors needed to reproduce the original image. At the same time, the black separation is being determined electronically through scanner analysis of the other three signals.

To compensate for detail lost in this sampling and thresholding process, a second set of information is generated through the scanner's "unsharp masking" optics. Unsharp masking causes a scanner to exaggerate or electronically "peak" its signal in areas where it detects shifts in tones across the original. This peaking causes the overall contrast of the image to be exaggerated, thus giving the illusion of greater detail.[7]

As the scanning beam moves across the original, it is sending continuous tone data to a temporary storage area or buffer zone. Once a complete row of information has been sampled on the input side, the data is ready to be interpreted by the screening software and plotted to film on the output side.

The screening software, or screening algorithms, give a digital image its halftone characteristics. Screening algorithms refer to the mathematical descriptors that scanners employ in generating halftone dots. The algorithms determine the size, frequency, and angle of the halftones. For each type of

scanner, there is a different algorithm, based on manufacturer specifications, as well as specific user requirements. They are, to an extent, modifiable.

Digital halftones differ from conventional camera halftones in the way they determine screen ruling and screen angles. Because they are not limited by the screen resolution and angles of a manufactured contact screen, digital halftones facilitate variations in these attributes within a separation in order to achieve optimal quality. Some scanners, for example, can specify and successfully output dots based on screen angles that are described in hundredths of degrees. As a result of these precise algorithmic computations, digital halftones are often said to have "irrational" values.

It is useful to think of a high-end color scanner as an intelligent dot generator. In analyzing the input signal, the screening computer calculates a screen frequency and an angle for each separation color that minimizes the chance for moire. A 133-line Crosfield separation, for example, may end up being 129 lines per inch with traditional angle values. This slight deviation still results in good color reproduction with no sign of a moire pattern. On the other hand, Hell gmbH, a manufacturer of high-end color systems, uses its patented High Quality Screening technology to create separations using irrational screen angles[8] with more-or-less conventional line screens.

As the screening algorithms convert the data into various sized dots, the output scanning beam is busy exposing the film. Once the signal is given to create a dot, the output scanner optics will expose the film for the desired dot size, frequency, angle, and placement, as dictated by the screening software. Dots are then plotted in raster motion, line by line, across the output film. A separation is made in register for each of the process colors of cyan, magenta, yellow, and black.

According to Southworth, most scanners employ six crystal modulators for the purpose of exposing halftone dots.[9] When signaled by the screening software to expose the film for a dot, the modulators open. Figure 2 depicts the plotting of a row of halftone dots by a high-end scanner. The dot shown is a 50 percent round dot plotted at 90 degrees.

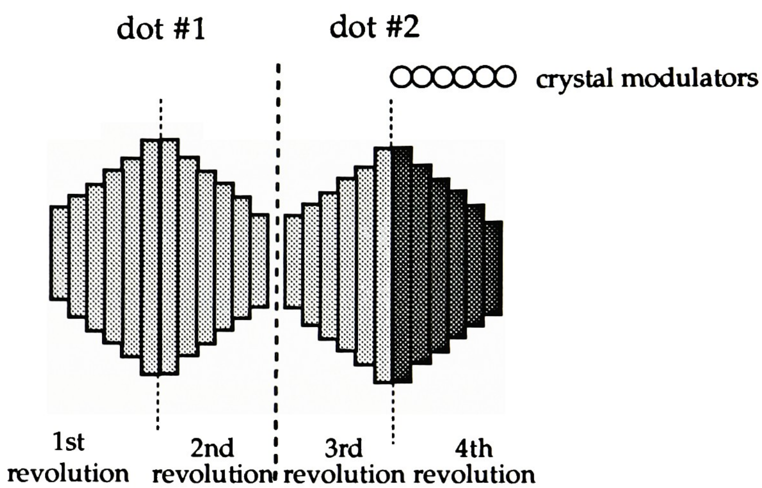

Figure 2. Graphic representation of the plotting of halftone dots by a conventional scanner.

The six modulators above work in tandem, opening and closing according to the signal to mark the film. In the case of six-modulator output scanners, it takes two revolutions of the input drum to create one halftone dot. Therefore, each halftone dot is two revolutions, twelve beams wide.

If the same data used to produce the above halftone dot were sent through a PostScript-driven output device, the resulting halftone output would appear quite different. These differences are attributable to PostScript's limitations with regard to screen frequency, screen angle, and dot placement.

Screen angle and screen frequency are determined by the screening algorithms inherent in halftone-dot generating devices. In the case of high-end scanners, the screening function resides in the sophisticated and expensive hardware and software of the scanning unit. In the case of PostScript-generated graphics, the PostScript interpreter itself serves as the screening function.

In desktop publishing, angle and frequency are determined by the particular application software being used to create the four-color separations. Quark XPress, for example, recommends different screen angles from what Adobe's Photoshop program recommends. In addition, most software programs offer the option of manually specifying screen angles, allowing the user to change the standard settings to correct deficiencies that may be apparent after the initial output is seen.

