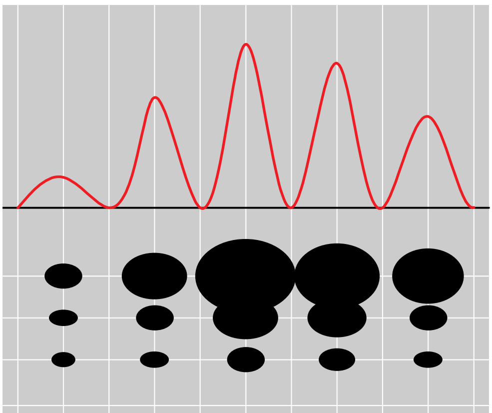
8. Halftone printing

The original artwork to be halftone printed is frequently a photographic image. Images of this kind cannot generally be raster printed in their original form: photographs are always continuous-tone images, where the gradient from light to dark has no discernible point structure.

The artwork must first be converted into a printable form. This is done by translating the continuous-tone image into halftone dots, using an AM or FM raster.

8.1 AM halftone (amplitude modulated rastering)

An area of continuous tone is resolved into a grid, with rows of larger and smaller dots. Viewed under a microscope, it becomes clear how the dot size is related to color intensity, while the distance between the dots is fixed. In other words, we have a fixed dot spacing with variable dot area. If we draw a plot of dot area on the vertical axis against dot spacing on the horizontal axis, the result is a curve whose amplitude changes according to the dot coverage, while the dot spacing remains fixed. The general shape of the curve is not unlike an ”amplitude modulated” waveform, with fixed frequency and changing intensity or amplitude.



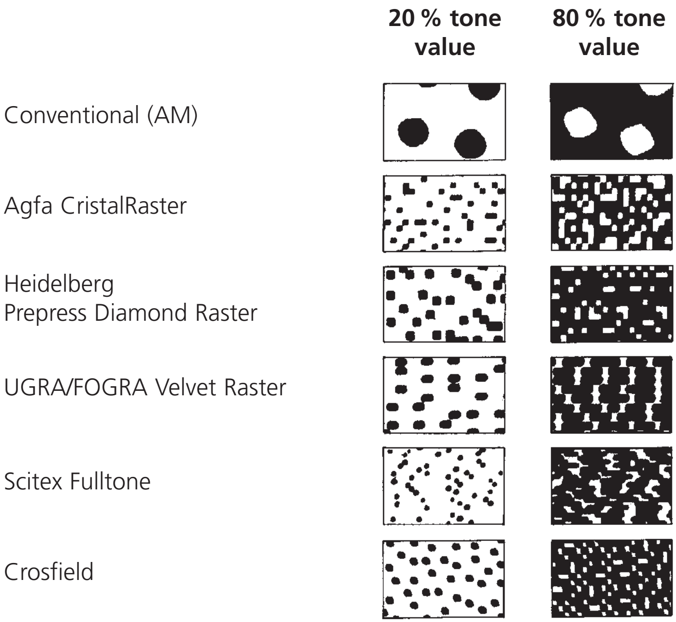
Analog raster with variable area (amplitude)

Although the printing process is inherently digital (1/0, ink/no ink), the end result is an apparently analogue (smooth tone) representation of the original image. Applied to color printing, the very nature of the technique encourages moiré patterns. Counter measures, such as angling the individual color separations, are required to minimise the moirés inevitably produced by multi-color printing.

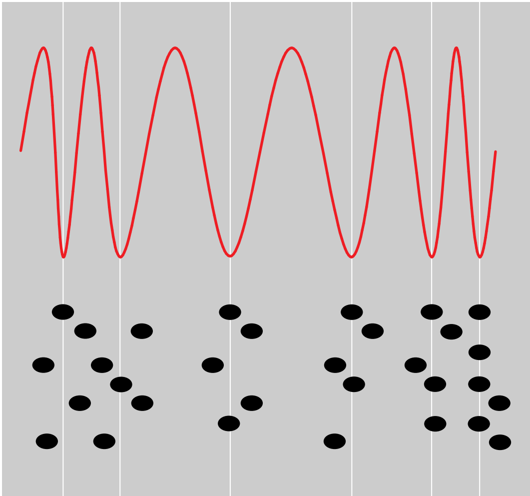
8.2 FM halftone (frequency-modulated rastering)

The ability to produce laser-generated points smaller than the smallest practicable analog raster dot opens the possibilities of emulating analogue rasters, or pursuing a new, digital half-tone model. The first laser and film recorders were designed merely to reproduce the well-established analogue raster angles and pitches. However, the technique's growing popularity has given rise to new rendering models that go under the general name of “frequency-modulated halftones”.

The recording technology allows representing a continuous-tone image by varying the distribution of uniformly sized, extremely small dots. Varying coverage is achieved by varying the number of recorded dots per unit area.



Examining the dots, it is clear how they are much finer distributed than with an AM raster, as well as being all the same size. If we draw a plot of dot size as amplitude on the vertical axis against dot spacing on the horizontal axis, we obtain curves of constant amplitude, but variable distance between adjacent peaks. The curve's general character corresponds to a frequency-modulated waveform – which is why we speak of a frequency-modulated raster.



Coverage and frequency modulation

Various methods have been devised for positioning the dots in an optimal manner.

On a practical level, it is clear that an FM raster results in considerably finer dots on the film, and hence uniform color coverage. It should also be apparent that this type of halftone translation virtually eliminates moiré effects. In their place come other disturbances such as clustering or heaping.

It is important for the halftone printer using FM dots to know and control the minimum printable and reproducible size. We recommend a dot diameter corresponding to at least 2 threads plus 1 mesh opening of the halftone printing mesh.

8.3 Types of halftone rulings

For a halftone image to be effective at a given size and viewing distance, one must determine a number of factors, including the type and fineness of the raster ruling.

