A Study of Performance Differences between a Hybrid and Rapid Access Film System, and Calibration Strategies for an Imagesetter

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Abstract: An imagesetter can be calibrated by measuring solid density and using a linearizing program. However, a better method consists of adjusting exposure in order to optimize resolution. This method works well with some rapid access films; but preliminary tests showed that it may not be applicable to a hybrid system. This study investigated tone reproduction for a hybrid film and a rapid access film on a laser exposure imagesetter, to evaluate the applicability of calibration and linearization methods using checkerboard patterns. An attempt was made to explain the differences between the two films in terms of their fundamental characteristics of spread function and modulation transfer function. It was concluded that optimizing resolution is a good calibration method, if the necessary precautions are observed.

Introduction

An imagesetter is an output device for a desktop publishing system or digital high-end scanner. The basic principle is that the laser

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beam generates laser spots on a light sensitive material which mostly is film today. As the laser sweeps across the film, the electronic signals from the raster image processor (RIP) control the beam when to turn on and off in order to create the image. Normally, the laser is turned on as long as spots are needed in scanning direction; therefore, they produce scanning lines rather than spots. In cross scanning direction, the laser is turned on and off to produce a spot for each pixel. The scan lines and cross scan lines will look like those shown in figure 1, and halftone dots will look like those in figure 2.

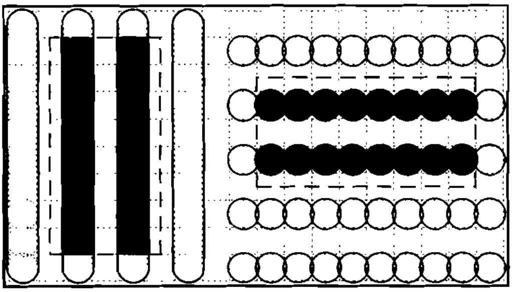


Figure 1. Scan lines (left) and cross scan lines (right)

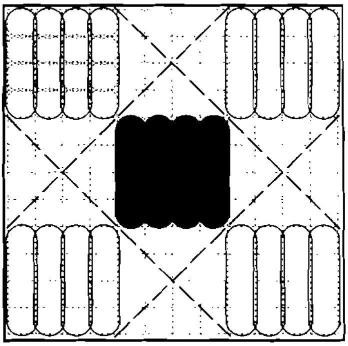


Figure 2. 50% halftone dots made from 4x4 pixels

Calibration and linearization of an imagesetter

When a halftone image is output, dot size has to be controlled in such a way that the produced dots on film are the same as those requested by input program. Therefore, the imagesetter has to be calibrated and linearized. Most recommendations for calibration require that exposure is adjusted until a specified solid density on the film is obtained. The next process, which is characterization, is to relate the input to the output dot area. This process can be done by outputting a halftone scale at the pre-determined solid density and measuring the percent dot areas on the halftone scale. If the output dot areas are not what was specified by the input side, the output dot areas have to be adjusted to obtain the correct results. This process is called linearization which is normally done by linearization software. The measured output dot areas are input into the software. These numbers are used for creating and installing a linearizing curve into the RIP.

Although spot size is strongly dependent upon the laser intensity, it is also influenced by mechanism of generating the laser beam (rise and fall time), film characteristics (modulation transfer function and spread function), spot size relative to addressability, and film processing (development time, developer activity, and developing temperature). It was found that solid density alone is not a sufficient criterion. For instance, in the situation of an under replenished, weak developer, it is necessary to overexpose the film in order to obtain the required solid density. This in turn causes dot gain.

Another way to calibrate an imagesetter is to use the UGRA/FOGRA PostScript Control Strip[1] (Figure 3). Optimum resolution is obtained when exposure is adjusted so that the 1x1, 2x2, and 4x4 checkerboard patterns and the 50% tint patch have the same density. In theory, by calibrating an imagesetter this way, linearization is not necessary for a linear film system such as rapid access. However, it was claimed that this method may not work for very high contrast films (hybrid system) because of the non-linear response for very small image detail[4].

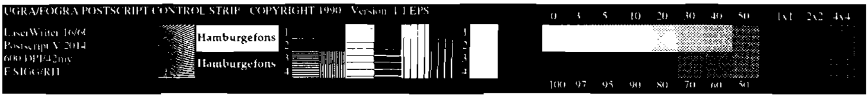


Figure 3. The UGRA/FOGRA PostScript Control Strip

Graphic Arts Film and Chemistry

Unlike photographic pictorial films, which are low in contrast to allow a continuous tone scale, graphic arts films have a high contrast. In general, the higher the contrast, the more desirable a film is for graphic arts applications. The film-chemistry combinations, used to achieve this desirable high contrast, can be categorized into three groups: rapid access, lith, and hybrid[3].