The shortcomings of PostScript four-color halftones are largely attributable to limitations inherent in the program's screening algorithms. At high screen frequencies (133-line screens and above), PostScript-driven devices simply cannot compute, as precisely as high-end scanners can, the screen angles needed without infringing on the screening patents of the high-end scanner manufacturers. Adobe recently purchased a license from Hell to use its patented screening algorithms, so this might be a way of remedying the problem. (More information on this development can be found in Chapter 3.)

Besides lacking the ideal screening algorithms needed to precisely control angle and frequency, PostScript separations are affected by the physical limitations the output devices impose on dot placement. As was discussed earlier, high-end scanners employ modulators which open and close to

expose dots across a sheet of film. These modulators are triggered by a signal from the sophisticated screening software for marking a dot in a particular place at a specific angle. PostScript-driven devices simply do not have such flexibility in generating halftone dot shapes. These devices are limited to exposing dots in a grid pattern in which the spot where the laser exposes the dot remains fixed at one size.

Figure 3 illustrates this problem.

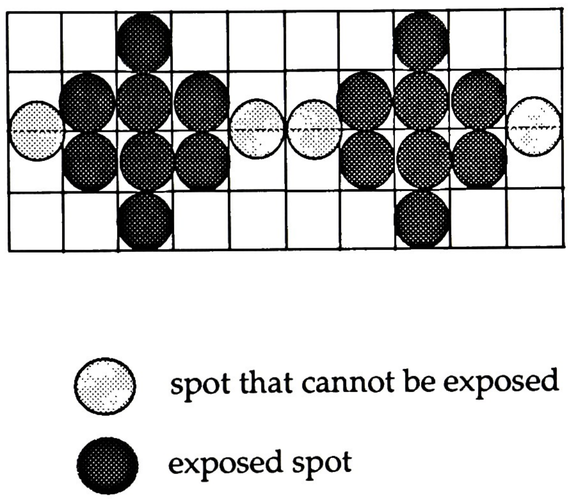

Figure 3. Graphic representation of the plotting of halftone dots by a PostScript-driven output device.

The laser dot, also called the machine spot, is responsible for plotting the many smaller dots which comprise a single, larger halftone dot.[10] The machine spot is a fixed size and cannot vary. The size of this spot ultimately determines the quality of the overall halftone dot. A smaller spot, for example, would render a smoother, more well-defined dot than would a larger spot.

Even the smaller spot size has the potential to cause problems in halftone dot generation. Without the variety and flexibility of spot sizing,

halftone dots take on an irregular shape. Note in the above illustration that the laser spot is either "on" or "off" within the bounds of any grid space; there is no provision for a partial dot. Hence, as the dotted circles reveal, there could be no dot exposed in the position indicated. The overall halftone dot would assume the squared-off shape as shown by the solid circles. This "all or nothing" threshhold results in "fuzzy, or soft" halftones,[11] a criticism often leveled at PostScript color. Detail is often lost and tonal ranges are compressed. In short, reproduction can suffer.

Previous versions of PostScript RIPs were even more limited due to the position of the halftone dot being locked to the grid. This put a restriction on the number of halftone patterns that could be created for any set of separations. For example, in Adobe's "locked rational screening" method "the center of each halftone dot was locked to the repetition rate of the halftone cell structure."[12] A new method called "unlocked rational screening," as instituted by Adobe in its new Emerald RIP, freed the output device from the confines of one set grid pattern. Dot centers are no longer limited by the cell-repetition rate. Dot placement can then be more precise, as can screen rulings and angles. (See Chapter 3 for related information on unlocked rational screening.)

Notes for Chapter 2

[1]Bill Woodruf, Real World PostScript: Techniques From PostScript Professionals, ed. Stephen F. Roth (Reading, MA: Addison-Wesley Publishing Company, 1988), 17.

[2]Hsieh S. Hou, Digital Document Processing (New York: John Wiley and Sons, 1983).

[3]Miles Southworth, Color Separation Techniques, 3d ed., (Livonia, NY: Graphic Arts Publishing, 1989), 4:19.

[4]Ibid. 5:1-4.

[5]Hou, Digital Document Processing, 83.

[6]Robert Ulichney, Digital Halftoning (Cambridge, MA: MIT Press), 1.

[7]Southworth, Color Separation Techniques, 6:20-21.

[8]Seybold Publications, "Color Production: Theory and Case Studies," The Seybold Report on Desktop Publishing 5, no. 3 (1990): 19-27.

[9]Southworth, Color Separation Techniques, 6:26-27.

[10]Steven Hannaford, An Introduction to Digital Color Prepress, (Wilmington, MA: Agfa Corporation, 1990), 16.

[11]Steve Roth, Real World PostScript: Techniques From PostScript Professionals , ed. Stephen F. Roth (Reading, MA: Addison-Wesley Publishing Company, 1988), 190 -191.

[12]Seybold Publications, "Emerald: The Curtain Rises Slowly," The Seybold Report on Desktop Publishing 20, no. 10/11 (1991): 11-12.

Chapter 3

Review of the Literature

Much attention has been focused on the controversy surrounding the quality of PostScript-generated halftones. The November 3, 1990 Seybold Report on Desktop Publishing details an experiment in which PostScript halftone output generated from three different color separation software packages was compared to high-end scanner output.