Monochrome halftone images can be achieved using so-called ”effect rasters”. These are:

– Corn raster

– Worm raster

– Line ruling

– Circular ruling

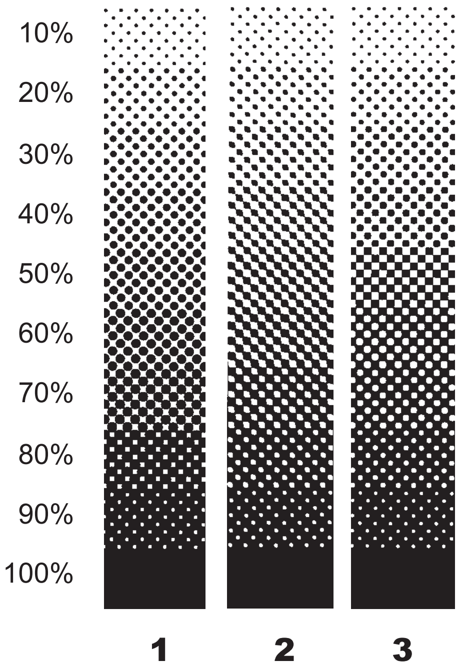
Corn raster example

The uneven structure of corn and worm rasters is less prone to moiré effects than line, point or bead-string rulings.

For textile printing, there is a long-established type of graining known as the ”DIRACOP method”. Even now, halftones are often prepared by hand, using transparent foils with a grained surface to achieve the halftone structure.

Four-color printing uses the following dot shapes:

- – round dots
- – elliptical dots (bead ruling)
- – square dots (checkerboard ruling)



1 = Dot raster, dots blend at approximately 70 %

2 = Bead ruling, dots blend at a) approx. 40 %
b) approx. 60 %

3 = Checkerboard ruling, dots blend at 50%

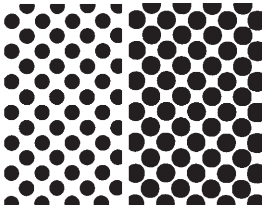
1 = Dot raster, dots blend at approx. 70 %

2 = Bead ruling, dots blend at a) approx. 40 %
b) approx. 60 %

3 = Checkerboard ruling, dots blend at 50%

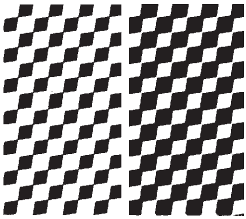
Dot transition/blending

Dot shape affects the way raster dots transition within total ranges. Here, we examine each dot shape in turn at 46% and 52% coverage respectively.



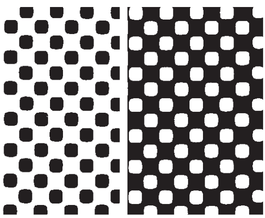
Round dots at 46% and 52% coverage, and at blending

Round dots blend at 65–70%. When this happens, though, it affects four neighbouring dots simultaneously, and this results in a steep tone value transition.



Elliptical dots at 46% and 52% coverage

With a beaded raster, the dots blend at two distinct tone values. This results in a virtually unnoticeable transition. Dot blending is direction-dependent: two neighbouring dots first chain together, then the two parallel chains combine.



Square dots at 46% and 52% coverage

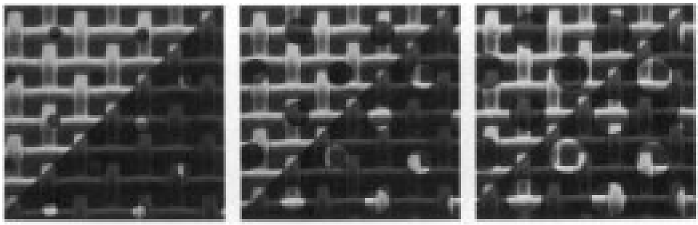
Square dots blend with four neighbouring dots simultaneously, resulting in a steep tone value transition. In halftone printing, the effect is further emphasised by the high ink deposit.

8.4 Halftone line ruling

The fineness of the halftone line ruling (lpi) is always linked with the fineness of the mesh and the type of stencil.

Mesh and halftone fineness

The finest details should properly adhere to the mesh. Areas with the highest ink coverage, i.e. where the smallest dots of emulsion must cling to the mesh, are particularly critical. The smallest points should not be allowed to rest on just one thread, or even fall through the mesh opening.



Critical dot sizes

Strictly speaking, the diameter of the smallest halftone dot on the film should be microscopically measured, in order to select a mesh of the correct fineness.

coverage **lpi**	**5%**	**10%**	**15%**	**20%**	**30%**	**70%**	**80%**	**85%**	**90%**	**95%**
51	126	178	218	252	309	309	252	218	178	126
56	114	162	198	229	280	280	229	198	162	114
64	101	142	175	202	247	247	202	175	142	101
71	90	127	156	180	220	220	180	156	127	90
76	84	119	145	168	206	206	168	145	119	84
81	79	111	136	157	193	193	157	136	111	79
86	74	105	128	148	182	182	148	128	105	74
102	63	89	109	126	154	154	126	109	89	63
122	52	74	90	105	128	128	105	90	74	52
137	46	66	81	93	114	114	93	81	66	46
152	42	59	72	84	103	103	84	72	59	42

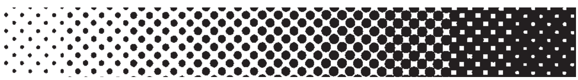


Table of dot sizes

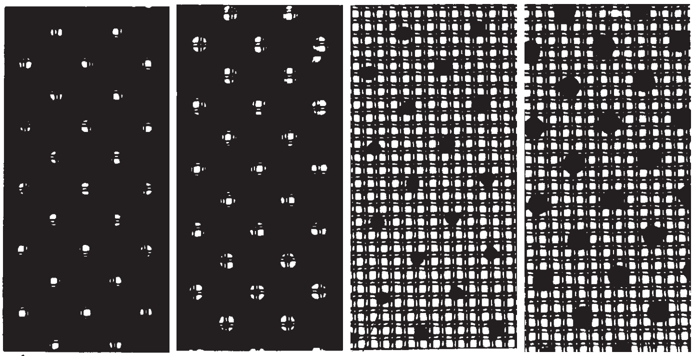
From the examples above, it is clear that the diameter of the smallest dot must correspond to two threads plus one mesh opening, if the halftone dot is to be adequately supported by the mesh.