Rapid Access film and processing generally results in the lowest contrast of the graphic arts choices. It, however, benefits from the simplest film-chemistry combination, with moderate tolerance for temperature and replenishment variations. In addition, the density produced is directly related to the exposure received and there is little, if any, interaction between adjacent exposed areas. Rapid access film-processing also tends to have a lower maximum density, at practical exposure levels, and a somewhat larger dot fringe that is associated with a softer toe of the DlogE curve.

Lith film and processing was the traditional approach used to achieve a higher contrast from graphic arts films. Lith film-processing achieved this increase in contrast through the use of chemical effects produced as a result of the initial stages of development. One simple model, for some types of lith development, suggests that a more active developer is formed from the by products of development that migrates outward from the area of core development. This more active developer is able to develop areas with sub-threshold exposure, resulting in a very hard edge with a short transition or fringe area. The draw back to lith film-developer pairs is that these are generally a balanced combination where both film and chemistry contribute to the desired effects. In addition, the chemical balance, associated with time, temperature, and replenishment, is much more critical than is found in rapid access combinations. In lith development, there is interaction between areas of exposure and the density produced may not have a linear relationship to the exposure received. However, like rapid access films, density will only be produced in areas actually exposed (either directly or by light spread in the film emulsion).

Hybrid film and chemistry combinations represent an attempt to achieve the high contrast usually associated with lith development using simpler chemistry associated with rapid access development. Generally, some type of infectious development is present. In the simple explanations of this type of film-chemistry combination, chemical by products of the initial development of the core area may produce chemical fogging agents that make areas immediately adjacent to the exposed area also developable. As these products must diffuse through the emulsion the resultant density profile is usually very high with even a smaller fringe than is found with lith film-chemistry combinations. The drawback is that density may occur in areas where no exposure occurred. This is sometimes referred to as chemical spread. In many situations, particularly imagesetters, this may be compensated for in setup. The newer hybrid films attempt to restrict the magnitude of the diffusion of these chemical agents to minimize the physical magnitude of chemical spread. Note that some films may be processed in more than one type of chemistry and as such may exhibit different characteristics in different film-chemistry pairings.

Lith films are no longer used today. In general, it is claimed that the hybrid system renders high solid density, high contrast and less fringe. However, it has possibly lower resolution, low exposure latitude and a non-linear response. Rapid access, on the other hand, has lower contrast, less solid density and more fringe, but it gives higher exposure latitude and linear response to the entire range of halftone dot areas.

Spread Function (SF) and Modulation Transfer Function (MTF)

One of the mathematical models that work well for graphic arts films was proposed by Frieser in 1960 as follows:

MTF $$m(v) = \frac{1}{(1+(\pi k v/2.3)^2)} \quad (1)$$

SF $$I(x) = (2.3/k) * 10^{(-2|x|/k)} \quad (2)$$

where			
	m	=	modulation
	I	=	intensity
	v	=	spatial frequency in cycles/mm
	x	=	distance in microns
	k	=	Frieser coefficient

When the light distribution at the sharp edge of a line is considered, the actual light distribution inside the emulsion can be calculated by convoluting the ideal edge intensity profile with the point spread function. The relationship of the intensity and distance is described by the following equations:

$$I(x) = (1/2) * 10^{(x/k)} \quad \text{for } x = -\text{infinity to } 0 \quad (3)$$

$$I(x) = 1 - (1/2) * 10^{(-x/k)} \quad \text{for } x = 0 \text{ to infinity} \quad (4)$$

By using the above mathematical models, David Q. Mc. Dowell has shown[2] that the MTF and SF of typical graphic arts products can be derived by the following procedure: an exposure series of 150-lpi, circular dot tints of 30% and 70% dot area are performed on the film of interest in a contact frame; then dot radius at different exposures is calculated; a graph of dot radius change as a function of exposure is then plotted; and the the Frieser coefficient (k) value can be derived.

The Frieser coefficient, k, indicates the degree of spreading of the image, compared to the image that reaches the film. A system with higher k value has a larger spread than one with lower k values. In other words, the decrease of modulation transfer factor as a function of spatial frequency is faster. It was found that most of graphic arts products' MTF and SF fit the Frieser model with k values of between 5 to 12. Furthermore, a plot of dot size change vs. relative LogE can show the presence of chemical spread.

