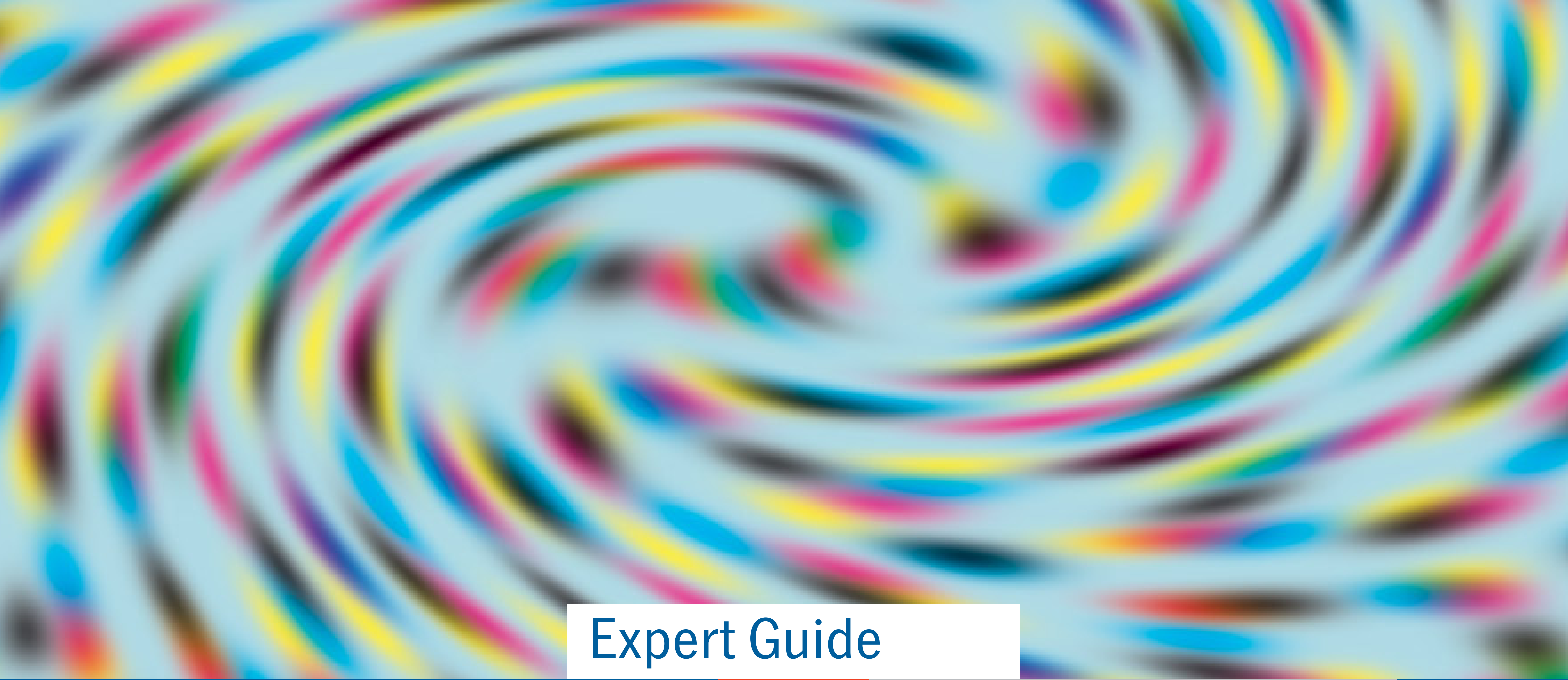
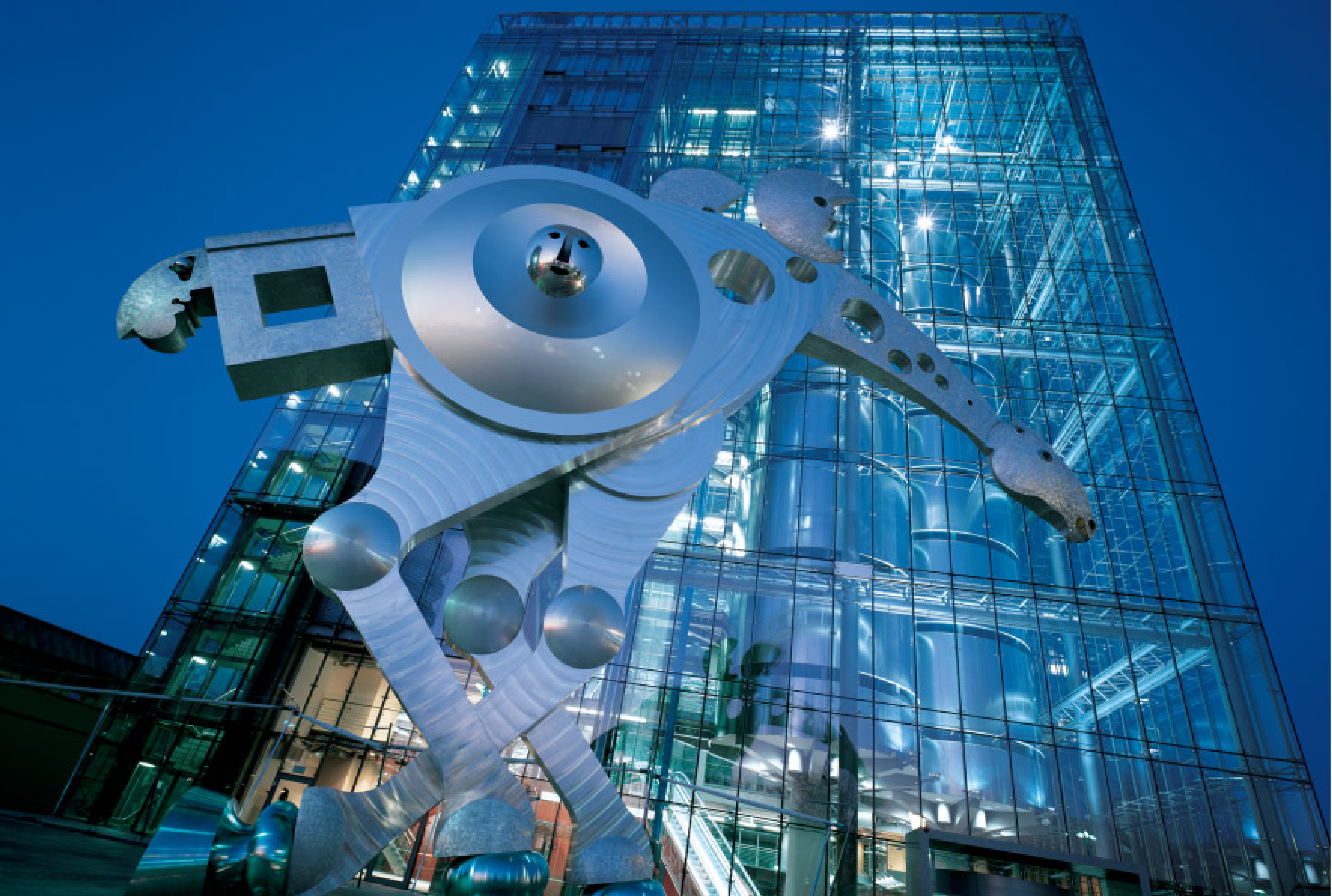