Using a Dainippon scanner, two images were scanned, saved as continuous tone data in Scitex CT format, and output by way of a Scitex Raystar film plotter. Matchprints were then made from the film. At this point, the Scitex CT files were downloaded into three color programs: Letraset's Color Studio, Adobe's Photoshop, and Data Translation's PhotoMac. The data was separated in each program, output on a Linotronic L-300 imagesetter, and proofed.

As expected, the Scitex output was judged to be the best match to the original art. The goal, then, for the remainder of the experiment was to use the color correction tools available in the three software packages to try to match the quality of the Scitex color.

The conclusion states:

> . . . given a high-quality scan, desktop separation software can provide relatively high-quality images. The main uncorrectable flaw we encountered is a degree of moire in certain colors, evidently an output recorder issue rather than a separation software one.[1]

It is important to note that nowhere in the article was mention made of the type of PostScript RIP used to drive the film plotter. Recent upgrades to PostScript have resulted in significant improvements to the screening program, but it is difficult to evaluate these results without knowing what version of PostScript was used to RIP the output.

The study further concludes that although better, faster PostScript imagesetters are on the horizon, high-end color systems seem to be the "best bet" for high-quality color separations. (As a side note, Hell GmbH's acquisition of Linotronic should add an interesting dimension to the race for better screening algorithms, as Linotype now has access to Hell's patent for ideal screening angles.)

Macworld came to the same conclusion in its October overview of desktop color.[2] "Mac color and moire patterning go together like summers at the beach and sunburn: where there's one, there's a good chance of finding the other, "[3] it writes, citing PostScript's screening algorithms as the cause of the problem.

A solution may come in the form of faster machines operating at higher output resolutions, as well as the arrival of PostScript Level II. Adobe is also touting its Emerald RIP as being able to calculate screen angles "to within a few hundreds of thousandths of a degree."[4]

Alternate screening technologies for PostScript halftones were the topic of another article in the November 5 issue of Seybold.[5] Discussed was the Flamenco screening system. With Flamenco, all dots are set at 45 degrees. To avoid moire, the dots are offset from each other, one row vertically and one

row horizontally. The drawback is that in the absence of perfect press registration, large color shifts will result as dots begin to overlap.

In the same article, Hell discussed its irrational screening algorithm technology, already acknowledged as the standard for high-end color separation systems. It would appear that Hell would like its High Quality Screening (HQS) technology to become the standard for PostScript devices as well.[6]

Adobe also discussed its new "unlocked rational screening" technology.[7] Unlocked rational screening would change the orientation of the center of the halftone dot so that it is not locked to the grid of the imagesetter. In other words, the halftone dots could be placed in more positions and patterns within a film separation. This flexibility and precision available for dot placement might serve to alleviate some of the soft edges and moire patterns that are often common to PostScript-generated color.

Unlocked rational screening technology was further discussed in the February 25 issue of Seybold as it relates to Adobe's new PostScript product, the Emerald RIP.[8] Whereas, in previous RIPs, "the center of each halftone dot was locked to the repetition rate of the halftone cell structure,"[9] the Emerald RIP no longer fixes them in position. As stated above, unlocked rational screening frees the imagesetter to create a variety of halftone patterns, thus allowing for a higher quality of reproduction.

The Emerald RIP is further reviewed in this article, as is the Agfa SelectSet 5000, an output device driven by Agfa's Emerald Star RIP. Since the Agfa-Emerald Star set-up was used to generate halftones for this study, this Seybold Report was of particular interest. The article did not address any

specific quality issues, however, as its purpose was to provide an overview of currently available PostScript output devices.

An important issue that was touched on in this issue was the advantage drum recorder devices have over roller-fed devices.[10] According to Seybold, register is tighter and more controllable in a drum output device since the film stays stationary and the laser moves. Output devices in which the film moves across the imaging area on rollers using pinch pins are prone to registration problems. Agfa's SelectSet uses internal drum technology to image the film; the film stays stable while the laser exposes from the inside of the drum.

All of the literature suggests that screen angle and resolution problems have plagued PostScript halftones since their inception. One would expect, then, that similar problems would arise in the course of the experimentation related to this project. However, since more sophisticated screening algorithms have been developed along with more precise output devices, it is reasonable to assume that some of these problems have been overcome and that reproduction has improved.

Notes for Chapter 3

[1]George A. Alexander, "Desktop Color Software is Here, but Expertise is Still Needed," The Seybold Report on Desktop Publishing 5, no. 3 (1990): 19-27.

[2]Joe Matazzoni, "Prepress Progress Report," Macworld, Oct. 1990, 168-175.

[3]Ibid., 172.

[4]Ibid., 173.

[5]Seybold Publications, "Color Production: Theory and Case Studies," The Seybold Report on Desktop Publishing 5, no. 3 (1990): 19-27.

[6]Ibid., 16.

[7]Ibid., 17.

[8] Seybold Publications, "Emerald: The Curtain Rises Slowly," The Seybold Report on Desktop Publishing 20, no. 10/11 (1991): 11-12.

[9] Ibid., 11-12.

[10] Ibid., 11-12.