Ink flow in shadow areas

Halftone printing is a print-through process and not – as in offset – a transfer process. The raster printing form (mesh + stencil) produces a thicker ink deposit than a litho plate. This is the characteristic and advantage of raster printing, namely, the intense and effective depth of color. In halftone printing, however, the ink deposit should be relatively thin, because the finer the line ruling and the higher the degree of coverage, the more difficult it is to avoid ink running in the high-coverage, dark print areas (smudging).

The thinner and finer the mesh, the less ink is deposited. Thinner mesh therefore is better suited for fine halftone printing.

When printing areas with low percentage coverage, the ink should flow freely through the smallest mesh openings without any obstruction from threads or stencil thickness. In this respect, a relatively light mesh is more advantageous than one with thick threads.



5% coverage *10% coverage* *95% coverage* *90% coverage*

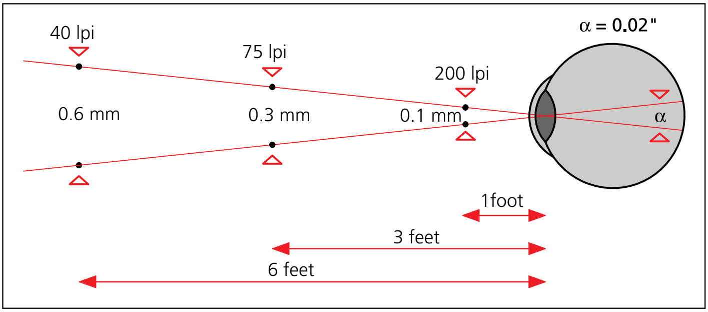
Fineness and viewing distance

The halftone simulates continuous tone in as much as the eye cannot distinguish the individual dots anymore.

Under normal conditions, the human eye discerns two adjacent points or lines as separate when their images do not impinge on two neighbouring retinal cells (rods or cones). There has to be at least one intervening retinal cell.

The dots therefore become indistinguishable when their images fall on the same or two adjacent retinal cells.

The minimum angular resolution of the human eye is approx. 0.02°.



Raster rulings discernable to the eye

Guidelines:

Image Size (inches)	Viewing distance	Halftone dots per inch
<8.5 x 11	22 inches	91-122
8.5 x 11	22 inches	61-91
11 x 17	22-44 inches	46-61
17 x 22	3-11 feet	38-51
24 x 36	7-18 feet	30-46
34 x 44	11-36 feet	30-38
>34 x 44	11-72 feet	-30

The following factors should be considered when determining whether a given print job is feasible:

– Adapt the line ruling to the surface structure of the printing material.
– Glaring or highly intensive colors require a relatively coarser raster ruling than pastel colors. The coarser the halftone ruling, the higher the contrast of the print.
– For finer or softer images, choose a finer line ruling.

From the commercial viewpoint, a halftone printer is advised to first print with course line counts to gain experience before moving on to finer halftones. When selecting a halftone line count, the viewing distance should always be taken into consideration.

8.5 Tone values of halftone dots

Tone value expresses the relative area coverage of the halftone dots compared to maximum (100%) coverage.

In offset printing, the percentage coverage of the dots can range from 95% to 5%, whereas the screen printer must be satisfied with a tone value range from approximately 85% to 10%. This applies to raster rulings of approximately 12 lpi and finer.

For a perfectly printed 15% dot, the ink must be relatively fluid in order to keep the dots open in the mesh. However, this leads to difficulty in obtaining the tonal range because the dots for 85% coverage tend to smudge if the ink is too thin. On the other hand if the ink is made more viscous, the smallest dots tend to dry too quickly and block the mesh openings.

Tone value:
Therefore, ink viscosity is a compromise in order to prevent smudging in dark areas, while permitting fine dots in the light areas of the image.

Tone value of the color separation:
For halftone raster printing, the film maker should calculate the maximum coverage for all four colors together, to reach an optimum density of 300%. For reproductions with predominantly dark areas, the color black should not attain more than 75% coverage. Yellow, however, can show higher coverage in order to produce the correct tone values for green and red.

Typically, the finer the raster ruling, the greater the difficulties will experience. This illustrates present-day limits to commercial halftone printing.

Examples for perfect reproduction of halftone values in raster printing:

up to 60 lines/inch   5-90 %

up to 100 lines/inch   10-85 %

up to 120 lines/inch   15-80 %

These examples are based on the following general rules:

The finest printable dot should have a diameter of 80–100 µm (This corresponds to the sum of 2 thread diameters + 1 mesh opening in Pecap LE 7-380-31 PW mesh).

8.6 Halftone printing process line

The process line is the characteristic curve describing the relationship between tone values on the film positive and those of the corresponding printed image.

The halftone printing process line serves as a correction guideline, which helps the printer avoid the problems that would otherwise arise in half-tone printing.

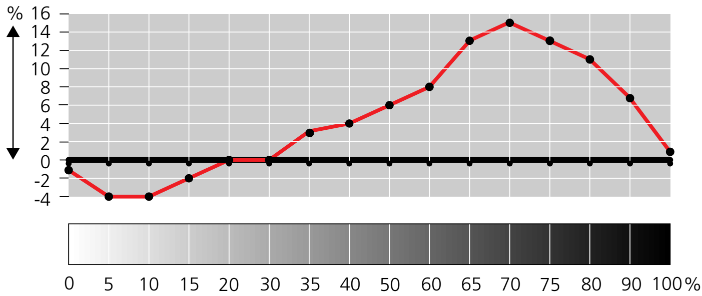
The raster printer therefore needs no measuring instrument. A halftone step wedge with at least 10 tone values should be printed alongside the artwork. The printer uses a transmission densitometer to measure the halftone values on the positive film, and a reflection densitometer on the print. The results can be compared on a chart.