Expert Guide

05•2002 Heidelberger Druckmaschinen AG

An Introduction to Screening Technology

HEIDELBERG



Contents

Prologue

This book was written to help the user become familiar with digital screening. It provides an overview of Heidelberg's (Heidelberger Druckmaschinen AG) screening technologies, explains how PostScript[1] RIPs (Raster Image Processors[2]) work and provides some tips and tricks for dealing with these systems. Over the years, a wide array of digital screens were developed, offering special benefits for specific uses. Excellent reproduction results are possible if users have the know-how for choosing the best screen. That is where this book will help, with attention being drawn here in particular to Diamond Screening® and Megadot™.

Diamond Screening is a frequency-modulated screen that offers a previously unattainable resolution for offset printing bordering on photographic realism. More details about Diamond Screening can be found in Chapter 4.

The development of Megadot Screening has resulted in a smoothness in overprints never thought possible before, and since it eliminated 'offset rosettes', Megadot Screening has improved resolution as well. In many aspects, Megadot is the ideal screen as it can be processed simply and without additional expense. To be able to select the correct screen for a specific purpose, the user must be aware of the many factors that can influence screening. Thus, the first few chapters of this book contain a few fundamental explanations about the screens, specific screening aspects, screen-related aspects in printing, and RIP and imagesetter properties.

Customers, agents, trade schools and other interested parties have asked Heidelberg® for information about screening and the technologies involved. Since this book is aimed at a broad spectrum of readers, little prior knowledge about screening is needed. However, to understand the general context, basic knowledge about printing and color reproduction is helpful. The use of mathematical formulas has been kept to a minimum, and they have only been used to illustrate a point, whenever this was necessary. This book is not intended to replace formal training, but it will probably offer even the experienced operator some interesting tips.

1 General Screening Information

1.1 History

Ever since man has had the wish to reproduce and print images, artists have been asking themselves how they can solve the problem which contones and the tones in between present. Woodcut, the earliest form of letterpress, was accomplished by using knives to carve lines for ornaments and simple figures. Before Gutenberg invented poured and movable type in 1450, complete printing forms with text and images were made of woodcuts. The woodcuts were limited to clearly defined contours, and rarely did the depicted objects contain any detail. Instead, the prints were hand-painted afterwards in order to give the illusion of plasticity.

Slowly, artists during the Middle Ages were able to create lifelike representations graphically by inventing crosshatching. In order to differentiate light from shadow, as well as contones, the artists carved horizontal, vertical, diagonal or curved lines over and next to each other. By crossing over lines several times, as well as by adding hooks and dots, they elaborated continually on the system of crosshatching. This technique was perfected with copperplate engraving, which eventually evolved into the versatile reproduction process of gravure printing.