Chapter 4

Hypotheses

There are no perceived differences between four-color halftones generated from a PostScript-driven output device and those generated from high-end color system output devices. This is true for sharpness, detail, contrast, tonal range, and overall pleasing color reproduction.

Furthermore, there are no differences between a publishing professional's and a non-professional's views of certain images with regard to the above criteria.

Chapter 5

Methodology

The focus of this study was to determine if PostScript-generated halftone output met the requirements of high-quality magazine color. To that end, five continuous-tone color images were chosen for scanning. The images fulfilled the basic overall requirements of having good tonal range and contrast, as well as having good detail in the highlight, midtone, and shadow areas. Color copies of the images can be found in the Appendix. Note that these copies are for general reference purposes only, as they are not representative of the resolution or color of the actual separations.

The transparencies were scanned at G. S. Imaging Services in Carlstadt, NJ, using a Crosfield Magnascan 646 scanner. Once a preliminary scan was made, the images were previewed on a Crosfield Scanview 600 Color Previewer. Using the previewed color as guide, overall color corrections were made to G. S. 's standard 35mm scan set-up. Once set-up was complete, the operator began to scan the images, first for the electronic data, then again for the film output.

As the images were spinning, the continuous-tone data was being written to an FSD 330 megabyte disk pack, where the continuous-tone Crosfield data was converted to Scitex CT format. From there, they were downloaded onto a nine-track magnetic tape for importation into a Macintosh environment.

Two nine-track tapes--one tape containing four of the images, the other containing one image--were taken to a Scitex Assembler unit. The tapes were loaded into an Assembler station and onto a desktop track. A Macintosh operator accessed the files on this track and pulled the data across the Scitex Gateway into the desktop environment. The files, still in Scitex CT format, were copied onto an 80 megabyte internal hard drive. From there the files were copied to two 44 megabyte SyQuest removable cartridges.

At Applied Graphics Technologies in Carlstadt, the cartridges were loaded into a portable, removable hard drive. Using Adobe's Photoshop program, the Scitex CT images were called up and previewed. The parameters for screen ruling and screen frequency were set, though changes were made to the standard recommended Adobe screen angles.

Table 1 shows the angles recommended for 133-line screen Photoshop documents.

Table 1.--Recommended Adobe Photoshop Screen Rulings and Angles

Color	Screen Ruling (lines per inch)	Screen Angle (degrees)
Cyan	126.5	108.4
Magenta	126.5	161.6
Yellow	133.3	90
Black	141.4	45

Past experience with PostScript four-color halftones shows better results are achieved if the magenta and black angles and frequencies are switched. Table 2 reflects these adjustments.

Table 2.--Adjusted Adobe Photoshop Screen Rulings and Angles

Color	Screen Ruling (lines per inch)	Screen Angle (degrees)
Cyan	126.5	108.4
Magenta	141.4	45
Yellow	133.3	90
Black	126.5	161.6

At this point, the images were saved as 8-bit binary, 5-part Encapsulated PostScript (EPS) files. The five files represent the four separation files and one composite file for viewing the color on the monitor.

A Quark XPress (version 3.0) page was then created. Four of the five images were brought into one page, and the fifth, onto another. The revised Adobe angles superseded the Quark presets in determining the final screen ruling and screen angles. The images were positioned and cropped on the pages, then sent to an Agfa SelectSet 5000, driven by an Emerald RIP, for right-reading emulsion down negative film output. Output resolution was set for 2400 dots per inch. (Details regarding the SelectSet and the Emerald RIP can be found in the Chapter 3.)

In order to output film separations directly from the Crosfield unit, the images had to be rescanned and sent to the Crosfield output scanner. While the images were still mounted on the drum, the operator recalled the digitally-saved set-up program and began the rescan. Output from the Crosfield M unit was a 129-line screen at the traditional angles. Right-reading emulsion down film was processed through a Kodamatic 960 processor.

When both sets of film were complete, they were taken to G. S. Imaging, where all images were ganged on one Matchprint flat (publication stock) for proofing. Color proofing bars were included to assure that all exposures were made correctly.

Matchprints for the individual images were then cut from the large flat, and the PostScript and Crosfield versions of each image were mounted side-by-side on black display boards. Placement of the images, as to which one was on the right and which one was on the left, was randomly determined. The images were labeled "A" and "B," left to right.

Two groups of 20 viewers were then asked to indicate image preference with regard to the following questions:

1. Which image appears sharper? A, B, or Same.
2. Which image appears to have more detail? A, B, or Same.
3. Which image appears to have a better range of colors? A, B, or Same.
4. Which image appears to have more contrast? A, B, or Same.
5. Which image appears to have a distracting pattern? A, B, or Same.

(A response of "Same" would indicate that there was no perceptible difference between the two images regarding that particular criterium.)

The first group of 20 was comprised of professionals from the printing and publishing industry. It included art directors, color quality analysts, photo editors, dot etchers, and desktop publishing professionals. The second group was comprised of non-professionals, chosen from the population at large.

In order to get an overall opinion from the professionals, they were asked an additional question first: Which image meets your overall quality standards? A, B or the Same/Both? This question was asked first because of

the notion that professionals are too critical of image quality. In answering such a question after critiquing the image in terms of the other criteria, most professionals would have been hesitant to say that the two images were the same.

