CALIBRATION OF POSTSCRIPT-BASED COLOR REPRODUCTION SYSTEMS

By Michael Blum* and Michael Thorne**

Abstract

This paper presents an overview of the variables involved in imagesetter calibration. It describes some of the common methods used to control these variables in PostScript imagesetters, particularly the use of PostScript transfer routines to accomplish this purpose. Different approaches to managing transfer routines and the interactions of competing transfer functions are discussed. These include attaching transfer routines to individual documents, creating printer description files which include transfer routines, and downloading the transfer routines into the imagesetter. The advantages of a device-independent approach to calibration are discussed.

Introduction

In the past, color reproduction systems were available only as a package, typically offered by a single vendor who provided integrated hardware and software, and offered training, documentation, service, and technical support. With this type of system, device-independence is largely irrelevant.

PostScript-based color reproduction systems, on the other hand, are generally multi-vendor systems. The components may be assembled from various sources: a general-purpose computer from Apple, IBM, NeXT, or Sun; a high-resolution imagesetter from Linotype-Hell, Agfa/Compugraphic, or a number of other vendors; a scanner from Howtek, BarneyScan, Microtek, Sharp, or Nikon; and dozens of word processing, graphic manipulation, photo retouching, and page layout programs. In this context device-independence is all-important.

In building a traditional system, the designers had the flexibility to decide which tasks should be handled by hardware and which by software, and they had control over the entire process. In the PostScript environment, developers typically design just one component for a system, often not knowing what other components might be present when the system is running.

In looking at calibration of the output on traditional color reproduction systems, we find that the vendors provided appropriate tools to be used by skilled craftspeople and technicians. A prep shop and printing plant might be chosen partly on their ability to maintain accurate calibration of the system. With desktop publishing however, this crucial role might be left up to the document originator, graphic designer, or imagesetter operator.

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A common complaint is that films produced by imagesetters from desktop publishing programs are often inaccurate in terms of dot percentages. It is especially ironic that some of these programs give the user the ability to request screens in increments of .1% dot, yet the actual film output may be off by 10 - 20 % or more. This is partly due to a lack of standardization of the calibration methods for PostScript-based color reproduction systems. It is also due to a lack of knowledge on the part of users of such systems in properly applying the calibration techniques available.

Background

Typesetting machines in the past had been controlled by command languages which were specific to a particular manufacturer and even a particular product line. These command languages were designed to be used as part of a turn-key system in which all elements were integrated. With the rising popularity of personal computers and the use of mass-market software for imaging text and graphics, it became an enormous task for software developers to write device drivers to support the large variety of printers and typesetters which a given user might select. PostScript was developed as a page description language to meet the growing need to control the imaging of graphics; to deal with the imaging requirements of raster devices, such as laser printers, which must image an entire page at a time, rather than one character or one line at a time; and to allow software developers the freedom to create programs which would work with a variety of output devices. In a PostScript imaging system, the same page data can be imaged on a variety of PostScript devices of differing resolutions without modification. This is because no device coordinates are specified in PostScript page descriptions. Rather, coordinates in an abstract user space are specified. It is the job of the interpreter to convert these coordinates into the device coordinates. PostScript was designed to be a device- and resolution-independent imaging system.

Prior to the advent of PostScript, calibration of typesetting systems centered on monitoring the maximum density achieved on the photographic film or paper, and measuring the stroke width of the actual type. Monitoring the stroke width of type was particularly important to ensure that pasted-up corrections matched previously output galleys of type. A study by Blum (1979) showed that monitoring the integrated density of an array of dots generated by the typesetter was more indicative of stroke width changes than merely measuring maximum density.

As typesetting machines have given way to imagesetters, it is crucial that calibration not only provides consistent stroke width on type but also accurate dot percentages. This improves the black and white reproduction capabilities of such systems and is essential if such systems are to be used for color reproduction.

Document management issues and strategies

To understand some of the problems associated with the calibration of PostScript-based color reproduction systems, it is important to understand certain document management issues and strategies. Nearly all mass-market desktop publishing software packages provide an option of outputting directly from the application to a high-resolution PostScript printer. During output, the pages are translated from the native graphic imaging system used in the application, to PostScript page descriptions which can, in turn, be interpreted by the Raster Image Processor (RIP) of the imagesetter. To speed up this process, many applications make use of PostScript dictionaries which are sent to the RIP and are used to allow the application to send its page description in a shorthand notation.