Etching, the process where a drawing is engraved onto a metal plate, was just one of the many other artistic techniques to follow. The lines in crosshatching can be closer in an etching than in a copperplate engraving and thus produce the effect of a chalky gray. Wood engravings achieved extremely fine nuances of light and tonal gradations by covering the surface with dots. Intersecting white lines resulted in the soft, almost picturesque transition between light and dark that is so typical of wood engravings.

Lithography, which was invented in 1798, used sandstone's natural grain to simulate intermediate tones. Greased sticks were used to draw a print copy on stone, with grease particles adhering to the grains, the size of which depending on the contact pressure. In this planographic printing process, the grease particles absorbed the oily ink, while the damp stone repelled it. That is how prints were transposed from drawings to stone. This process made it possible for the first time to simulate contones using minute elements so that they were no longer viewed as a disturbance.

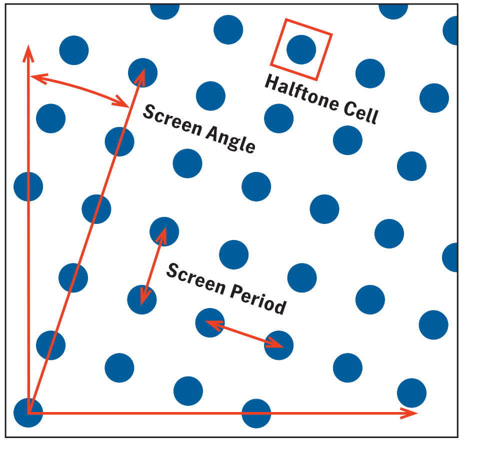
All of these processes had one common goal: to create the perfect illusion of three-dimensional reality; a goal that was nevertheless instantaneously derided as being 'unrealistic' when photography was discovered in the middle of the 19th century and became an immediate success. Since then, photography has been able to recreate people, animals, nature, objects and everyday scenes as the eye perceives them to be. Film which was invented in 1887 has also made it possible for us to make any number of copies of the original in any size desired. It is only when photographs are used in print that compromises must again be made. And this is when we think back very fondly on the techniques used by the old masters.

1.2 What is a Screen?

Unlike photography, differences in lightness cannot be directly reproduced in offset printing. Printed paper either has color or none at all, meaning there is no such thing as 'a little color'. However, screens trick the human eye into thinking that it sees differences in lightness.

In a black-and-white image, different gray tones can be simulated by printing a number of small dots larger or smaller. These small dots are arranged at regular intervals in a grid structure that is called a screen. The relationship of the dot size to the screen mesh or halftone cell,

Figure 1: Example of a screen.



to use the technical term, results in a dot percentage that gives the optical illusion of gray. Whether or not the individual dots can still be recognized depends on their size and on the distance from which they are observed.

The classic screen with a regular, usually square grid structure, has a screen period and a screen angle. The reciprocal of this period is called screen frequency or screen ruling and is usually measured in lines per centimeter. To keep things simple, the dot shape is depicted here as a circle, although dots can come in elliptical, square, round-square, rhombic or other shapes, and the shapes within light, middle and dark areas may vary yet again.

There are screens with regular structures and screens with irregular structures, as you will read later on in the chapter covering frequency-modulated (FM) screening. Parameters that can be applied to regular screens such as screen frequency can't be used in this case, so the smallest dot size is often used as a criterion instead.

Usually, screening is used as a helpful tool for producing print media, but in some rare cases it is also used as an artistic design element. Accordingly, the screen should not be visible or if so at least not in a disturbing way.

The principle used in black-and-white printing can be applied to color printing as well. Every color image can be broken down into process color separations with the help of suitable filters and can be printed with the help of screening. That is actually all there is to screening.

Screening is the art of being able to use only three solid tint colors and black as a contrasting color to simulate a natural-looking color image. As with all forms of art, screening requires substantial expertise.

1.3 Color Shifts

Before we delve into screening processes any further, there are two effects that you should be aware of.

One of these effects is color shift, an important aspect when working with color separations. An extreme case of it occurs when two identical screens with different colors are printed on top of each other. During the printing process, a slight shifting of the color separations cannot be excluded, which means that screen dots are sometimes printed on top of each other and sometimes side by side. The resulting color will be very different each time, as illustrated in figure 2.

Screens that tend to shift color during printing are avoided because you cannot control the results. The extreme example used in figure 2 of two screens with the same angle and frequency cannot occur using a Heidelberg screen system.

Similar but less significant effects can also occur with different screens.

1.4 Moirés

If two screens with slightly different screen frequencies are superposed, disturbances occur in the pattern, similar to the interference seen on a television screen when the screen's resolution superposes the newscaster's patterned jacket, and the bright colors of the jacket dazzle your eyes. The effects produced by this superposing of two screens is called moiré. This also occurs when the two screens are rotated by slightly different angles. To illustrate this, the diagram here shows moiré patterns that result when screen frequencies vary and when screens are rotated.