The data was collected and analyzed to determine if there were response patterns for images "A" and "B" that would indicate a preference for one halftone over the other. A detailed description of the statistical analyses follows in Chapter 6.

Chapter 6

Results

The first hypothesis of this study stated that there are no perceived differences between four-color halftones generated from a PostScript-driven output device and those generated from high-end color system output devices, and that this is true for sharpness, detail, contrast, tonal range, and overall pleasing color reproduction. The second hypothesis stated that there are no perceived differences between a publishing professional's and a non-professional's views of certain images with regard to the above criteria.

These hypotheses were constructed as "null" hypotheses, meaning that the response patterns of the two groups are hypothesized as being the same. The concept of the null hypothesis is analogous to the principle of "innocent until proven guilty," whereby a person is innocent unless he is proven guilty beyond a reasonable doubt. The reasonable doubt component of the statistical argument is referred to as the "level of significance," or p-value. It is this criteria by which the null hypothesis will be either accepted or rejected. The hypothesis cannot, therefore, be rejected unless there are statistically significant results to indicate otherwise. Only then would the null hypothesis be rejected.

Input data for this analysis came from the surveys themselves. All choice "A" responses were translated into the numeral "1", all choice "B" responses into the numeral "2", and all "Same" choices into the numeral "3". Table 3 shows the matrix of data that was analyzed.

Table 3.--Input Data Matrix To Be Statistically Analyzed

1	1	3	2	2	1	3	3	2	2	1	2	2	3	2	1	1	3	3	2	1	3	3	1	3	3
2	1	1	3	3	1	3	1	3	3	1	3	3	3	1	3	3	2	1	2	2	2	1	1	2	3
3	1	1	2	1	1	1	1	2	3	1	2	3	1	2	2	2	1	2	2	1	1	3	1	1	1
4	2	2	3	2	1	3	3	1	2	3	2	3	3	2	2	2	2	2	2	2	3	3	1	3	3
5	1	1	3	2	1	1	1	1	2	3	2	2	3	2	2	2	2	3	2	2	3	2	3	3	3
6	2	1	3	3	1	2	1	3	2	1	3	3	3	2	2	1	2	3	1	1	1	2	3	1	1
7	3	3	3	3	1	2	3	3	3	3	2	1	2	2	3	2	3	2	2	3	3	3	1	3	1
8	1	1	2	1	2	1	1	2	1	2	2	2	1	2	1	1	1	2	1	2	1	1	2	1	2
9	1	2	3	2	1	1	1	3	2	3	1	3	3	1	1	2	2	3	2	2	3	3	3	3	1
10	1	3	1	1	1	1	2	1	1	1	3	1	3	3	3	1	2	1	1	3	3	3	3	2	3
11	2	2	2	2	1	1	2	1	1	1	1	2	1	2	1	1	2	1	2	1	1	3	2	3	1
12	1	1	1	1	2	1	1	1	1	3	1	1	1	2	3	1	1	1	1	2	3	3	3	3	3
13	2	3	2	3	2	1	3	1	3	3	3	3	3	3	2	2	2	2	3	2	3	3	1	2	3
14	2	3	2	1	1	2	3	2	1	2	3	3	2	3	2	1	2	2	1	2	3	3	1	2	3
15	3	1	3	2	1	3	3	3	3	3	3	1	3	2	3	3	1	3	3	3	3	2	3	3	3
16	2	1	2	2	1	2	3	3	2	3	3	3	2	2	1	1	1	2	2	1	3	3	3	2	3
17	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1	2	2	1	1	3	3	1	3
18	2	1	2	2	2	2	1	3	2	2	2	2	2	3	2	2	1	2	2	2	3	1	3	1	3
19	1	3	3	2	1	1	3	1	2	1	3	3	1	2	1	1	3	1	2	1	1	3	3	3	3
20	1	1	1	1	1	1	1	1	1	2	3	3	3	3	2	3	1	1	1	2	1	3	1	1	1
21	2	1	3	2	2	3	3	3	2	3	3	3	3	2	2	3	3	3	3	3	1	3	3	1	3
22	1	2	3	1	2	3	3	3	3	2	1	3	3	2	2	1	3	3	2	2	3	3	3	3	3
23	3	3	1	3	2	3	3	3	3	3	3	1	3	2	2	3	1	1	2	3	3	3	3	2	3
24	3	1	1	1	2	3	1	3	2	3	2	3	3	2	3	2	1	3	2	2	3	1	2	3	3
25	3	3	1	3	1	3	1	3	3	3	1	2	3	2	3	1	1	2	2	2	3	3	3	3	3
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27	1	3	1	1	1	1	1	1	1	1	2	3	3	2	2	1	3	3	1	1	3	3	3	2	3
28	3	2	3	2	3	3	3	3	2	2	1	2	3	2	2	1	2	3	2	2	3	3	3	3	3
29	3	2	1	3	3	3	3	1	1	3	3	3	3	3	3	3	1	3	1	3	1	3	1	2	1
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31	3	3	3	1	1	1	1	1	2	1	1	3	3	2	3	3	3	2	2	1	3	3	1	3	3
32	2	3	2	2	1	2	1	2	2	1	3	2	3	2	3	3	2	3	2	3	1	2	1	3	1
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36	3	1	3	2	1	3	3	3	3	2	2	3	3	2	3	3	1	2	2	1	3	3	3	2	3
37	1	2	1	2	1	3	2	2	2	1	3	2	1	2	1	1	2	2	1	1	3	3	1	3	3
38	1	2	3	1	1	3	3	3	3	3	3	3	1	2	3	3	2	3	1	1	3	3	3	2	3
39	3	1	2	3	3	3	1	3	3	3	2	3	2	2	1	2	1	3	2	1	3	3	1	3	3
40	1	2	2	3	2	1	3	3	2	2	3	2	2	2	2	1	2	3	1	2	3	3	3	2	3