Densitometer

Example of a printing process line

Film tone value %	Print tone value %	Dot gain / loss	
99	100	+1	100
91	98	+7	90
83	94	+11	80
76	89	+13	75
69	84	+15	70
63	76	+13	65
53	59	+8	60
47	53	+6	50
40	44	+4	40
32	35	+3	30
28	28	0	25
22	22	0	20
17	15	-2	15
11	7	-4	10
6	2	-4	5
1	0	-1	0

The variances in tone values, plotted as a curve, result in the so-called process line:



Schematic representation of the printing color scale

Every process line must also specify the following operational parameters:

– film	lines/inch, type
– mesh	type, threads/inch, tension N/cm
– type of stencil	emulsion, capillary film, indirect film
– stencil thickness	specified in µm
– surface roughness	Rz value in µm
– ink	type, manufacturer, composition, viscosity
– machine	type, manufacturer
– squeegee	hardness, thickness, clearance, angle, pressure
– printing stock	precise description, e.g. type of paper, etc.

The color scale can be significantly influenced by a change in any single item in the list above.

8.7 Printing control strip

The FOGRA DKL-S1 control strip has been specially developed for halftone printing, and may be used for visual and densitometric monitoring of the following:

- Stencil production
- Changes in tone values
- Color caste
- Color balance
- Dot gain

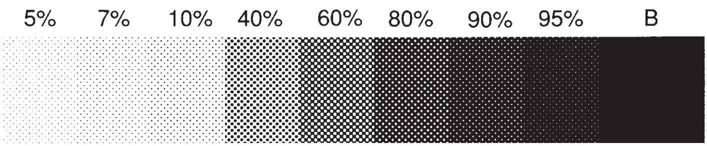
Halftone field

This area features halftone dots with coverage levels from 5% to 95%. The raster count is 61 dots/inch. This facilitates visual and (preferably) densitometric checks on tone value transfer during printing.

Full tone field

A further check, which is of utmost importance in raster printing, is to measure the intensity of the printed ink.

A reflection densitometer is used to measure the ink intensity of the four colors in the full tone fields. To achieve a good grey balance, all three process colors must lie within a close tolerance range.



Raster and full tone

Example full tone measurement:

Color	Required density	Tolerance
CYAN	1.45	± 0.10
YELLOW	1.00	± 0.05
YELLOW 47B	1.40	± 0.10
MAGENTA	1.40	± 0.10
BLACK	1.85	± 0.15

Measuring instrument: Densitometer

Printing stock: Artistic printing papers

Overlaid printing fields M/Y, C/M, C/Y, and C/M/Y

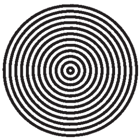
These areas allow color acceptance to be assessed both visually and by measurement. It is important to use the same print-color sequence for proof prints as well as for the production run.

M/Y C/M C/Y C/M/Y

Overlaid print

Ring field

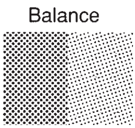
This allows monitoring of transfer errors during printing, which can be caused by smearing effects.



Ring field

Balance field

The combined three-color print in the balance area should be a neutral grey, with a tone value approximately equal to the 40% half-tone field. This is a very sensitive indicator of shifting color balance during a print run.



Balance field

8.8 Types of stencils

Generally speaking, one can use any kind of stencil for halftone printing. However, one should take into consideration a few points that are typical for this kind of printing.

The difficulty with printing single or multi-colored halftones is that both light and dark areas must be neatly printed. There should also be no shifts in tone values. To maintain a perfect tonal range, the stencil emulsion should be as thin as possible.

The preferred stencils for halftone printing are therefore indirect stencils, or direct stencils with film and water (capillary film), and minimal film thickness.

Direct stencils with photo emulsion are also used for long press runs. However, it is essential that they have a thin coating (5–10% of mesh thickness) and low Rz value (less than the coating above the mesh in µm).

Important: Direct stencils should use yellow dyed mesh to avoid light scatter during exposure.

Only impeccable film positives are suited for halftone work. For correct reproduction of the complete range of tone values, it is essential that all the dots are completely opaque right up to their edges. (See chapter 5.4)

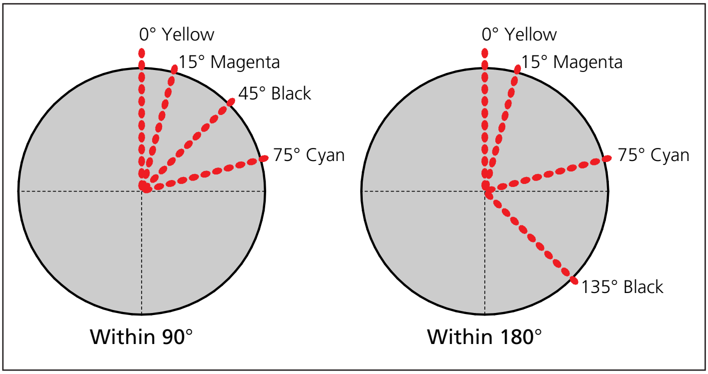
8.9 Avoidance of moiré effects

In film making, suitable angling controls the moiré effect produced between the halftone lines of the individual component colors.