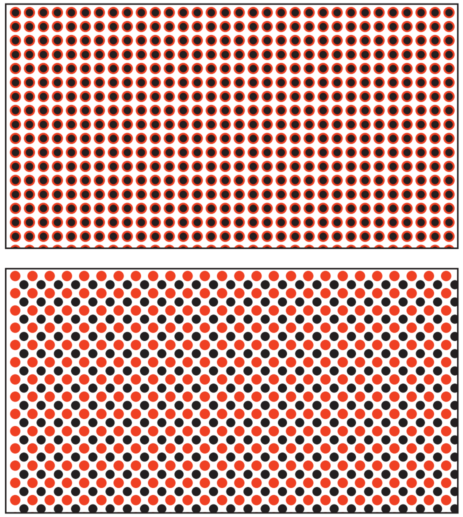
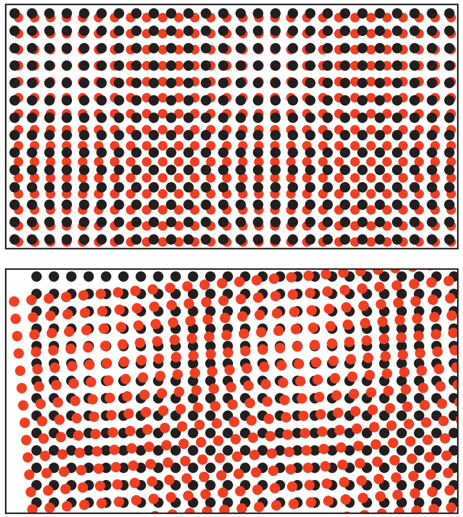


Figure 2: Color shift. The same screens printed on top of each other and side by side.

Figure 3: Example of moiré resulting from differing screen frequencies (top) and from screen rotation (bottom).



1.5 Laser Dots and Screen Dots

Today, plates and films are produced almost without exception using laser imagesetters. All laser imagesetters work on the same principle, which is that a laser beam, or several in parallel, moves line by line over the film or plate. The laser is switched on in those areas in which the film or plate is to be exposed; and where no exposure is required, the laser is switched off. The laser beam is switched on and off digitally at precisely defined cycles, as illustrated in figure 4. The individual laser dots are known as pixels, a somewhat ambiguous term deriving from 'picture element', and each screen dot is made up of a certain number of pixels. This principle lies behind the way a screen is constructed into the pixel matrix of an imagesetter. Understanding this is important in order to understand the upcoming chapter on screening methods and technologies.

There is also another term which seems to cause some confusion. Resolution refers to the number of laser lines per inch and is measured in dpi (dots per inch) whereas screen frequency refers to the number of screen dots per inch and is measured in lpi (lines per inch). It is simpler to use the metric equivalent and speak of lines per centimeter, for example, a 60 screen is a screen with 60 lines per centimeter or 150 lpi.