The raw data was first subjected to a dual scaling analysis. Dual scaling is a statistical technique whereby "weights," or scores, are assigned to the rows and columns of the data matrix. By assigning weights to row and column variables, dual scaling captures the latent structure of the dominant patterns of the different variables. The questions were weighted so that response differences between options could be examined. In another analysis using dual scaling, specifically forced classification, weights were assigned to the responses of both professionals and non-professionals in such a way that the two groups were optimally separated over all questions.

For each question, within each group, a two-sample t-test was used to determine if the pattern of responses for the "A" and "B" options were significantly different. The results of the two-sample t-tests are summarized in the following tables.

Table 4.--Professionals' Responses, Across All Images

Question, as it pertains to:	t value	p
1. sharpness	-1.40	0.21
2. detail	0.59	0.58
3. range of color	0.45	0.67
4. contrast	1.77	0.12
5. objectionable patterns	-0.23	0.83
6. overall quality	-0.87	0.43

Note that in all cases, the level of significance, p, is greater than 0.05. For professionals in this study, the "A" and "B" response patterns are not statistically different. Therefore, for professionals, the hypothesis stating that there are no perceived differences between high-end color system halftones and PostScript-generated halftones cannot be rejected.

The same conclusions apply to non-professionals. (See Table 5 below.) Since all the p-values are greater than 0.05, it can be said that there is no statistically meaningful difference between the response patterns of "A" and "B." Therefore, among non-professionals, there is no basis for rejecting the hypothesis that there are no perceived differences between high-end color system halftones and PostScript-generated halftones.

Table 5.--Non-Professionals' Responses, Across All Images

Question, as it pertains to:	t value	p
1. sharpness	1.77	0.12
2. detail	-0.86	0.43
3. range of color	-0.15	0.89
4. contrast	2.17	0.067
5. objectionable patterns	-0.10	0.92

A two-sample t-test was used to address the second hypothesis as well. The results are presented in Table 6.

Table 6.--Professionals' vs. Non-Professionals' Views, Across All Images

Question, as it pertains to:	t value	p
1. sharpness	-3.19	0.0005
2. detail	2.97	0.0052
3. range of color	4.68	0.0000
4. contrast	3.35	0.0019
5. objectionable patterns	2.22	0.033

As evident in the above table, there are statistically significant differences between the way that professionals and non-professionals view certain images. Therefore, the second hypothesis, stating that there are no differences between a publishing professional's views and a non-professional's views, must be rejected.

Chapter 7

Summary and Conclusions

To review, the first hypothesis for this study stated that there are no perceived differences between four-color halftones generated from a PostScript-driven output device and those generated from high-end color system output devices, and that this will be true for sharpness, detail, contrast, tonal range, and overall pleasing color reproduction. Furthermore, it was hypothesized that there are no differences between a publishing professional's and a non-professional's views of certain images with regard to the above criteria.

From the results, it can be concluded that for this sample of individuals, statistically speaking, neither professionals nor non-professionals perceive any meaningful difference between four-color halftones generated from a high-end color system and those from a PostScript-driven output device.

There is, however, a statistically significant difference between the two groups with regard to how each responds across the individual questions. This would indicate that professionals and non-professionals view color images differently. The dual scaling analyses of the two groups together, question by question, did not uncover any significant patterns that might serve to explain why the two groups view color images differently. However, it might be expected that professionals view color in certain images

somewhat differently from non-professionals as professionals would tend to be more critical in evaluating an image.

It is important to note that conclusions reached in this study pertain only to this study and do not presage any far-reaching changes in perception of color.

The results of this study, though supportive of one hypothesis, came as somewhat of a surprise. When this project was first undertaken eight months ago, it was expected that in a comparison test, high-end scanner halftones would be preferred over PostScript-generated halftones. In fact, for the professional viewers, an additional question concerning overall quality was included in the survey to offset what was expected to be overly critical responses from that group. That extra question proved to be unnecessary, as the statistics suggest that neither group perceives a meaningful difference between the two types of color output.

Before coming to any broad conclusions, it must be made clear that this study dealt with only a small sample of individuals. Furthermore, it was not a "random" sample. The images on which the survey is based also carry a caveat: The five images chosen may not be considered representative of all types of images. It remains to be seen how the results obtained in this thesis might apply to the entire populations of professionals, non-professionals, and image types.