In an imaging service bureau, on the other hand, it is also common to have customers create PostScript files from the application (sometimes known as a "PostScript dump" or "printing to disk") for downloading to the RIP by the service bureau. With this approach, the application still converts its native graphic imaging system to a PostScript page description and may still make use of various dictionaries in the RIP — but it is instructed to save this file to disk for transport to the imaging service bureau, rather than output directly. From the service bureau's point-of-view, this approach is often easier, since it does not require that they purchase and become proficient with the specific application used to create the file, and it provides one solution to the font-naming problems that have plagued the industry. This approach, however, does require extreme care with respect to calibration of the imagesetter, as will be discussed later.

While PostScript is theoretically device- and resolution-independent, some applications attach device-specific code when the file is output or printed to disk. This would be initiated by the user selecting an appropriate printer description file prior to outputting. Such files include PPD files — PostScript Printer Description files — for use with software from Adobe and others, and APD files — Aldus Printer Description files — for use with Aldus software. Since the code attached by the printer description file is device-specific, a file printed to disk from an application using this approach may not image properly if another device is substituted for the target device. Furthermore, software calibration instructions may be contained in the printer description files, although these may not be appropriate for current conditions.

Another issue related to document management has to do with the variety of methods that may be used to specify positive or negative output from a PostScript imagesetter. An imagesetter used to output type on resin-coated paper will usually be set up for right-reading emulsion up positives. For color work, though, right-reading emulsion down negatives or another combination of image orientation and polarity may be required. Switching from positive to negative output may be done in one of three ways: through a page setup option in the application (which we may refer to as a software negative); at the recorder's control panel (which we may refer to as a hardware negative); and by modifying the RIP by downloading a "negativeprint" command (which we may refer to as an inverted positive). Some care must be exercised in the choice of these options, since their use in combination will negate one another. This can particularly be a problem in an output service bureau environment where customers may furnish PostScript files for output with software negative commands imbedded in the files and service bureau personnel may accidently invert those commands with negativeprint downloads or control panel settings requesting hardware negatives. More significantly, in the context of this study, and discussed in more detail later, is the fact that the method of choosing the output polarity in a PostScript imaging system may also affect software calibration of halftone dots.

PostScript provides a transfer function via the settransfer command for the purpose of linearizing grayscale response. While the settransfer command is a legitimate PostScript operator, Adobe's document structuring conventions strongly suggest that it not be used, or be used only with caution, in page descriptions, since a transfer function will usually render a page description as device-dependent. However, many popular desktop publishing applications, including programs published by Adobe, include this and other device-dependent commands. When PostScript files are encapsulated in one another these transfer commands can interact with one another in undesirable ways, thus impeding the accurate calibration of the system.

Some variables associated with imagesetter calibration

Intensity of the laser light in a PostScript imagesetter is a major factor in calibration for accurate halftone dot exposure. Fink (1990a) noted the trend towards overexposure in studying the output from service bureaus across the United States. Overexposure is commonly used to produce high densities which are pleasing to the eye, though often unnecessary for production conditions. As imagesetter operators increase laser exposure to achieve crisp black type and line art on resin coated paper, they are simultaneously darkening any screen tints and halftones on the pages they image. As laser light intensity is increased, it generates negative films with a higher maximum density, while at the same time lightening — or sharpening — any screen tints or halftones on the printed page. Figure 1 shows the relationship between laser intensity, film maximum density, and dot error at the 50% level. Note that dot error roughly parallels the increase in film density. The next generation of imagesetters with tightly focused laser beams having spot sizes on the order of 10-microns, should help improve this problem. Fink (1990a) and Thorne (1991) have noted that the relationship between overexposure and dot size will vary from emulsion to emulsion.