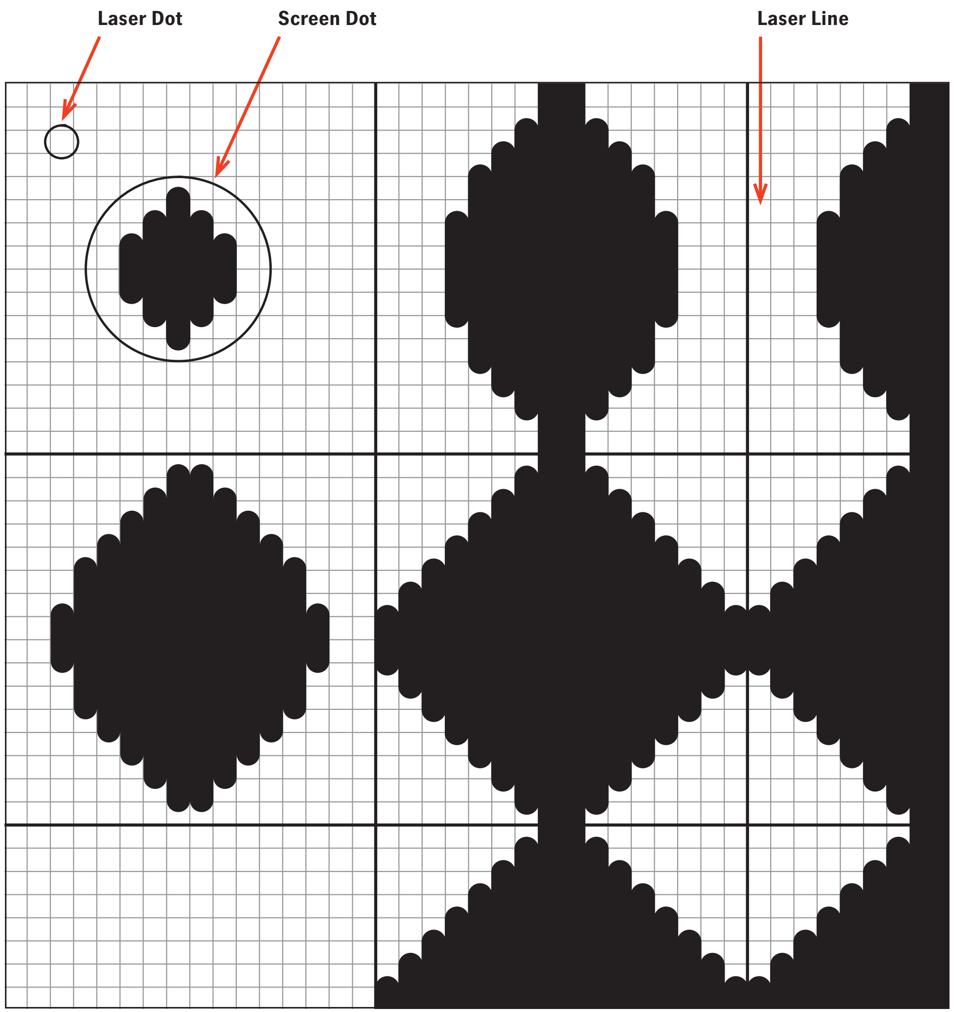


Figure 4: Laser dots and screen dots.

2 Screening Methods

Traditional screening methods were described in Chapter 1.1. In this chapter, we will cover digital screening, but we will also include old screening methods when we discuss conventional screening. The main purpose of this chapter is to talk about screening characteristics that are not linked to any one screening method.

2.1 Conventional Screening

We know that, to be used in print, photographs must first be converted to screened artwork, but the question is 'how?'. The most common solution in the early days of this technology was to use the repro camera. This was accomplished by placing a precision-made rotatable glass plate in front of the film that was to be exposed. The glass plate was etched with a screen pattern and when the color separations were exposed, the image and the screen were superposed on the film, resulting in a screened image. Naturally, color filters were still required to create the individual color separations.

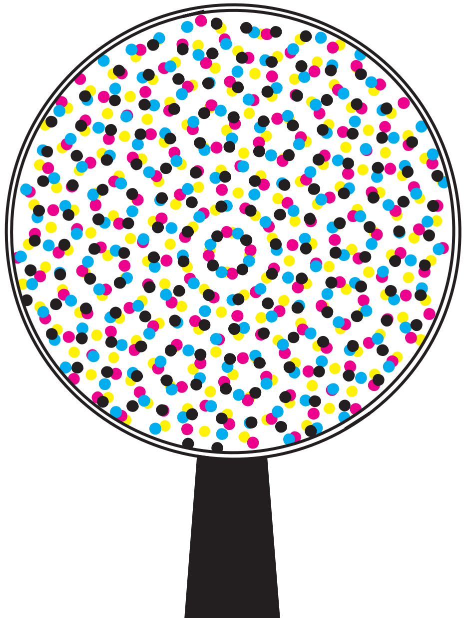
Conventional screening evolved through trial and error. It soon became clear what difficulties were involved in overprinting colors, especially where moiré was concerned (see Chapter 1.4 for more information on moirés). Without knowing the mathematical correlations, it was discovered that cyan (C), magenta (M), yellow (Y) and black (K = key[3]) had to be positioned at the 15°, 75°, 0° and 45° screen angles in order to achieve the best results in the overprint. Because of the way separations were produced, they all had the same screen frequency. Conventional screening is the answer to solving color shift and moiré.

Later conventional screening used a contact screen instead of a glass plate. Conventional color screening produces offset rosettes in the overprint (see Figure 5).

This rosette is also an overprint moiré but is not considered disturbing since the screen period is very small and inconspicuous. When you look at the rosette, it actually seems coarser than the screen itself – it seems like a screen with one and a half times the screen period.

When screen dots are arranged around a white space, it is called a clear-centered rosette. A clear-centered rosette is generated automatically when digital screens are created. The advantage of this is that the dots of the different colors are only overprinted minimally. In shadows[4], in particular, this shape is more open and has slight advantages over the dot-centered rosette. A dot-centered rosette is one in which screen dots are arranged around a dot. Accurate clear-centered rosettes will rarely be seen in practice since even the slightest misregistration[5] can influence a rosette's shape.

Figure 5: This is what an offset rosette looks like when viewing a conventional screen through a magnifying glass.



