Instruction Bulletin 1.1
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Preparation for 4-Color Screen Printing

General Information

4-color screen printing is the reproduction of a full color original subject as a halftone. The three basic halftone colors (yellow, magenta and cyan) plus black are printed sequentially in close register to form the image.

4-color reproduction on 3M™ Scotchcal™ and 3M™ Controltac™ Films with 3M™ Halftone Inks allows the production of durable exterior or interior markings and emblems.

The exposure of the photosensitive emulsion on the printing screen requires a set of halftone positives which accurately represent the subject to be printed and are balanced to the particular inks to be used. This bulletin is a discussion of input required to ensure that the positive and proofs are satisfactory for their intended use.

Note: This bulletin considers only the procedures required to obtain films and proofs satisfactory for 4-color screen printing. For details of printing operation and color control, refer to Instruction Bulletin 3.10.

While screen printing 4-color graphics is similar to lithographic color printing, there are some important differences which need to be appreciated by both the screen printer and the separator.

Color Standards

Unless instructed otherwise, the separator will probably provide separations made to existing lithographic color standards. Neither of these standards, commonly referred to as SWOP (Standard Web Offset Publications) and Euroscale (DIN 16539), are a particularly good representation of the process colors available in screen printing inks. Neither are the color densities presented in the standards necessarily viable targets for screen printing inks.

Excess Density

Printing operations which produce an image that is read by reflective light generally will not produce print reflection densities higher than 2.0 OD (optical density) in any color. In the case of 4-color printing, which uses transparent inks, the maximum obtainable density is much lower.

The image and color information for most 4-color screen printing originates in a color transparency. Color transmission densities in a transparency may be as high as 4.0 OD. In order to print as much of the image information as possible, the density range must be compressed to fit within the printable density range of the printing system. The technique for doing this is called masking and is applied at the time of separation.

Separation Methods

There are currently three basic methods utilized to separate color for print. These are conventional, electronic scanner and laser scanner. Conventional separation is by means of red, green and blue separation filters on a graphic arts camera. Exposure of the halftone negative is through a contact screen which forms halftone dots whose size is proportional to the light intensity. Final positives are obtained by projection of the separation negatives. Density range control (masking) is accomplished by the interjection of photographic masks made for each image and color.

Conventional separation is not recommended for obtaining screen printing films. The method assumes the inks to be the complimentary colors of the separation filters and that the final halftone ruling is obtained by the same magnification which will translate the separation negative to the final size positive. These objections can be overcome in most cases by the use of color correction filters and/or careful resizing, but the process is laborious and may not produce the optimal image quality.

Electronic separation (non-laser scanner) utilizes electronic light detection to sense the intensity of each color of light. Exposure of the halftone dots is proportional to the intensity of a light controlled by the electronic system. Density range control is accomplished by electronic manipulation of the light signal.

Electronic separation is also not recommended as the method of choice for obtaining screen printing films. While the color corrections and masking can be effected more easily than with conventional separation, the consideration of halftone ruling and sizing remains.

The system of choice for screen printing separations is the laser scanner. Here the image color is read electronically, corrected for color and density electronically and used to modulate a pulsing laser beam which exposes the negative. No contact screen is used. The halftone ruling and size are independently controlled by the program which controls the pulsing of the laser.

Color Removal

The dark area of an image, unless corrected, will be printed with large amounts of all three colors plus black. While percent trapping is not normally a serious problem for the screen printer, very high coverage factors may lead to problems with drying and color balance. There are techniques available with the modern scanners which remove (from the separations) excess amounts of the colors while preserving the image quality and color rendition. The use of some form or color removal can, in the case of images with significant dark areas, be an important aid to the screen printer.

Undercolor removal or UCR is used to remove a selectable amount of all three colors from the high density areas where they contribute little to what is basically a toned black image. To illustrate with an oversimplified example, if an area would normally be printed with 60% yellow, 80% magenta, 80% cyan and 70% black, UCR can be used to remove up to 60% from the yellow, magenta and cyan. The final print in this area could then be 20% magenta, 20% cyan and 70% black.

This example is grossly simplified because, in fact, the amount of the three colors removed would not be equal but would be in the ratio to each other which constitutes a neutral gray.