Halftone angling is often given in two different ways:

- within 90° for rulings with two axes of symmetry (e.g. checkerboard and dot rulings)
- within 180° for rulings with one axis of symmetry (e.g. bead ruling)

Example:



Strong colors like CYAN, MAGENTA and BLACK must always be at an angle of 30° from each other. This minimizes visible moiré patterns due to the interplay of the raster rulings. YELLOW, being a weaker color, can be set at a 15° angle from a darker color. In raster printing, yellow should be on the vertical axis of the image, since a moiré caused by the stencil mesh is barely visiable.

Angling of 4-color halftone rulings

Images with a high black content (deep tones)

	Within 90°	Within 180°
YELLOW	0 °	0 °
MAGENTA	15 °	15 °
CYAN	75 °	75 °
BLACK	45 °	135 °

Images where YELLOW + MAGENTA are predominate, e.g. skin tones, orange tones

	Within 90°	Within 180°
YELLOW	0 °	0 °
MAGENTA	45 °	135 °
CYAN	75 °	75 °
BLACK	15 °	15 °

Images where YELLOW + CYAN predominate, e.g. green and turquoise tones

	Within 90°	Within 180°
YELLOW	0 °	0 °
MAGENTA	15 °	75 °
CYAN	45 °	135 °
BLACK	75 °	15 °

General suggestions:

The strongest, most dominant colors should be at 45° in the 90° disposition or at 135° in the 180° disposition (45° left).

For five, six or more colors, the angling should be chosen in such a way that the light colors coincide with their complementary colors, e.g. dark red and light blue, dark blue and light red. An additional grey plate should be angled in such a manner that it does not coincide with colors strongly related to grey.

Angling of 3-color halftone rulings

	Within 90°	Within 180°	
Dark color	45 °	a) 45 °	b) 135 °
Light color	15 °	105 °	75 °
Third color	75 °	165 °	15 °

Angling of 2-color halftone rulings

	Within 90°	Within 180°	
Dark color	45 °	a) 45 °	b) 135 °
Light color	75 °	105 °	75 °

Angling of single color halftone rulings

Within 90°	Within 180°
45 °	a) 45 °

Moiré between the film and the mesh

In raster printing, an additional moiré effect can result from unsuitable angling of the halftone lines of a particular component color in relation to the mesh. This effect is most plainly visible in monochrome prints, whereas multi-color printing tends to conceal it. The moiré effect is most apparent in the 40–60% range.

The moiré can be wholly or partially eliminated in the following ways:

1. By the type of stencil:

   The moiré effect is less apparent with an indirect stencil, since the influence of the mesh is less pronounced than in the case of direct stencils.

2. By the fineness of the mesh:

   The finer the mesh in relation to the raster ruling, the less visible is the moiré effect.

   Recommended ratio between mesh count and the fineness of the halftone ruling:

Mesh count/inch	:	Halftone L/inch
2.50	:	1.00
3.75	:	1.00
5.00	:	1.00

   Examples:

mesh	Ratio	Halftone L/inch
Pecap LE 7-355-31:	2.50 : 1	142 lines/inch
	3.75 : 1	95 lines/inch
	5.00 : 1	71 lines/inch

   i.e. the mesh number is divided by the ratio.

   If these recommendations are followed, there will be hardly any visible moiré effect at halftone angles of 15°, 45° and 75°. In the rare event of moiré still appearing, it is advisable to increase or decrease the number of halftone dots/inch by one or two:

either	0.5-2 halftone dots more
or	0.5-2 halftone dots less.

3. By the mesh angling:

   a) An ideal, universal angle for the mesh on the halftone printing frame lies between 4° and 9°, provided the halftone lines of the component colors, as in the previous examples, are aligned with the vertical or horizontal axis.

Angling the mesh, e.g. to 7.5°, has the additional advantage that the cause of striped print appearance can be traced with certainty to the mesh, or a poorly ground squeegee blade.

Stretching at a certain angle can be ordered from your stretching service. A well-equipped stretching service can provide an evenly straight stretched frame, which is essential for avoiding moiré.

b) It is difficult to load a frame into an automatic printing machine at anything other than right angles. Therefore, it is advised not to angle the image on the stencil, and feed the printing stock at a corresponding angle.

c) There remains the angling of the whole set of film positives (e.g. +7.5°) with respect to the image axis.

4. By the type of halftone raster

a) According to current theory, grained raster, line raster and circular are only suitable for monochrome printing. There is little danger of moiré with these types of halftones. For a line raster, the mesh is angled.

b) Halftones with elliptical dots (bead ruling) can, under certain circumstances, lessen the chance for moiré development. It is for this reason that they are selected to soften abrupt color-tone transitions.

8.10 General recommendations

- A basic requirement for perfect image reproduction is the quality of the film positive, with complete opaque half-tone dots.
- The color separations and the printing inks should follow the same color scale, e.g. EUROSCALA.
- Place the halftone positive on a glass plate, illuminated from below. Place the stretched halftone on the positive, parallel to the image axis. If a moiré appears, turn the film left or right until the moiré effect disappears (approx. 7° is sufficient in most cases).
- The critical zones for the formation of moiré lie in the direction of the threads and their cross-overs.
- Dominant or darker colors tend to cause more moiré problems.
- For 4-color prints, stable metal frames of the same dimensions should be used.

- All frames are stretched with the same mesh.
- Use a dyed mesh for direct stencils.
- Stretch the mesh tightly along the directions of the threads.
- Stretch all 4 frames with the same tension and procedure.
- A perfectly ground squeegee is crucial to a high quality print.
- The squeegee blade should be of about 70° shore hardness.
- The squeegee should be set at an angle of 75°. If the squeegee is set at too flat an angle, it tends to smudge. Set it too steep, or there is a greater risk of mesh distortion.
- The flood bar should not be set too low. The stroke should leave a thin film of ink on the stencil. If the doctor blade is set too low, the stencil becomes overfilled with ink and the print is smudged.
- Halftone images are printed with high-viscosity inks.
- Initial halftone printing trials should be carried out with coarse raster rulings.
- The finest mesh counts require relatively high color pigmentation.
- UV inks tend to smudge, but do not dry in the mesh. For this reason, the halftone film should have a tone value range of 5–80%.
- In 4-color process printing using UV inks, ensure that the additional stencil thickness and the Rz value are no higher than 5 µm.
- To control UV ink smearing when overprinting colors, the following color printing sequence may be used:

  CYAN – MAGENTA – YELLOW – BLACK
- For UV inks, the squeegee should have 75° shore hardness, i.e. generally somewhat harder than with conventional inks.
- The squeegee angle should be approximately 75°.