Objectives of the Study

This study investigated whether the calibration method of matching density of the 1x1 checkerboard and that of 50% reference tint is applicable for a film of hybrid technology (Kodak Imageset 2000 film) and a traditional rapid access film (Kodak PagiSet film). The performance differences between the two films were also investigated in terms of the sensitivity to dot size change and change in control element size as a function of exposure variation. It also attempted to explain the differences in terms of sensitometric contrast, film modulation transfer function (MTF), and chemical spread, and define the preferred control elements and control strategy for each system.

Methodology and the Results

The experiment was performed on an Agfa SelectSet 5000 imagesetter/Star 400 RIP. Kodak PagiSet film which is a rapid access film, and Kodak Imageset 2000 film which is a hybrid film were used in the experiment. Both films were output at the addressability of 2,400 dpi (10.6μ per spot), and processed in 1:2 (developer : water) Kodak RA 2000 rapid access developer at 95°F, 30 sec developing time, and 50 ml/sq.ft. replenishing rate. The experiment was divided into two major parts: continuous-tone stepwedge exposure series, and halftone exposure series.

Continuous-tone stepwedge exposure series

Continuous-tone stepwedges were taped emulsion-to-emulsion in the feeding cassette using thin, clear tape in the darkroom. A solid area created in QuarkXPress was output to the imagesetter through these continuous-tone stepwedges onto the films. A series of exposures was performed for each film in order to obtain the results from underexposure to overexposure. The densities on the original and reproduced stepwedges were measured using a transmission densitometer. DlogE curves then were plotted as shown in figure 2. To find the relationship between laser intensities and exposures, the original densities that reproduced the density of 0.3, 1.0, and 2.0 on film were determined, for each laser intensity setting, from the Dloge E curves shown in figure 4. Then a plot of these densities and log laser intensities was made for each film as shown in figure 5.

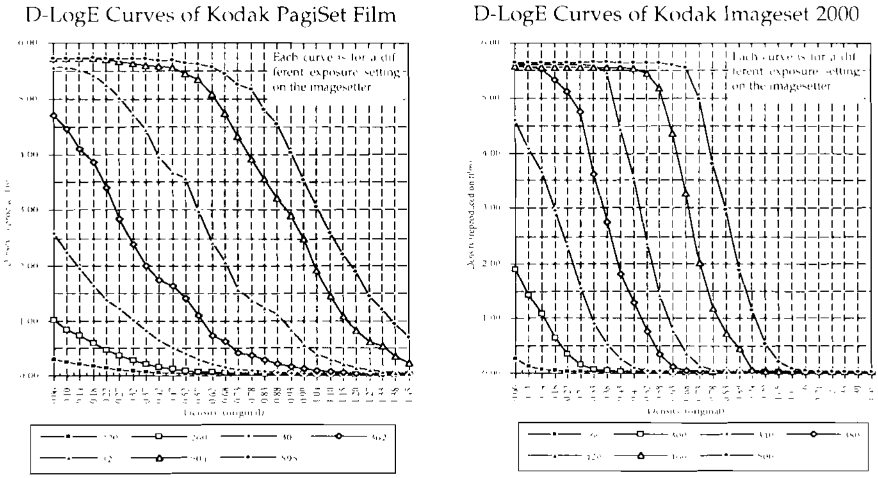


Figure 4. D-logE curves of Kodak PagiSet and Kodak Imageset 2000 Film

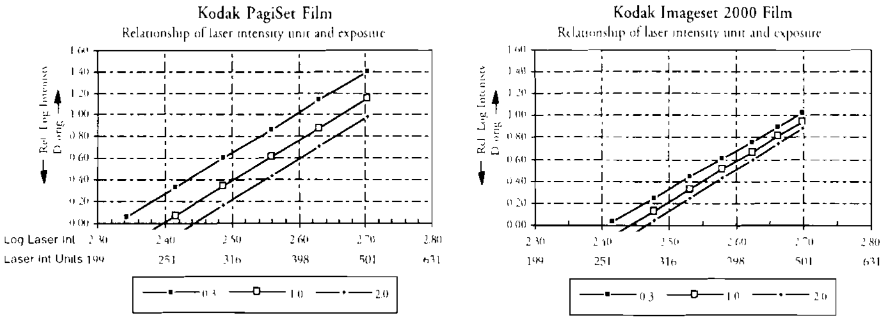


Figure 5. Relationship between Relative Log Intensity and Relative Log Laser Intensity Unit on Kodak PagiSet and Imageset 2000 film