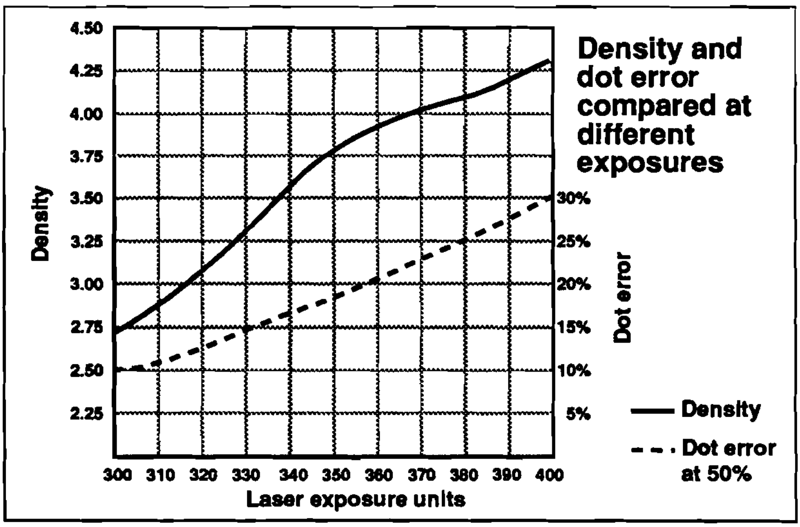

Figure 1

Differences in dot sizes output as positive vs. negative with PostScript imagesetters were described by Thorne (1991). Figure 2 represents the dot sizes output compared to dot sizes requested for a typical system using positive paper and negative film. Note that the two curves appear symmetric with respect to the diagonal.

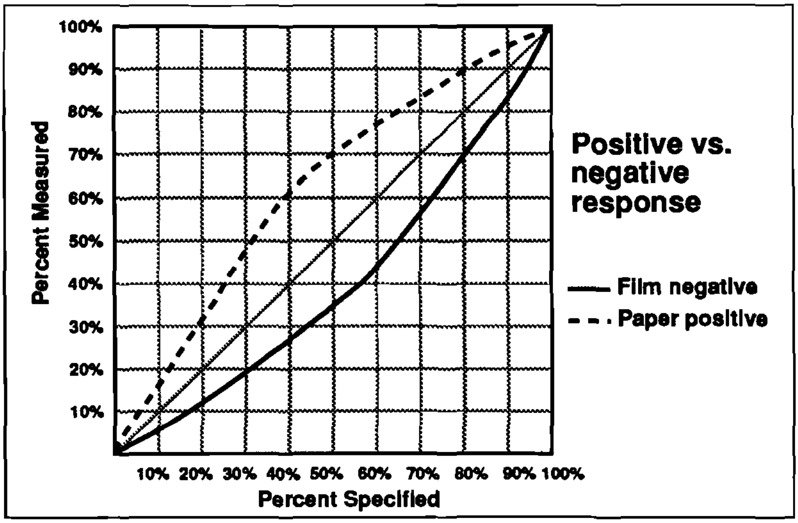

Figure 2

Rotating the upper curve about the diagonal reveals approximate symmetry, as shown in Figure 3.

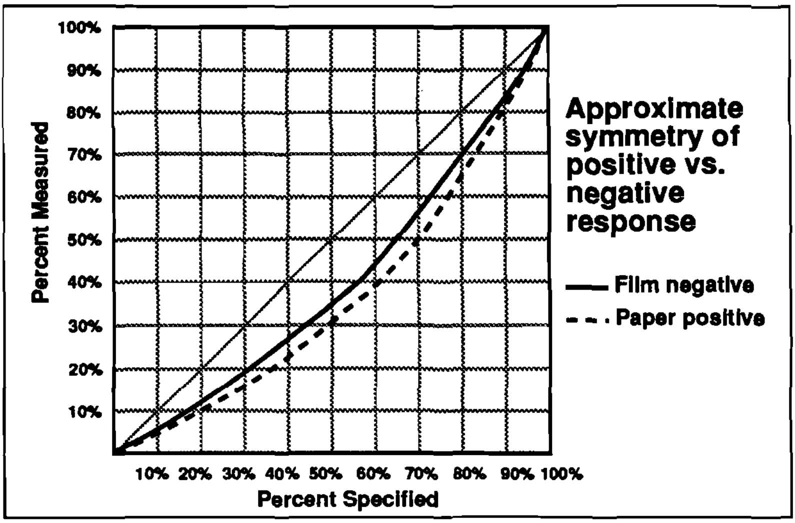

Figure 3

Thorne explored changing processing conditions in order to be able to use one set of transfer values to calibrate an imagesetter for both paper and film. As Figure 4 indicates he was able to achieve a high degree of symmetry by modifying both laser exposure and development. Alternately, laser exposure and development may be left constant, and a different set of transfer values loaded for each type of material used.