Recommended halftone line ruling (inches) in relation to mesh count (inch)

The following basic parameters must be established before making use of the recommendation:

a) Type of printing job

b) Type of ink

c) Fineness of halftone ruling

Graphical work, CDs:

Ink type	Halftone lpi	Mesh threads/inch	Thread diameter
Solvent-based inks	up to 120 dots/inch	305 - 420	27, 31 and 34 µm
UV inks	up to 150 dots/inch up to 38 dots/inch	355 - 460 230/2	27, 31 and 34 µm 34 µm
Water-based inks	up to 120 dots/inch	355 - 460	27 and 31 µm

Direct printing onto ceramics:

Ink type	Halftone lpi	Mesh threads/inch	Thread diameter
Water-based inks Floor tiles	up to 60 dots/inch	103 - 195	80, 70, 64, 55 and 48 µm
Solvent/water based inks Wall tiles	up to 90 dots/inch	305 - 355	34 and (31) µm

Ceramic transfers:

Ink type	Halftone lpi	Mesh threads/inch	Thread diameter
Solvent-based inks	up to120 dots/inch	305 - 355	31 and 27 µm

T-Shirt printing:

Ink type	Halftone lpi	Mesh threads/inch	Thread diameter
Pigment ink	up to 60 dots/inch	156 - 195 230	64, 55 and 48µm 40 µm
Plastisol ink	up to 90 dots/inch	230 - 355	48, 40, 34 and (31) µm

8.11 Improved printing stability through achromatic reproduction

Helmut Acker, Production Manager in an electronic prepress house

Helmut Acker writes about achromatic reproduction from the repro house's point of view.

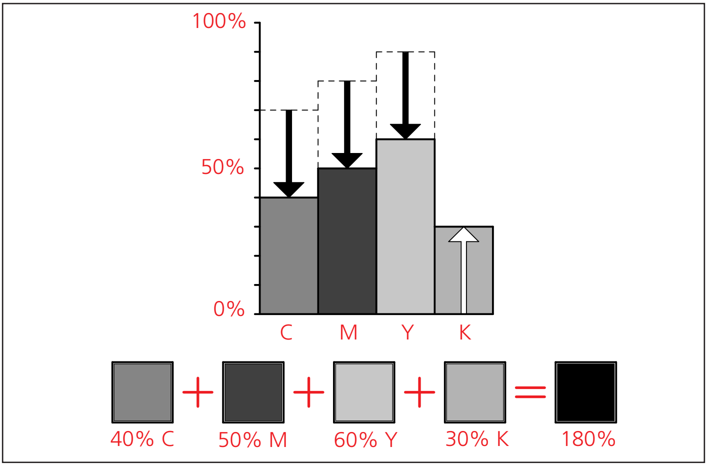
Regardless of the printing process used, multi-color reproductions, where the various hues are produced by rastering, now tend to originate on scanning equipment. Specialized raster types, and rulings, dot shapes and raster angles are either built-in, or are available from dealers as plug-ins.

Modern, customisable color scanners facilitate color separations based either on traditional chromatic techniques, or newer achromatic methods. Given the right software, achromatic films can be produced which are just as reliable and accurate as traditional three-color separations.

There are wide differences of professional opinion about the production of achromatic separations. Some authorities maintain that grayscales should be achieved using black alone, and all composite colors obtained from two process colors plus black. This offers the prospect of saving on expensive process colors, while improving or even matching the brilliance of deep colors – a result much sought-after by offset printers.

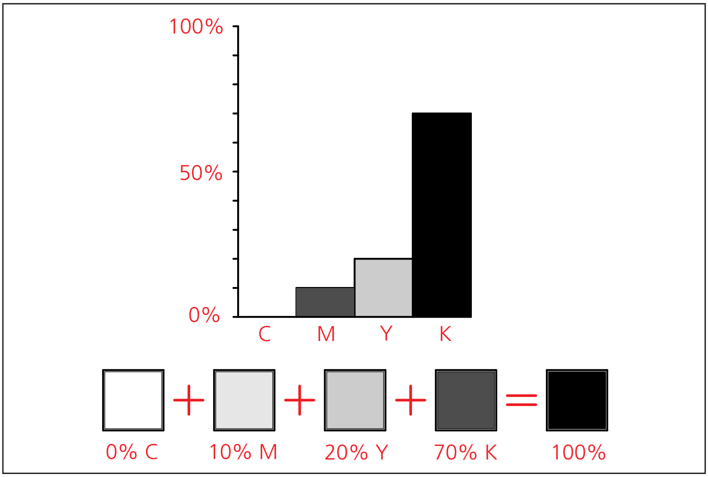
A technical discussion of achromatic films must distinguish between achromatic in a narrower sense, and increased UCR (under-color removal). Practical experience shows that repro specialists must adopt a very different approach to UCR. For technical illustrations of objects like radios, televisions, cameras, binoculars etc, UCR together with a corresponding combination of full black is very successful in reducing coverage from at least 280% to approximately 200%. This gives a more brilliant result, while avoiding color interference effects in areas of dark red or green tones.

On the other hand, illustrations of predominantly full-colored, dark subjects should be given only minimal UCR, to counter the risk of being unable to use black to compensate for strong color removal. This is mainly a problem in gravure and offset printing.