The average gamma of Imageset 2000 film was 18.20 whereas that of the PagiSet film was 7.75. Figure 5 shows that the relationship between log laser intensity unit and relative log exposure is linear. The slopes of the lines for both films are approximately the same because they are a function of the laser beam, and not of the films. However, the proximity between lines of Imageset 2000 film and those of PagiSet film are different due to the difference in film speed. The higher the film speed is, the closer the lines are. The average of slopes of these lines is 3.72. By knowing this slope, the difference of log exposures between two given laser intensity units can be calculated from the following equation:

$$\Delta \log E = S * \log(L2/L1)$$

where S = slope of lines of graphs shown in figure 29
L = laser intensity unit

This analysis made it possible to plot the graphs in terms of relative log exposure rather than just in arbitrary laser units.

Halftone exposure series

A test form created in QuarkXPress contains the UGRA/FOGRA PostScript Digital Control Strip, the RIT Digital Output Resolution Tester, the RIT Pixeldot Test Target (Figure 5.5), and halftone scales with different screen rulings (100-lpi, 150-lpi, 200-lpi, and 21-µ FM Velvet screen). First, for each film, laser intensity was adjusted to reproduce the 50% patches of 100-lpi, 150-lpi, 200-lpi, and Velvet-screened scales as close to 50% dot area as possible. This is called ***practical exposure*** in the remainder of the report. Next, for each film, laser intensity was adjusted to match the density of 1x1 checkerboard to 50% tint. Then the dot areas on the halftone scales and the RIT Pixeldot Test Target were measured. The requested dot areas in PostScript were plotted against the dot area differences between the actually obtained dot areas and the requested ones, as shown in figures 6 to 9. Finally, the laser intensity was adjusted in order to obtain results from underexposure to overexposure. Each exposure step was different by a constant factor of 1.044.

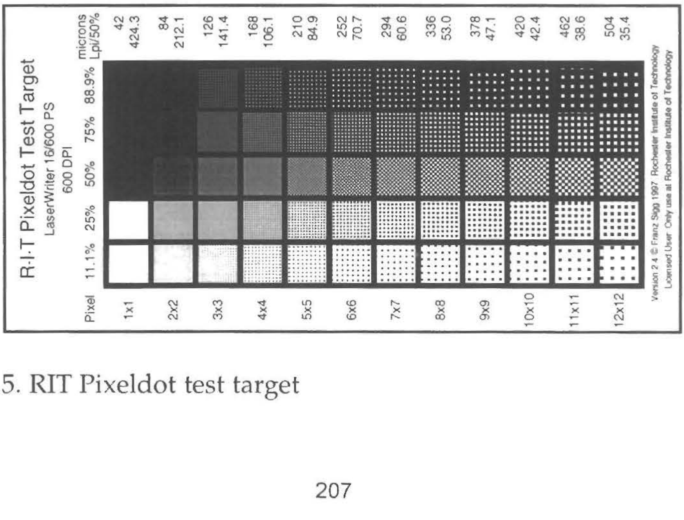


Figure 5.5. RIT Pixeldot test target

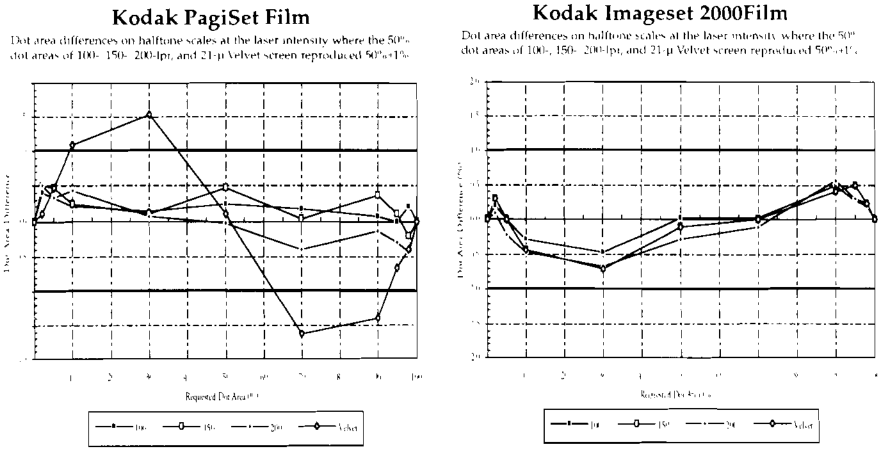


Figure 6. Dot gain and loss of halftone scales output on Kodak PagiSet film and Kodak Imageset 2000 film at practical exposure