2.1.1 Overprint Properties in Conventional Screening

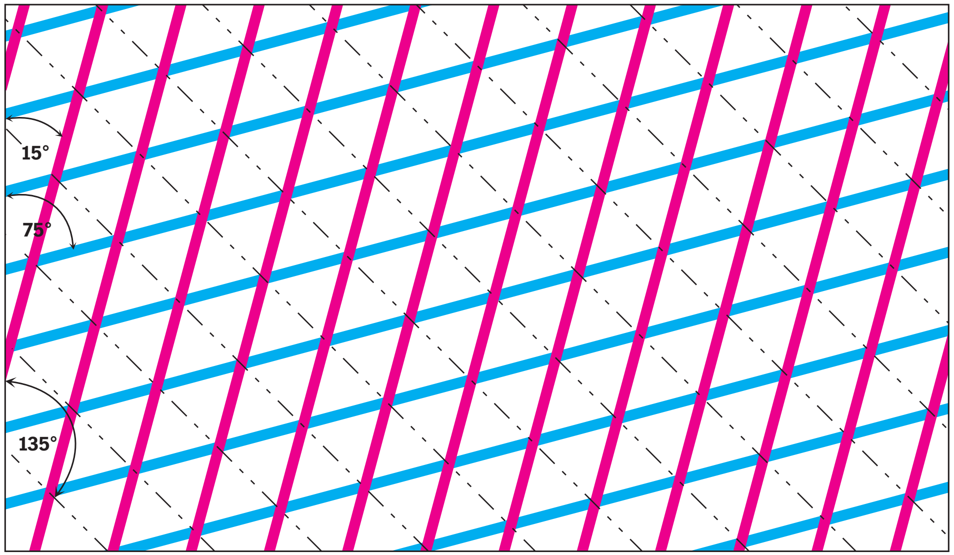
In conventional screening, separations are set traditionally at screen angles of 15° (cyan), 75° (magenta), 0° (yellow) and 45° or 135° (black). Cyan and magenta form a moiré at 45° with an identical screen period (equilateral triangles). This usually isn't visible since the period is too fine. Problems occur when the black separation is superposed at 45°, which nominally also has the same screen frequency. Many hues will have a long-wave moiré or color shifts if even the slightest deviations in screen angles or screen frequency occur in the screen. Users shouldn't take this too lightly, because quality controllers with a trained eye, for example, in advertising agencies, aren't the only ones to spot these mistakes.

2.1.2 Accuracy

If unwanted effects such as color shifts or moirés are to be avoided in overprints, you must keep to very stringent tolerances in your work. A color shift has the most impact if distortion amounts to one color period across the format. If you are unlucky, in some cases a color shift can still have a maximum effect with half a period. This means that, if you want high-quality work, a deviation of a 1/4 of a screen dot across the entire format can just about be accepted.

On an A2-sized signature that has a screen of 60 l/cm (150 dpi), the maximum deviation for the screen angle is 0.003° and the maximum relative deviation for screen frequency is 0.00005. These accuracy requirements are applicable for the entire production process, but it is not always possible to comply with them in printing. Therefore, it is all the more important to be as accurate as possible when generating screens so that errors don't become cumulative. The tolerances specified in the DIN 16547 regulations might be broader, but they were not based on what was required but on what was technically feasible at that time.

Figure 6: Cyan and magenta produce a moiré at 45° (shown as a broken line). A line screen was selected to make this clear.



2.1.3 Screen Angles

Cyan (C), magenta (M) and black (K) as defining colors usually are spaced at angles of 30°. Yellow (Y) as the lightest or least defining of the four process colors is sandwiched in between so that it is only 15° away from its neighbors. In conventional screening, the smaller distance between yellow and its neighboring colors can cause the overprint to have a slight yellow moiré in skin tones in particular or in smooth gray-green tones. This moiré is especially noticeable when color separation films are laid on top of each other.

To further minimize these overprint moirés, especially with the elliptical screen dots generally used today, cyan, magenta and black are generated at angles of 60° from each other, resulting in an allocation of the following colors and angles:

Color	Screen Angles
Cyan	165.0°
Magenta	45.0°
Yellow	0.0°
Black	105.0°

Table 1: Allocation of colors and angles.

Magenta was set at 45°, as you are sure to have noticed, so that the angle difference between yellow and magenta would be large enough to avoid a yellow moiré with magenta. This trick is used to produce very smooth skin tones, which by their very nature contain a considerable amount of yellow and magenta.