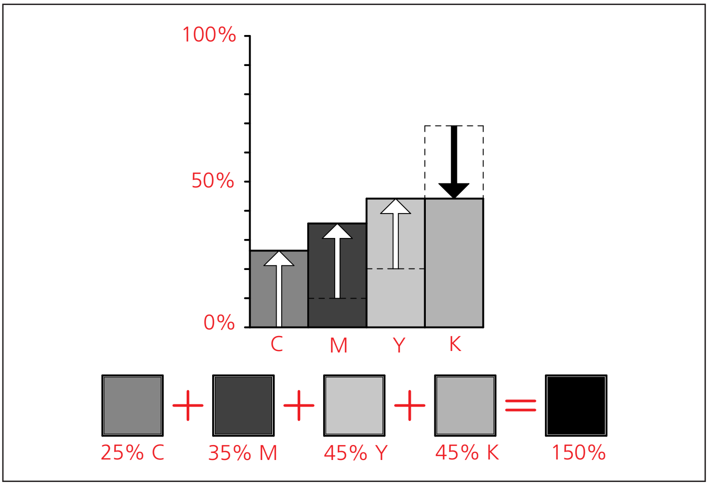
Process color buildup with under-color reduction

In our experience of making software-generated achromatic separations, we generally assemble the separation from cyan, yellow, magenta, and a skeletal black mainly for enhancing the dark tones. We also remove any trace of impure composite color and replace it with black. This results in color separations with much reduced color saturation and an unusually rich black. For example as a result, brown tones no longer contain cyan, while green to olive contains no red. The missing color is always replaced by black. This brings great advantages during the print run. The image generally gains in brilliance, and we notice time and time again: achromatic is more colorful!



Achromatic buildup

Experience shows that, while technically possible, it is inadvisable to carry removal of the third process color to extremes. We know that a grey made up of process colors is more pleasant visually than a half-tone black. We therefore recommend not completely removing the third process color in impure colors, in order to retain a harmonious effect. This technique is known as achromatic buildup with process addition.



Achromatic buildup with process addition

It is fair to ask the reason for discussing achromatic buildup in a raster printing context. It is an established fact that achromatic films offer particular economic and qualitative advantages to offset printers working with four-color and web offset machines. The same can be said of gravure, where offset films are used. Initial results with raster printing indicate that this process stands to gain most of all from achromatic techniques. The missing process color in the final result accelerates drying considerably. The reduction in the amount of ink overprinting virtually eliminates velvet effects. Reduced ink usage brings its own set of advantages. Register problems are much less visible, since black is the only detail-printing color.

Given that on-raster assessment of the color separation is not yet perfect, proof prints remain essential. This inevitably leads to higher film production costs. Extreme use of achromatic technique exacts a price in side-effects and artefacts which have to be taken into consideration. Complete removal the third process color can make certain tones appear harsh, the absence of certain dots in the color rosettes may even lead to moiré, and the smallest differences of register can cause white flashes on some print run specimens. All these aspects, in particular the degree of color removal, must be given due attention by the repro specialist making the color separations.

8.12 Fake color reproduction for textile printing

Heuristic rastering is a digital coloration and design system in which the desired color tones are produced by overlaping textile printing inks on the fibers themselves. A precision-calculated raster doses the individual color elements. A combination of specialised litho work, precision stencil production, and a fine-tuned printing process deposits successive individual ink doses on the mesh fibers, where they subsequently blend together. Four stencils suffice to print a design with a virtually unlimited range of colors . This technique is suitable to producing attractive, multi-colored designs at low cost, with minimal environmental impact.

History of halftone textile printing

There was a time when the printer, as well as the colorist, were artisans if not indeed artists. The requirements were primarily aesthetic, and technical resources were limited.

Times change. It was no longer considered acceptable for the printing machine to limit the maximum number of colors on a printed fabric. Various halftone techniques were developed, including halftone rasters. One well-known example is the "DIRACOP" process, which uses a kind of corn raster. Even now, suitable color separations are prepared by hand, using transparent foils with a grained surface to achieve the half-tone structure.

The corn raster is produced photographically using a magenta contact raster.

There have been repeated attempts at introducing standardised 4-color halftone techniques to the textile printing industry.

Incentives for developing fake color films

The driving forces behind the development of fake color techniques are:

- ability to realize attractive designs
- improved economic factors
- reduced environmental impact

Fake color halftone printing can emulate the appearance of the following techniques:

- halftone
- gradation
- overlay
- multi-color halftone print
- combinations of the above techniques

The basic principles of *fake* color printing can also be found in:

- offset printing
- ink-jet printing
- screen printing

Principles of various printing techniques

The basic principles of the following printing techniques are summarized here, to aid understanding:

- traditional stencil printing
- standardized 4-color halftone printing
- heuristic multi-color halftone printing

Traditional stencil printing

In traditional textile printing, the design is separated into its individual colors. A separation film is used to make a stencil for each color. Areas of the stencil are either permeable or impermeable to ink. These areas may also be occupied in whole or part by various halftone rasters, with due attention to color overlays and underlays. The choice of mesh depends on the textile material to be printed, and is a factor in determining the amount of ink-paste to apply. Ink-paste is pre-mixed to the right color and pressed through the stencil onto the appropriate places on the textile. The maximum number of colors allowed in a design is governed by the size of the printing machine.

Standardized 4-color halftone printing

This technique is similar to graphic raster printing in that the design is separated into primary colors: cyan, magenta, yellow and black. The color parameters used in separation originate from a standard color scale (e.g. EUROSCALA). The color separations are used for graphic raster printing.

Recreating an original design using textile dyes is very difficult, needs much experience, and involves a large number of tests and proof prints. One must be prepared to compromise in matters of color rendition. A restricted color space and color elements produces dull, over-saturated designs. Over printing of the basic colors is usually unavoidable, and the results are unsatisfactory.