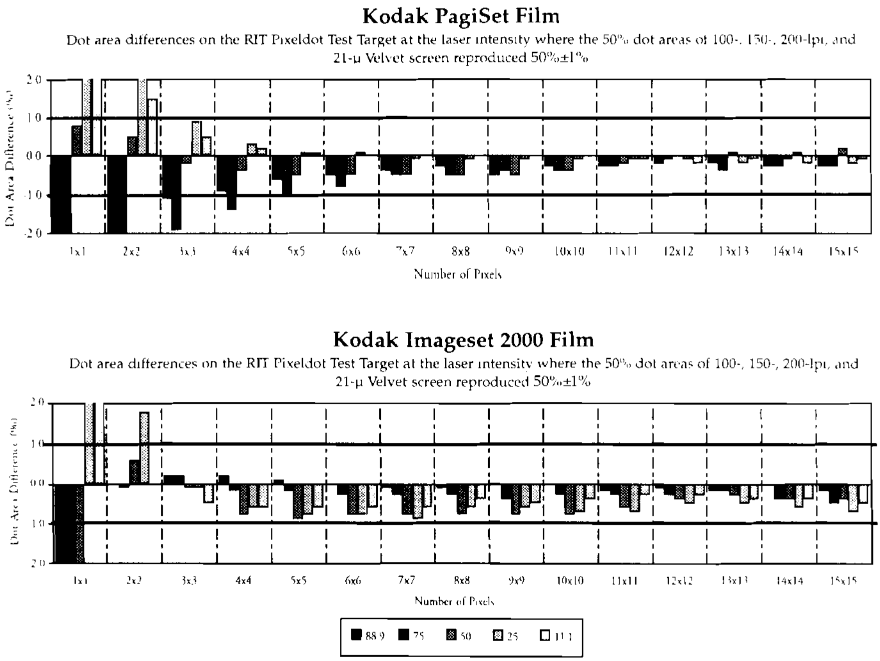


Figure 7. Dot differences of the RIT Pixeldot Test Target at practical exposure for both films

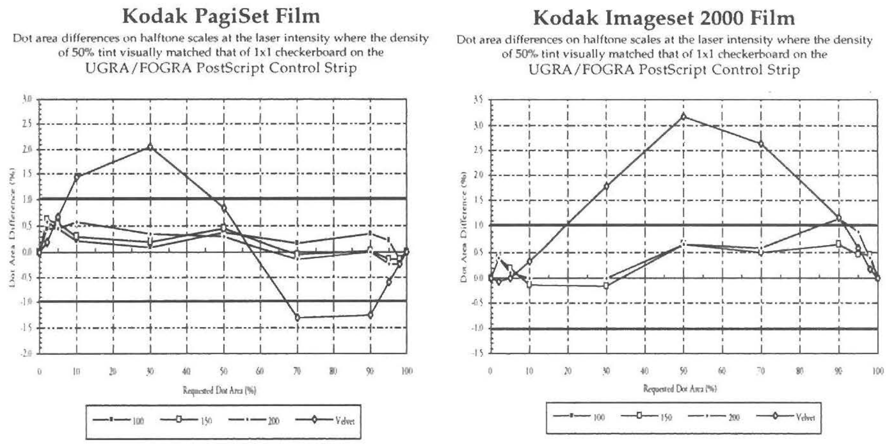


Figure 8. Dot gain and loss of halftone scales at the exposure of which the density of 50% tint visually matched that of 1x1 checkerboard on the UGRA/FOGRA PostScript Control Strip