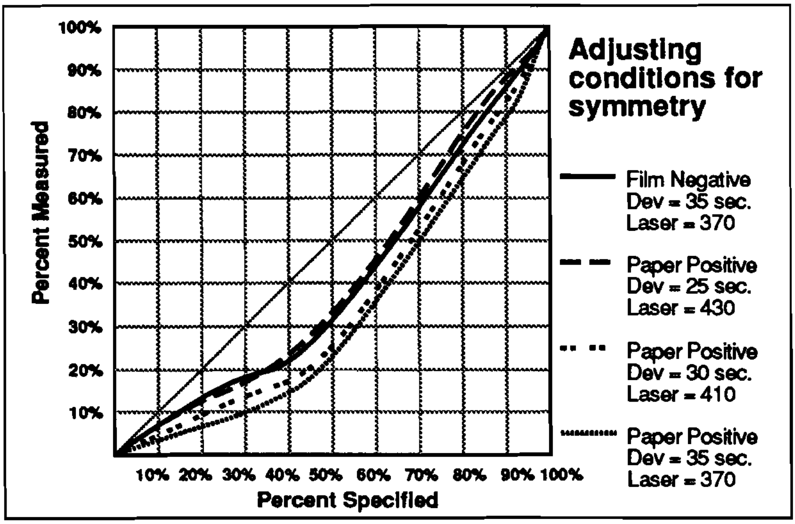

Figure 4

PostScript halftones and their calibration through software

The PostScript setscreen command allows programmers to specify the screen frequency (or ruling), screen angle, and halftone dot shape. On interpreting a setscreen command, the RIP selects an appropriate frequency and angle that will tile seamlessly, and generates 256 bitmaps for use in imaging this screen. The bitmaps vary from totally white to solid black, and grow in a pattern defined by the PostScript spot function. As a page description requests various gray levels, the appropriate screen bit-map is referenced, and used to determine which pixels to turn on or off in the imagesetter. The PostScript transfer function re-maps the requested gray values to alternate halftone bitmaps as desired. This is sometimes used within an application to create particular effects on a given image, such as a contrast change, a negative, or a posterized image.

A variety of factors affect the accuracy of halftone dots on film. Software calibration, through the use of the PostScript transfer function, can compensate for all of the factors affecting the current size dots imaged on the photographic medium. This can be likened to the linearization process commonly used to calibrate color separation drum scanners to a particular set of exposure, film, and processing conditions, so that the actual dot sizes obtained on the film are the same as the requested dot sizes at the scanner. Thorne (1988) described a practical method for entering the screen values obtained on a PostScript imaging system and generating a transfer curve to linearize these values.

Since the transfer function involves re-mapping of the gray values, a system which is significantly out of calibration to begin with — say grossly overexposed — can lose some available gray levels through truncation. Overexposure of a film negative will result in the first group of highlight gray values being imaged on the film as solid black. When the transfer function re-maps the requested highlight gray levels to bit-maps which do not turn solid black on the film, a certain number of the original 256 gray levels will be lost, as there will be more requested gray levels than available with the output system being used.

In practice, given reasonable control of the variables, this is rarely a major problem. However, vendors of calibration software are quick to point out that their programs work best if the imagesetter is already operating in an environment with a film processor in good control, and density levels not set excessively high. The exact numbers recommended vary, but are on the order of 1.80 - 2.00 for paper and 3.50 - 4.00 for film.

The three operands required for the setscreen command — screen frequency, angle, and spot function — all may have some impact on calibration. Their affect varies with emulsion, exposure, and processing conditions. Higher screen frequencies in some systems exhibit a trend towards the printed reproduction sharpening on negatives and gaining on positives, as illustrated in Figure 5. PostScript's spot function provides the programmer with total flexibility with respect to the shape of dots, and their method of growth through the range of gray values. An example of this might be the differences in dot sizes found near the 50% level in conventional dots compared with elliptical dots. Since certain dot shapes may exhibit non-linear characteristics as they grow, calibration should be done for each dot shape.