Gray component removal or GCR is a technique which removes all three colors in the ratio which constitutes a neutral gray and replaces them with black. The technique is applied at all density levels. In the case of 100% GCR any area of the image which would normally print all three colors would be reduced to no more than two colors plus black. This greatly reduces any concerns about color balance.

Color removal results in the benefits of printing lesser amounts of ink, plus it simplifies the process of obtaining and maintaining color balance.

Defining the Printing System

Before proceeding to obtain separations, it will be necessary to define accurately the screen printing system which will be used. It will be necessary, as instructed later in this bulletin, to provide the separator with screened test samples of the inks to be used.

A complete definition of the screen printing system will include answers to each of the questions in Table 1.

Table 1. System Definition

1. Printing order?
2. Halftone ruling?
3. Screen angles?
4. Final size?
5. Ink color and density?
6. Printable dot range?
7. Dot gain?
8. Gray balance?

The questions listed in Table 1 are not all independent of each other. The relation between them will be explained in the following sections.

Note: In this Instruction Bulletin reference is made to the "printing system." This reference includes all items which have the capability to affect the final product such as ink, screen, stencil, press, squeegee, operator, processes, drying conditions and procedures.

The first four questions in Table 1 require only brief answers relating to the screening operation. We will consider these first.

Printing Order

Because screen printing yellows tend to be less transparent than the other colors, it is recommended that the yellow be printed first followed by the magenta, cyan and black in that order. While other printing sequences can and have been used, the sequence chosen must be used on the test screening, the proof and the pictorial without alteration.

Halftone Ruling

The dots which form a halftone are arranged along perpendicular lines and rows to form a complete plane of dots. The spacing between the lines and rows is equal and uniform and is normally measured in "lines per inch" which can also be read as "dots per inch."

It is common belief that the "best" pictorial will be obtained by printing the finest halftone ruling which the printing system will allow. This is often not the case and, in fact, the widest tonal range will be obtained by printing the coarsest halftone ruling commensurate with the customer requirements on viewing distance.

The choice of halftone ruling for a screen printed pictorial should consider the type of ink, the size of the pictorial, the typical viewing distance and the number of impressions needed. The following statements are offered as a guide in making this choice.

1. Heat dried inks are printed at halftone rulings ranging from less than 10 per inch to about 55 per inch. UV cured inks are printed at rulings as high as 100 lines per inch.

2. 25 lines per inch or fewer is used for large pictorials viewed at great distance (300 feet plus).
3. 50 lines per inch or greater is used for markings intended for close viewing (5 feet or less).
4. Pictorials intended for trucks and trailers are typically screened in the range of 25 to 35 lines per inch.
5. Rulings higher than 40 lines per inch are difficult to screen with heat dried inks and should be used only if required.
6. Rulings higher than 40 lines per inch increase the difficulty of printing long runs with heat dried inks because of small dot loss due to drying in the screen.
7. With any given ink system the printable dot range will decrease as the ruling gets finer.

To illustrate better the effect mentioned in point 7 above, reference is made to the following chart where the dot diameter in mils (0.001 inch) is plotted as a function of the halftone ruling for seven dot densities between 2.5% and 50%.