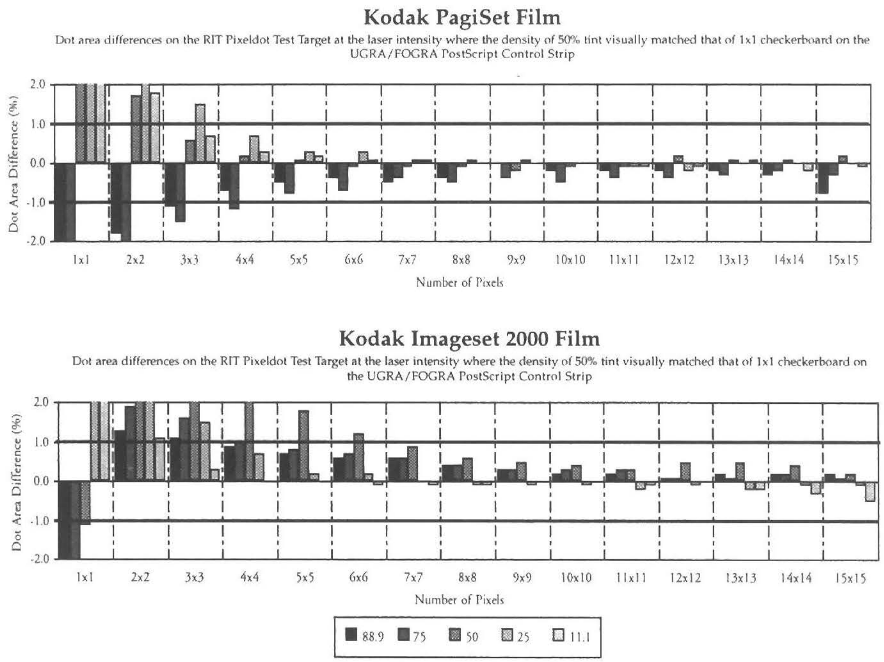


Figure 9. Dot differences of the RIT Pixeldot Test Target at the exposure of which the density of 50% tint visually matched that of 1x1 checkerboard on the UGRA/FOGRA PostScript Control Strip

Matching the density of 1x1 checkerboards with that of 50% reference tints is a valid method for rapid access systems for the dot size of 52.5 microns or larger. The smaller dot sizes show a non-linearity. However, maximum density of PagiSet film at practical exposure, which is 2.08 is too low. Overexposure is needed in order to reproduce an aesthetically acceptable solid density of 3.0. This increase of exposure makes tone reproduction non-linear which necessitates the use of a linearizing program (see figure 10 and 11). For Imageset 2000 film, when the density of

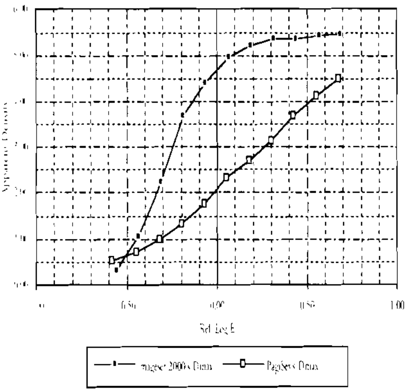


Figure 10. Maximum densities of two films as a function of exposure

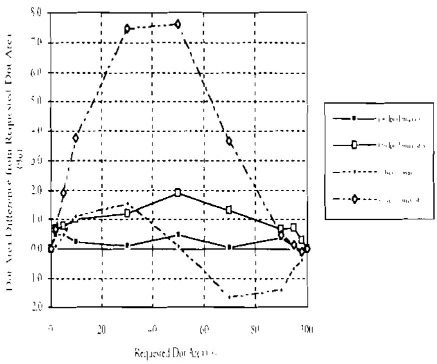


Figure 11. Linearity of halftone and 21-µ Velvet screen at Dmax of 2 and 3 on PagiSet film

the 1x1 checkerboard matched that of the 50% reference tint, small halftone dots (200-lpi and 21-µ Velvet screen) were not linear within ±1% (see figures 8 and 9). It was found that when exposure was adjusted so that 50% tints on halftone scales were as close to 50% as possible (figures 6 and 7), the density of the 2x2 checkerboard matched that of the 50% reference tint while the density of the 1x1 checkerboard was lighter. This exposure also provided a satisfactory solid density.

Spread Function (SF), Modulation Transfer Function (MTF), and chemical spread

In order to calculate SF and MTF by measurements of edge movement, the dot areas of 25% and 75% checkerboards were converted into dot widths. To simplify the calculations, it was assumed that the spot shape was square, and the density of solid area and that of halftone dots were same. The plots of relative edge movement and relative log exposure are shown in figure 10. Then Frieser's coefficient (k) was derived and Frieser's edge movement were calculated by using equations 3 and 4 .