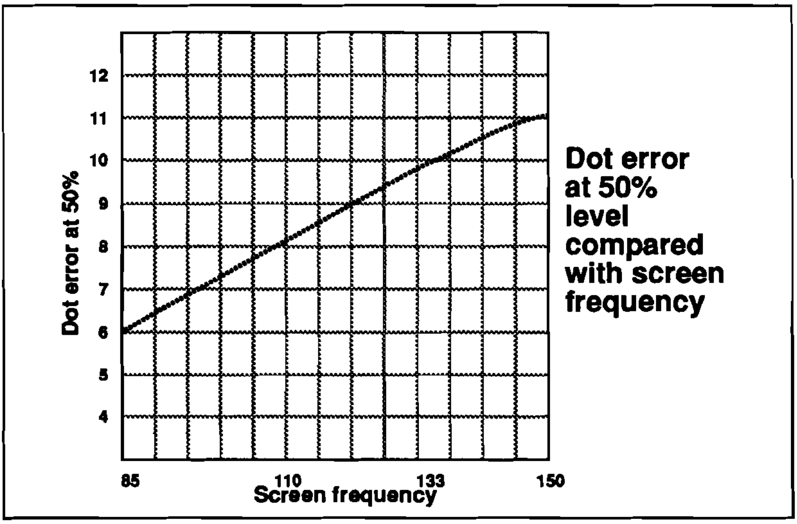

Figure 5

Of the three setscreen parameters, screen angle appears to have the least effect on calibration. Tests done on 4 screen angles revealed a maximum difference of .6% dot between any two angles. Recommended rational tangential (RT) angles that minimize moiré patterns usually involve changes in screen frequency in order to create seamless tiling of halftone dots. These differences in screen frequencies can be significant in some cases, and may require separate calibration for each angle for critical color work.

Implementation and strategies for software calibration

The syntax of the settransfer command is very clear; however, exactly how to apply it is subject to much confusion. Settransfer may be attached to virtually any part of a PostScript page description, although Adobe's document structuring conventions strongly suggest that it be avoided in documents in order to maintain device-independence. Nonetheless, we find one approach to calibration being that the halftoning or color separation application add a transfer command to the image which eventually may be encapsulated into another PostScript page description file. An example of this approach is seen with the calibration features of Color Access software from Color Imaging Systems (Barneyscan). Here we find a method to fine-tune a calibration gray scale for a specific imagesetter, and attach the appropriate transfer curves to color separation files as they are created.

A drawback to this approach is that it ties this calibration information to the image, and limits the re-use of the color separation file, in the event that the imagesetter goes out of calibration, perhaps due to a new roll of film being installed. In addition, encapsulating calibrated files into page makeup programs can be problematic if screen tints are to be used directly in the page makeup program. Calibration done in the color separation program will not effect these screen tints, and any attempt to correct them will disrupt the calibration applied to the color images.

Some page makeup programs handle calibration themselves. Quark XPress, through its XTras XTension has a printer calibration module. Calibration is based on the target output device, on the choice of paper or film output, and on screen ruling. XPress allows the input of calibration data for both high and low frequency screens, and interpolates the transfer curve with any user-selected screens which fall between these extremes. An appropriate transfer curve is sent to the RIP during actual printing or saved with a PostScript file created for subsequent downloading.

Naturally, this approach makes the most sense when the user is working directly with the imagesetter, rather than through a service bureau. Calibration data entered in XPress is saved with the document as it is printed to disk, and may not be appropriate if output conditions change. Care must also be used with this approach to be sure that additional calibration has not been attached to images such as color separations and illustrations which may be placed in the document

Aldus PageMaker uses an APD file for output to a specific brand and model of printer. APD files contain a transfer routine written for an idealized printer of the type specified in the name of the APD. The drawback to this approach is that it assumes calibration to be a static function, without variation between machines and due to emulsion, exposure, and processing conditions. The documentation for a number of commercially available calibration programs suggests that the transfer data be removed from these APD files to eliminate this bias.