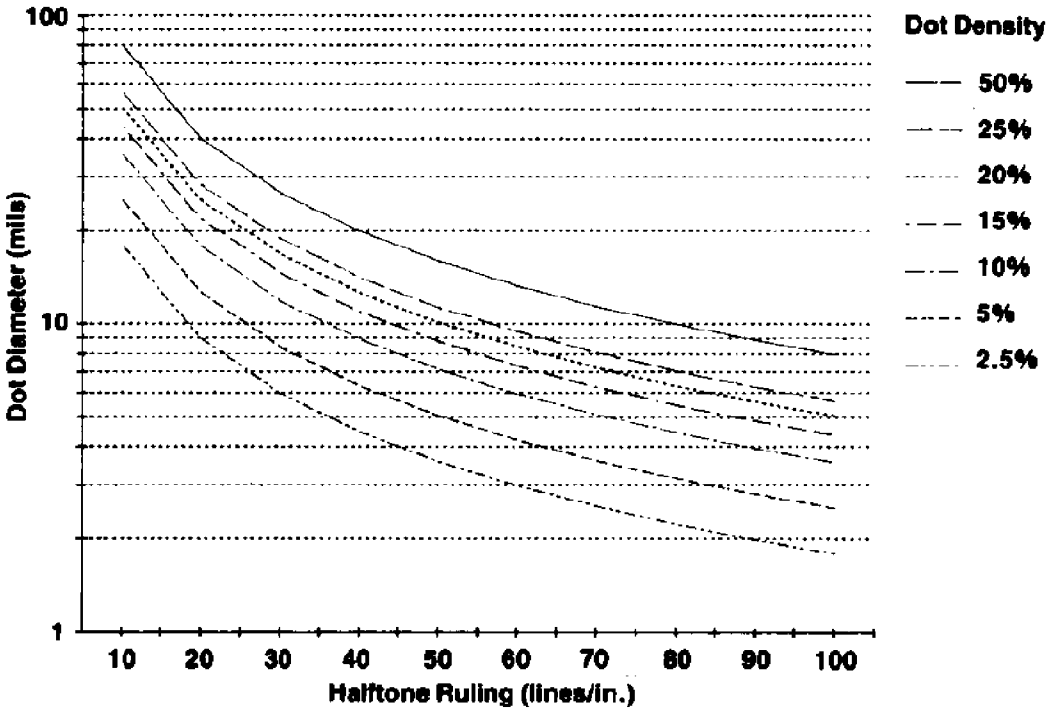
The chart is not carried above 50% because the concept of dot diameter is not valid when the dots have bridged one to another. The diameters given, however, can be applied to a reverse dot of the same density, i.e., the diameter of the hole in a 90% dot image is the same as the diameter of a 10% dot.

The limiting factor on ability to screen print a halftone will be the smallest dot (NOT dot percentage) which the system is capable of printing. In general, with heat dried inks, it will be difficult to print and hold dots much smaller than 10 mils diameter.

Reference to Chart 1 shows that a 10 mil dot is a 5% dot in a 25 line halftone, a 10% dot in a 35 line and a 20% dot in a 50 line halftone. In this situation then we would expect approximately the following tonal ranges:

25 line - 5 to 95%
35 line - 10 to 90%
50 line - 20 to 80%

Chart 1 — Halftone Dot Size
Dot Size vs Halftone Ruling



Each of these ranges will be expanded if the system is capable of printing dots smaller than 10 mils. For example, if it is possible to print and hold a 7 mil dot, the approximate tonal ranges for the same rulings will be:

25 line - 2.5 to 97.5%
35 line - 5 to 95%
50 line - 10 to 90%

The best visual contrast and reproduction of detail will be obtained from the coarsest halftone ruling possible within the constraint of the customer requirements.

Screen Angles

The superpositions of two identical or almost identical halftone dot patterns produces an optical interference pattern called moire'. This objection pattern can be minimized by rotation of one of the patterns. Because the halftone consists of rows and lines of dots at right angles, the maximum rotation one can achieve is 45 degrees. In 4-color printing, there are four identical dot patterns being overlaid. Because a 45 degree rotation is possible for only two of the screens, choices need to be made in order to minimize the moire' pattern.

In order to deal with only positive angles, consider that the first screen is placed at 90 degrees (the same as 0 degrees). The following example shows a typical set of angles and the net effect:

Color 1 - 90 deg.	
Color 2 - 45 deg. -	Minimum moire' with 1
Color 3 - 105 deg.-	Little moire' with 2
	Some moire' with 1
Color 4 - 75 deg. -	Little moire' with 2 & 3
	Some moire' with 1

The assignment of individual inks to the colors above needs to be made based on the specific pictorial being printed. A typical assignment with a skeleton black printer would be yellow as 1, magenta as 2, cyan as 3 and black as 4. This will produce minimum moire' in flesh tones and reds, little moire' in blues and dark shade magenta and cyan, and some moire' in greens and dark shade yellow.

A pictorial with large areas of green and little or no red might be best printed by making cyan color 2 and magenta color 3. Separations utilizing large amounts of color removal may be improved by assigning black to other than color 4.

The selection on inks as colors 1, 2, 3, or 4 should not be confused with the printing order, which, per se, has no effect on the moire' pattern.

Final Size

The final size of the pictorial is important in qualifying a separator and selection of screens and press. Screens should be large enough to provide at least a 6 inch well between the frame and the open stencil area.