Figure 12 shows the plots of the actual edge movements of 25% and 75% test elements, and the edge movement calculated by Frieser's equation. The average k's of checkerboards on PagiSet film and Imageset 2000 film

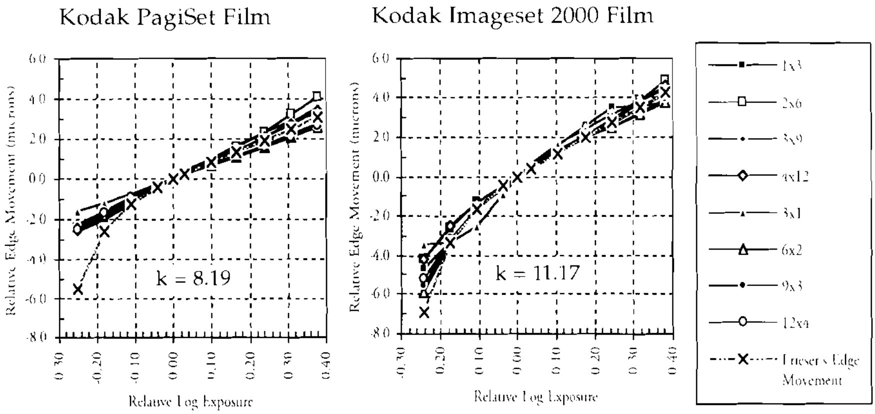
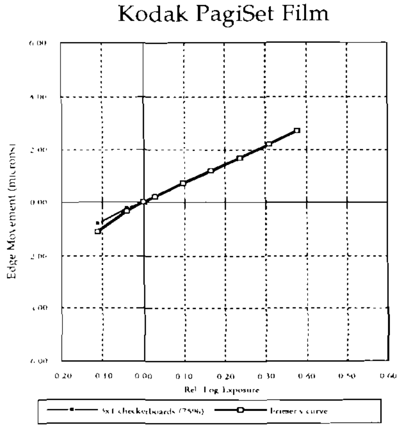


Figure 12. Edge movements of checkerboards as a function of relative log exposure

are 8.19 and 11.17, respectively. Figure 13 shows the plots of the Frieser's curve and the one for the 3x1 checkerboard. On PagiSet film, the curve shape of Frieser's curve matched very well the one of the 3x1 checkerboard. But on the underexposed side, the edge movements of the experimental curves were less than the one calculated using Frieser's equation. This probably results from the very low maximum densities of the underexposed PagiSet films. There are low density lines in between the scan lines. This significantly uneven maximum density causes some inaccuracy of edge movement calculations. Therefore, the plots of relative edge movement at the exposures that gave such low maximum densities were disregarded.

On Imageset 2000 film, Frieser's curve had the same curve shape as the actual 3x1 checkerboard's curve, but they were somewhat shifted relative to each other. This curve shift implies that there is chemical spread on Imageset 2000 film. Because the exposure axis is relative, the experimental curve can be moved relative to the Frieser's curve to match the curve shapes. In order to do that, the experimental curve also had to be moved in the edge movement axis by two microns. Therefore, the chemical spread on Imageset 2000 film is approximately two microns.



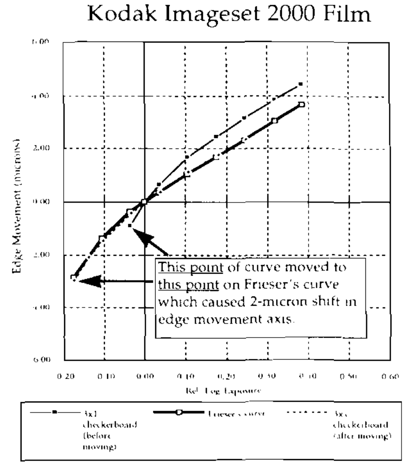


Figure 13. The plots of the Frieser's curve and the actual curve of the 3x1 checkerboards on PagiSet film, and Imageset 2000 film

Using the k's, the spread function and MTF were calculated from equations 1 and 2. The plots of MTF and spread function are shown in figures 14 and 15. Imageset 2000 film has a slightly inferior MTF.