An interesting approach to calibration has been taken in the Agfa MC Calibrator program. One option in this calibration utility furnished with Agfa/Compugraphic imagesetters is to automatically generate new APD and/or PPD files with the desired transfer curve replacing the default information. The original APD or PPD file is selected, automatically modified as needed, and then given a meaningful name, such as 150 line elliptical dot negative film. As the calibration changes, new APDs and PPDs are created and used for imaging. When printing from a program which makes use of printer description files, the appropriately calibrated file is selected prior to printing. Once again care must be used if the application is requested to print to disk, since the calibration information would be imbedded in the resulting PostScript file.

Adobe Separator is an example of a document management program which controls the output of PostScript language page descriptions to any PostScript printer. Separator has an option to add transfer values when printing or creating a PostScript file for later output. In the case of Separator, the transfer function is modified on a job by job basis as requested by the user.

There are a number of calibration utilities available on the market today which install a default transfer curve in the RIP. Included in this category would be utilities supplied by imagesetter vendors, such as the Linotype Utility 3, Agfa MC Calibrator, and the Varityper Tool Box. Two stand-alone programs for calibration are Color Calibration Software from Technical Publishing Services and Precision from Eastman Kodak. A similarity of all of these programs is the ability to download a transfer curve to the imagesetter's RIP where it will work with all subsequent files output. As conditions change, new calibration files may be sent. Some of these utilities require that the calibration files be resent whenever the RIP is powered down, while others make changes to the Sys/Start file on the RIP's hard disk, thus installing a default transfer curve on sytem startup.

The number of steps used in different calibration programs varies considerably: some have as few as 5 steps, others 11, 13, 24, all the way up to 101 steps. Color Calibration Software is unique in that it allows the user to calibrate for a specified screen angle and spot function if desired. It also provides the user with a test target ranging from 0% to 100% in 1% increments. Color Calibration Software provides some other useful calibration features: ink-on-paper dot gain values can be entered in a separate area to be calculated along with the transfer values associated with film exposure and processing; it also provides the means to dimensionally adjust imagesetter output. This may be necessary in order to correct for distortions caused by transport and processing stress, differences between PostScript's point system and the traditional printer's point, and distortion in images prepared for flexography.

Kodak's Precision software calibration utility takes a different approach with its automation and simplification of the calibration process. It allows the user to build and store calibration sets according to the imagesetter resolution, screen ruling, and type of media. An individual calibration set can be created for a range of screen rulings the user decides will work in conjunction with one another. Precision installs these calibration sets on the RIP's hard disk. As jobs are sent to the imagesetter, it automatically checks for the current resolution, requested screen ruling, and type of media. It then applies the appropriate transfer curve required. One price that is paid for this ease-of-operation on the part of the user is a degradation in performance of the RIP.

Problems associated with software calibration

Some of the problems associated with current software calibration of PostScript imagesetters should be apparent from the above discussion. An underlying problem is that there is no standard place where calibration takes place. Complicating the process is the fact that some programmers have chosen to hard-wire specific transfer values in their application or in an accompanying APD or PPD. One solution is to use the approach found in Agfa's MC Calibrator — change the transfer curve to the currently correct one. This means that applications not using APD or PPD files will need to be calibrated using another method. Hand-editing of these files can be done to remove the "Normalized" transfer routines. Color Calibration Software offers an automatic process for this, which it calls "unNormalize" — the program automatically strips out the offending code and renames the printer description file.

Since scanned images, illustration files, page makeup programs, printer description files, document managers, and the RIP may all have their own competing transfer values, care must be used so that these curves are not concatenated to one another. Concatenation of transfer functions is a common cause of poorly calibrated output .

The different methods used to change from positive to negative output may lead to additional problems in accurate calibration of the system. Software negatives and inverted positive output, as discussed earlier, are actually created by reading the transfer table from right to left, rather than from left to right. In hardware negatives, where the recorder's control panel setting is changed, the RIP reads the transfer curve normally, and just prior to outputting the page the recorder inverts all signals. This has the affect of taking each gray value and subtracting it from 1. Poor calibration can occur if one method of setting a negative is used to create a transfer curve, yet another one is used during production. Figure 6 illustrates this problem.