Test Screenings

The following test screening, properly completed, will supply the information needed by a separator to furnish properly balanced separations. Balanced separations are those which take into account the ink colors, printing order, printing density, dot gain, printable dot range and gray balance.

Note: Specific instructions regarding the screens and inks are contained in Instruction Bulletin 3.10 which should be reviewed and understood before attempting to screen the tests.

Ink Color and Density

Dot Gain

It will be necessary to screen, at the selected ruling, a halftone scale of each color which at the minimum must contain 25%, 50%, 75%, and 100% (solid) dots. The separator will use the solid patches to determine ink color and density while the halftone patches give a measure of dot gain.

Printable Dot Range

A halftone scale containing 5, 10, 15, 20, 25, 75, 80, 85, 90 and 95% dots needs to be screened, at the selected ruling, for each color. Examination of the printed samples will show the smallest and largest printable dot.

Gray Balance

Here it will be necessary to screen, at the selected ruling, a gray balance target which consists of overlapping halftone scales of the three process colors (no black). The printed target is then examined to determine specific ratio of the three colors which yields a neutral gray.

Note: As indicated in Instruction Bulletin 3.10, the test screenings must be done with the printing system set up exactly as it will be to print the pictorial being separated. That means that the ink, fabric, stencil, squeegee, substrate, printing order, density, halftone ruling and related processes can not be altered between the test screenings and printing the pictorial.

There are various commercial targets available which, when combined, will yield the appropriate test screening. All of the necessary scales have been combined into four 20 inch by 20 inch films (one for each color) suitable for direct use in making the test screens. The 3M Color Separation Guide Set for Screen Printing is available in a variety of halftone rulings. More information can be obtained from a 3M Technical Representative.

Obtaining the Separations and Positives

Color separators are most experienced at providing separation to the lithography market and may not have a complete understanding of the needs of the screen printer. Screen printers, on the other hand, may have little or no experience with color separation and printing 4-color halftones. The only satisfactory solution to this dilemma is a very close working relationship between the screen printer and the color separator.

Qualifying a Separator

There are several conditions which a separator must be able to meet to be considered as a viable source of screen printing separations. These are:

1. Separation by laser scanner.

2. Ability to supply single-piece full-size positives.
3. Interest in working with a screen printer to provide separations balanced to the inks.

Artwork

Color transparencies are most desirable for color separations but an original painting, a color print, watercolor or pencil sketch may be used. Retouched (airbrushed) artwork and previously screened prints require special treatment. Any doubts as to the suitability of the artwork should be resolved with the color separator before proceeding.

Required Input

Discussions between the screen printer and the color separator should include:

1. Color removal - Should it be applied to this particular piece of artwork and if so, at what level?
2. Screen angles - Angles should be selected to minimize moire' in the dominant color.

It will be necessary to provide the color separator with the following information:

Table 2. Required Information

1. Final size of the pictorial
2. What halftone ruling to use
3. What screen angles to use
4. What the printing order will be
5. Test screenings which will yield:
   a. Printable dot range
   b. Ink colors and densities
   c. Amount of dot gain
   d. Ink ratio for gray balance
6. Amount of color removal desired

Required Output

After color separation is completed, the screen printer should insist on receiving the following:

1. Final positives - the final positives must be one-piece full-size films supplied right-reading emulsion side up. The positives need to be supplied with register marks and proofing bars in the trim area.
2. 4-color proof - The proof must be made from the same separations used to make the final positives and must have a set of color bars in the trim area. The specific brand of proof is not critical but a separable proof (such as 3M Color Key) has some additional value in printing control.

⚠ **CAUTION:** Proofs made from separations with longer dot range (e.g., 5 to 95%) than supplied in the positives (e.g., 15 to 85%), are "prettier" but are not representative of the screen printed image and are not useful for printing control. Such proofs should not be accepted.

Details of the screen printing of 4-color pictorials are covered in Instruction Bulletin 3.10.

Related Literature

Listed below are other 3M Instruction Bulletins which may be of interest.

Subject	Instruction Bulletins
Cutting, Die Cutting	4.1
Premasking	4.3
Surface Preparation	5.1, 5.2
Storage, Cleaning, Removal	6.5
Film Removal	6.6
Application	5.4, 5.5, 5.6
Screen Printing Four Color	3.10

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