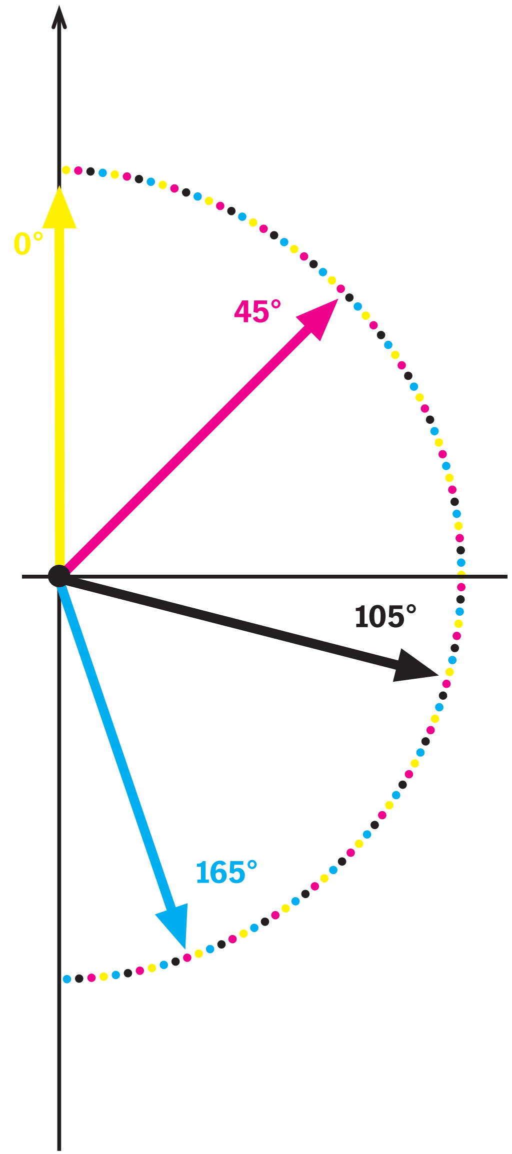


Figure 7: Cyan, magenta and black are spaced 60° apart to avoid moiré.

2.2 Rational Screening

Rational screens, the first digital screens, were developed at a time when computer performance and memory was still very expensive. Rational screening attempts to reproduce conventional screens as accurately or intelligently as possible.

Screens have to be constructed into an imagesetter's dot matrix. This dot matrix is then reproduced in the imagesetter's memory. The simplest way to create an angle is to line up a certain number of (a) dots in one direction and (b) dots vertically. The trigonometric function of tan ($^b/_a$) best describes this[6]. However, to start with, let us look briefly at these somewhat strange terms.

2.2.1 Rational and Irrational Screening

It is quite common to talk about rational and irrational screening in digital screening. Although these terms crop up in everyday use because they are short, they are strictly speaking incorrect. You should at any rate know what lies behind this terminology.

The terms 'irrational' and 'rational' are taken from mathematics. They define sets of numbers with certain characteristics. A rational number is one that can be constructed as a fraction of integers.

Example: $0.333333333... = ^1/_3$
or $0.25 = ^1/_4$
or $\tan(45°) = 1$

The opposite is an irrational number. These numbers cannot be constructed as fractions of integers.

Example: $\sqrt{2} = 1.4142135623730950488016887242097...$
or $\tan(15°) = 0.26794919243112270647255365849413...$
or $\tan(75°) = 3.7320508075688772935274463415059...$

That's about as much as we need to know about the theory of numbers. But remember, irrational numbers are well named.

Whether a screen is rational or irrational depends on the screen angle's tangent. Typical rational angles are 0°, 45° and 18.4°, with tangent values of 0.1 and $^1/_3$. Typical angles with irrational tangents are 15° and 75°. In other words, the conventional screen is irrational.

Based on this definition, we actually ought to talk about screens with rational tangents and screens with irrational tangents, but since this is too complicated for daily use, we talk about rational and irrational screening, also known as RT and IS Screening. RT, or rational tangent, is a more accurate term, as opposed to IS, or irrational screening. The chapter dealing with IS technology describes how to create angles such as 15° or 75° 'accurately'.

2.2.2 RT Screening

The attempt to recreate conventional screens digitally was the starting point for the development of RT Screening. This resulted in a screening technology in its own right that has its own special advantages.

Rational screening will be explained in more detail by using the 0°, 45° and 18.4° angles.