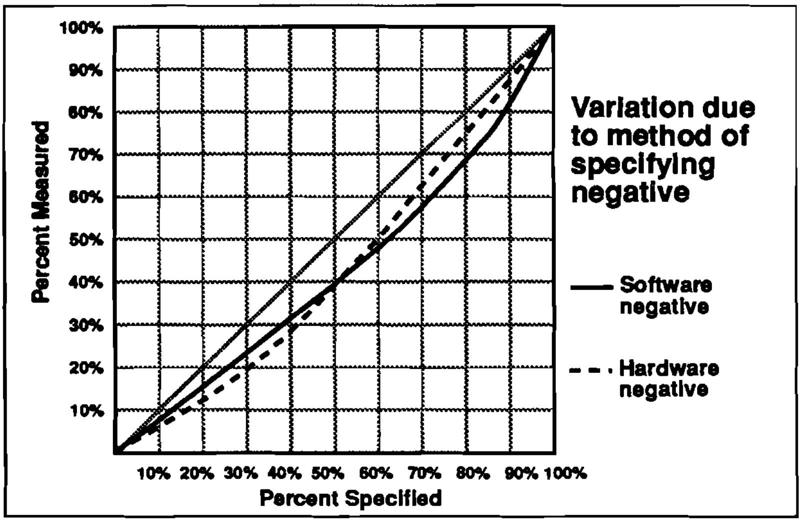

Figure 6

Summary and conclusions

Most of the problems associated with software calibration are due to a lack of a standardized approach to handling this important function. Although Adobe's document structuring commands offer the suggestion that page descriptions should be rendered device-independent by avoiding operators such as settransfer and setscreen within the document, many software vendors ignore this advice. PostScript is not just a page description language; it is also a printer control language. Page descriptions should be device independent, while printer control commands are necessarily device-specific. An alternate approach would be to remove all device-specific commands from a document and create an associated file, which might be called a print record or job docket, to contain the device specific information. The document file and the print record or job docket could then be merged in a print manager and sent to an appropriate PostScript output device. The print manager might also be used to monitor the current transfer curve. This approach would permit the same document file to be used to print 100 copies of a 53 line halftone on a duplexed PostScript laser printer, and then to output one copy on an imagesetter, using negative film and crop marks at 150 line screen. The document could just as easily be sent to a preview screen, facsimile device, slide recorder, or any other PostScript output device without modifying the original document file or rendering it device-dependent. Figure 7 illustrates the components of a system designed to facilitate this. The lines indicate the flow of data through this system. The proposed system provides backwards compatibility — existing applications can still process the document directly using the current approach, or they can save the file with its device-specific information in a separate, but associated file.

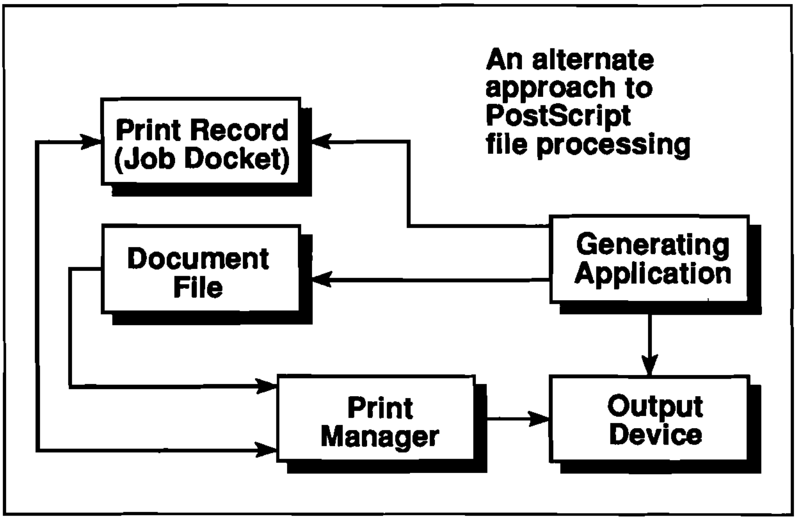

Figure 7

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