Over the past eight months, constantly-evolving technology has closed the gap between scanner-generated color and PostScript color. The argument that PostScript color is "good enough" can perhaps be appended to say that

with regard to this study, PostScript color has proven to be no less acceptable than that of high-end scanner color in terms of perceived quality.

This evolution of higher quality, less expensive output devices could have strong implications for the printing and publishing industries. By sending complete pages through a relatively low-cost PostScript-driven device, publications can reduce costs by eliminating the stripping step from the production cycle. Should desktop color scanners match the quality of high-end color scanners, publications could further reduce costs by separating their own four-color originals.

For now, however, on the basis of the findings of this study, there is reason to believe that four-color halftones generated by PostScript-driven output devices are capable of competing with high-end color system halftones in terms of image quality.

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Appendix

Appendix

Images Used in Survey

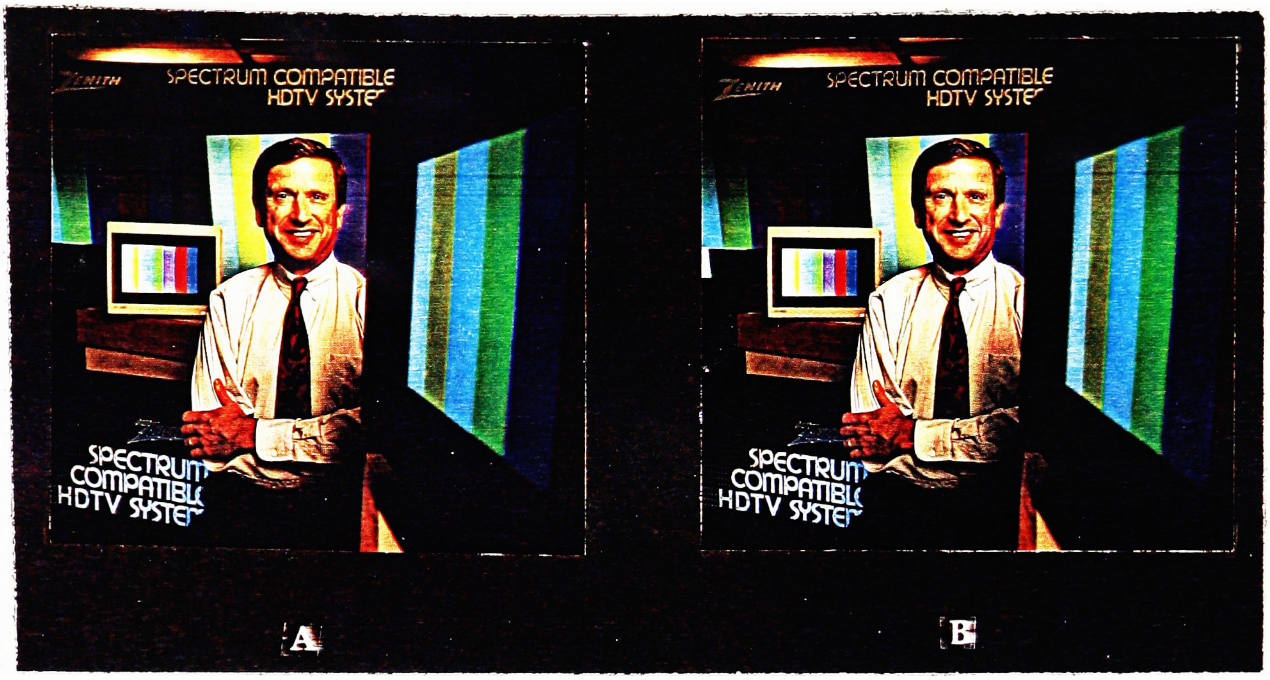

Figure 4. Image used in Survey.

Figure 5. Image used in Survey.

Figure 6. Image used in Survey.