Fake multi-color halftone printing (Ciba Specialty Chemicals)

In this technique, the first step is to digitize the design. The chosen raster ruling defines the number of lines/inch, as well as the resolution of the final print. This should take account of the characteristics of the textile stock to be printed, the expected viewing distance, and the desired visual effects.

The dot size controls the brightness (ink quantity) for every single color component. The dots are calculated from tone value scales specific to a given substrate and set of printing conditions. The fake color calculated dots are recorded on film (halftone separation)

The films are used to make printing forms, which reintegrate the individual component dots to reproduce the original design. Correctly sized dots, correctly located, at a calculated angle, on a suitable textile substrate and with the correct inks and concentrations, combine to reproduce the form and color of the original design.

Let us examine the build-up characteristics of inks used in traditional textile printing. Ink build-up is responsible for generating a visually perceptible printed color depth that is related to the ink-paste concentration. It is also a characteristic of the ink. The way in which the inks build up is affected by the following factors:

- the substrate
- pre-treatment
- ink- composition
- ink- volume

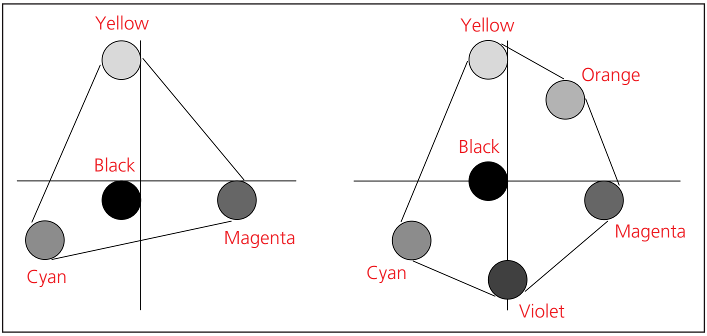
With *fake* color halftone printing, the tone value behavior of various raster values is similarly analysed under given production circumstances. The halftone value describes the proportional size of a dot relative to 100% (maximum) coverage. The tone value behavior on the textile substrate describes the color combination (visual color depth) as a function of percentage coverage (halftone dot size).

The tone value characteristic is fundamental to fake color halftone printing, and deserves a corresponding amount of attention.

Unlike traditional printing, the heuristic method varies the ink-paste concentration. This gives the fully-saturated color at 100% solid area, while a 1% tone value gives the smallest possible addition to the overall color mix.

The tone value characteristic, coupled with a suitable choice of inks, determines the achievable color space.

In heuristic multi-color halftone printing, the color space is not bound to a fixed number of inks. The original design may contain colors that lie outside the space that is printable using 4 colors. To reproduce a brilliant blue, for example, requires an extra blue ink. It is the same in the orange area, where an orange ink is necessary. Taken to the other extreme, there are designs with a color space that requires just 3 inks.



Example of multi-color halftone printing

Color values are first defined, then described in terms of corresponding raster ruling. Separations are then made, based on the textile inks specifically chosen for the job. The basis is the calculated tone value / raster ruling, taking all contributory factors into account (type, raster, angle, mesh, printing sequence, etc.). Production factors are recorded during process analysis, and required degree of reproducibility is achieved through optimisation and standardisation of the individual steps in the process.

The raster films are adjusted to the entire gravure technique (specially selected mesh), technical printing data, color influences and characteristics of the lithographic material. The resulting stencils, used in correct sequence with the defined ink colors and concentrations, give accurate color rendition of the original design on a given textile substrate.

8.13 Objectives of heuristic halftone printing

- more attactive designs
- cost/economic factors
- environmental considerations

More attractive designs

The Ciba multi-color technique with 100 brightness levels allows a theoretical palette of 4 million reproducible colors.

These can be printed using 4 screen. Textile printers can achieve soft color gradations, defined half-tone values, calculated overlays and 3-D effects.

Cost/economic factors

Using this technique, even multi-colored designs require only a minimum number of stencils. This has a strong influence on the overall printing cost.

Given that production printing never requires more than a few stencils, the number of personnel operating the printing machine can also be reduced. Setup times for printing a new design are shorter, since there are fewer stencils to change and the printing inks are the same for all designs, meaning that they do not have to be changed.

Heuristic halftone printing also reduces the workload in the ink mixing shop. It is no longer necessary to calculate ink quantities and mix their individual components. Checks and controls are needed only for the basic colors, which are produced in large quantities with associated economies of scale.

The number of expensive proof prints is minimized. Experience has shown that fake color halftone technique, correctly applied, eliminates the need for corrections and modifications.

Environmental considerations

The problem of processing and recyling old ink does not arise with this technique. Where the same ink-pastes are used for all designs, left-over ink is no longer an issue. Whatever is not consumed one day can be used the next.

Installations like ink scoops, delivery pipework, squeegee systems and ink cisterns no longer need to be cleaned during every design change; instead they can be used straight away for the next one. With traditional methods, clean up wastes approximately 10 kg of ink per stencil. Eliminating this step reduces the demands on the wastewater system.

In halftone printing, the ink-paste deposit depends not on coverage, but the average color density of the design. Lighter shades are achieved through a lower ink-paste deposit. From the fake color designs produced to date (approx. 400), the estimated average color intensity is around 40%. This in turn represents an approximate 60% reduction in liquid effluent from chemicals in the ink-paste (urea, alginate, additives, etc.).

8.14 Technical considerations

This technique requires cooperation between the end user and Ciba. Successful results depend on the quality of cooperation. A heuristic raster based on incorrect data is unusable. It is absolutely essential that the inks specified in the halftone calculation are also deployed in production.

The halftoning mechanism (mixing ink-pastes on the fibres themselves) necessitates transparent pigments. If non-transparent pigments are used, one can expect reproducibility problems within a production batch. Where halftone dots overlap, a non-transparent pigment will obscure the previous ink layer.