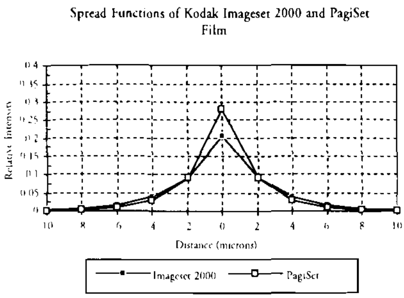


Figure 14. Spread functions

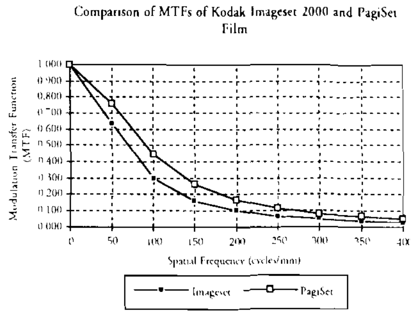


Figure 15. MTF of both films

Exposure latitude

In terms of exposure latitude, Imageset 2000 is more sensitive to exposure changes than PagiSet film. The smaller the dot size, the bigger the difference of dot area change between the two films is. However, within an acceptable tolerance of ±1%, the exposure latitude in terms of laser intensity units is only slightly different.

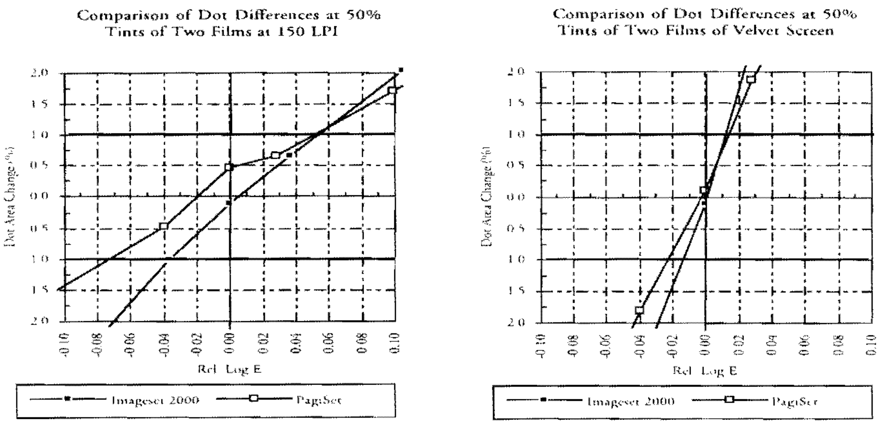


Figure 16. Exposure latitude of dot difference within ±1% from practical exposure

Summary

It was found in this study that matching the density of checkerboard patterns to 50% reference halftone tints provides an accurate means to determine practical exposure. However, different calibration strategies are required for hybrid and rapid access film. As far as resolution is concerned, matching the density of the 1x1 checkerboards with that of the 50% reference tints is a valid method for PagiSet film for the conventional screen rulings of up to 300 lpi. The smaller dot sizes show a non-linearity due to the low contrast of the film. However, if the exposure is adjusted for this resolution, the density of "solid" is only 2.08. Overexposure is needed in order to reproduce an aesthetically acceptable solid density of 3.0. This increase of exposure makes tone reproduction non-linear; therefore, a linearizing program is required. First matching the density of the 1x1 checkerboard to that of 50% reference tint and the increasing exposure to a solid density of 3.0 assures that the least amount of linearization is used.

For Imageset 2000 film, using the 2x2 checkerboard (21 microns) instead of the 1x1 checkerboard (10.5 microns) gives accurate dot areas within ±1%. The density of 1x1 checkerboard reproduced lighter than that of the 50% reference tint at the exposure where the 50% tint of a 150 l/in screen shows no dot gain, due to the low MTF and because the very small spots of the 1x1 checkerboard are less affected by chemical spread than the larger ones. At this exposure, Imageset 2000 film is also more linear over the range of screen rulings up to 400 lpi, and has adequate solid density. However, the conclusion from these two films may not be true for other rapid access or hybrid films, and for other system conditions (imagesetters).

In terms of exposure latitude, dot area change on Imageset 2000 is more sensitive to exposure change than that on PagiSet film. The smaller the dot size, the bigger the difference of dot area change between the two films. However, within an acceptable tolerance of ±1% dot area variation, the exposure latitude in terms of laser intensity units is small.

In addition, the results in this study showed differences between the two films in terms of contrast, modulation transfer function, and chemical spread. Imageset 2000 film has significantly higher contrast than PagiSet film. But Imageset 2000 film has a slightly poorer MTF than PagiSet film. Imageset 2000 film also showed some chemical spread while PagiSet film did not. These factors determine the response of films to exposure. At very small spot sizes, both MTF and chemical spread contribute to the spot size. However, above the certain dot size, the contrast of film is the dominant factor. Combining all three factors: contrast, MTF and chemical spread, Imageset 2000 film clearly gave better results in terms of maximum density, hard dots, and linearity over the range of halftone dot sizes.

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