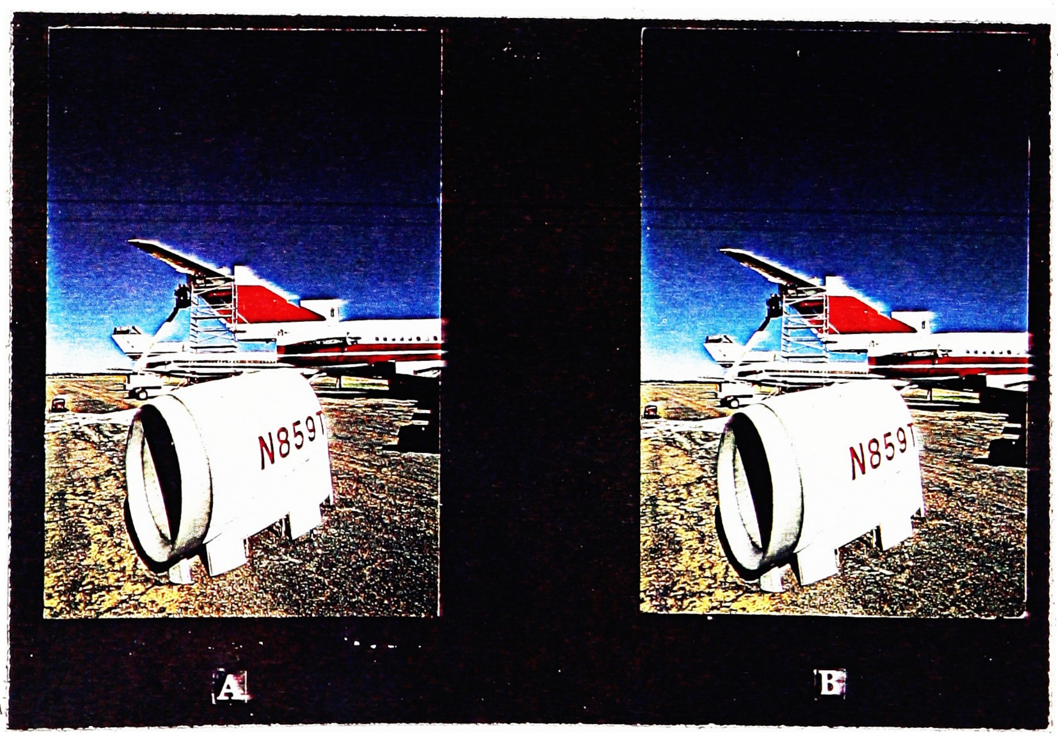

Figure 7. Image used in Survey.

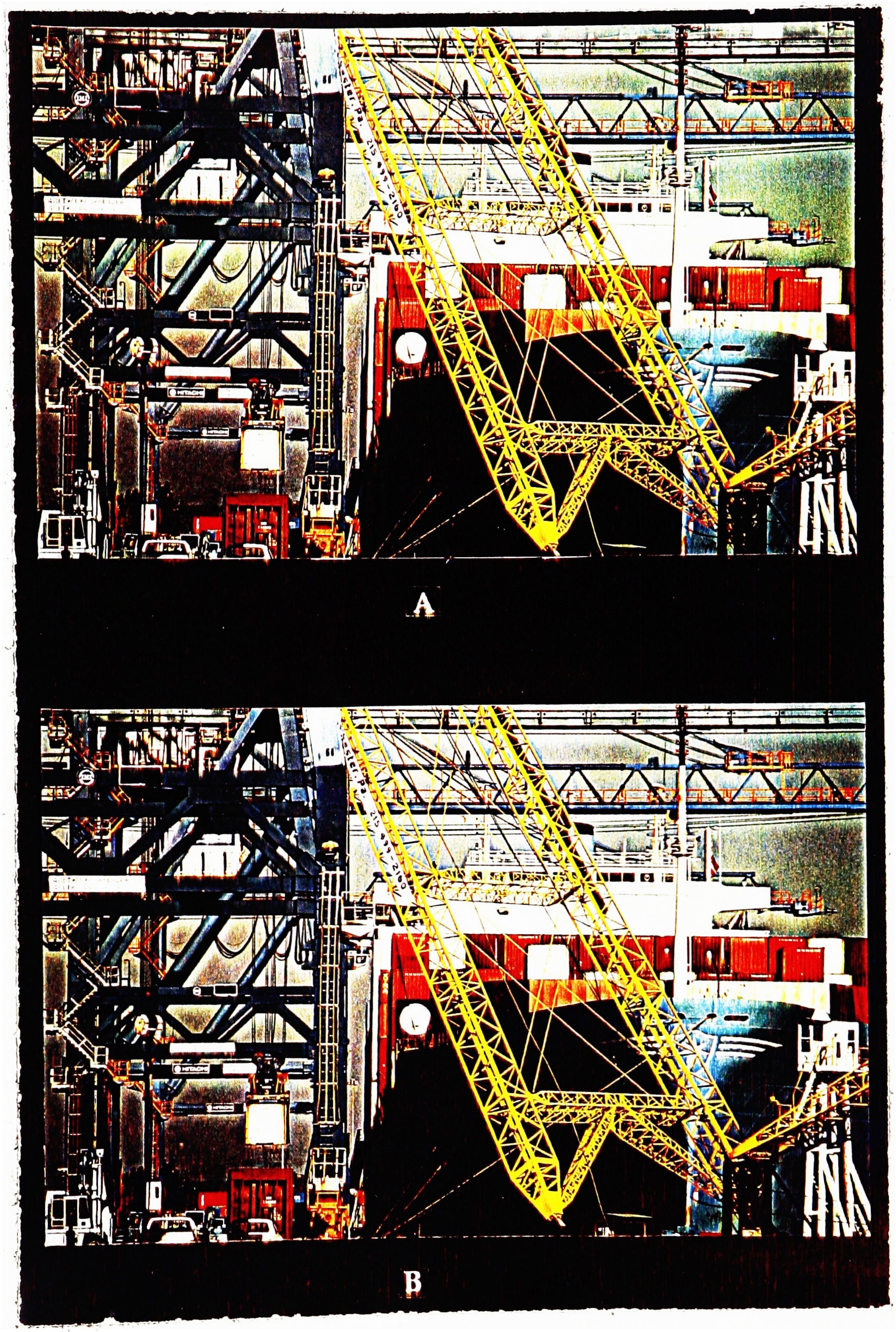

Figure 8. Image used in Survey.