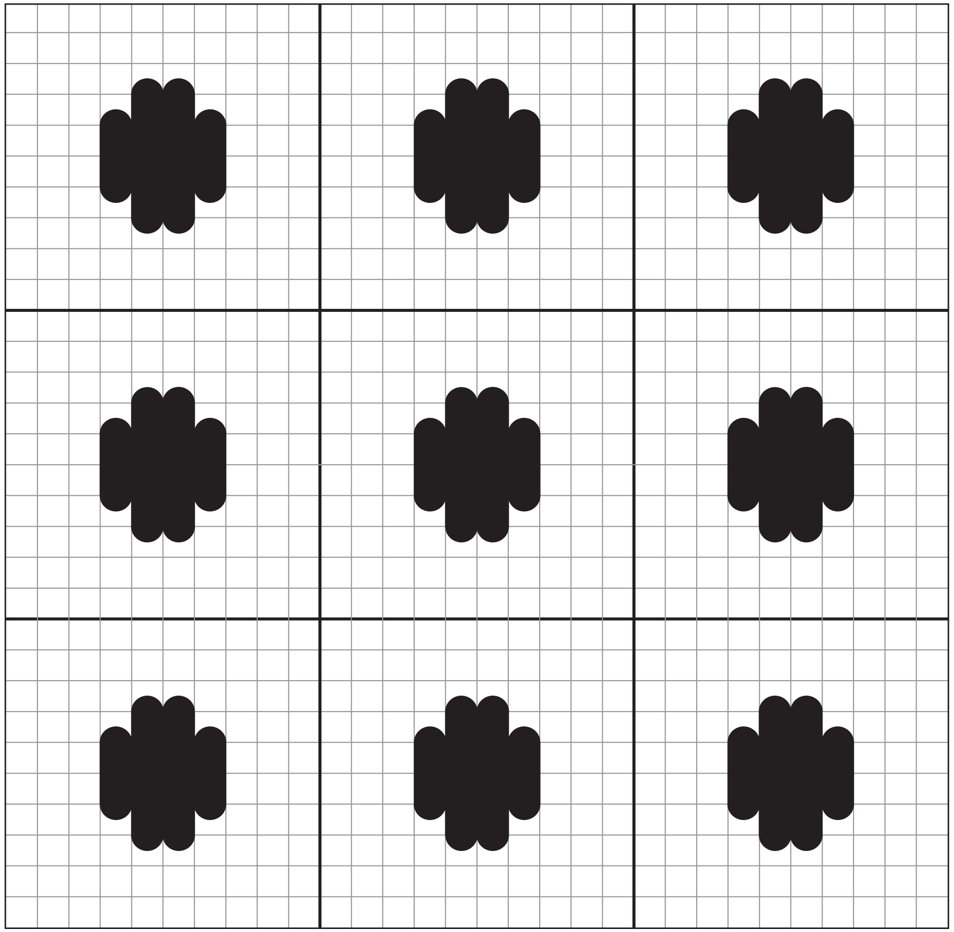


Figure 8: 0° screen dots. Dots set at an angle of 0° can be easily created. A large area is screened by simply lining dots up in a row.

In color printing, screen frequencies are chosen so that the size of three dots set at 0° is the same size as two diagonals of the dots set at a 45° angle.

An angle of 18.4° can no longer be seen as a rational approximation of conventional screening's irrational 15° angle. It is actually 18.43494882292...°. The number is the arctangent[7] of (1/3).

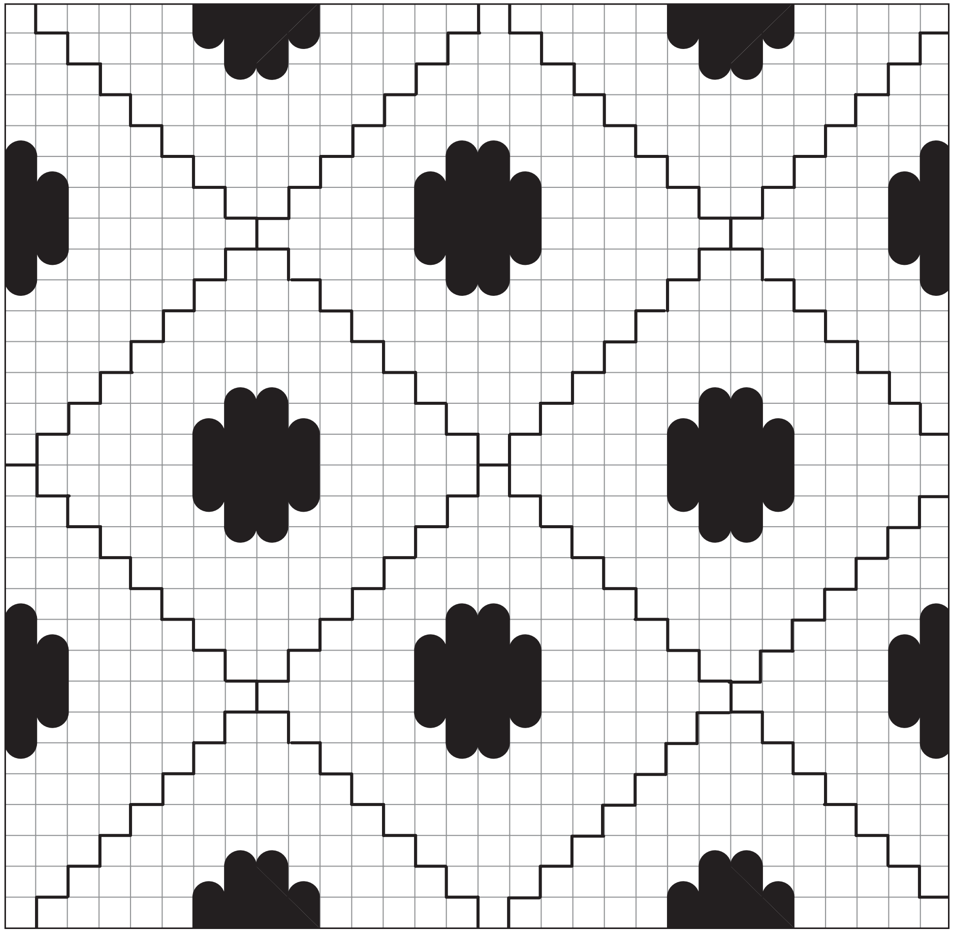


Figure 9: 45° screen dots. Dots set at a 45° angle can easily be created and a large area is screened by simply lining up screen tiles.

The 18.4° screen dots are arranged so that three dots in one direction are followed by exactly one dot in crosswise direction. This simple procedure can be used to create 'tiles' of 3 × 3 screen dots that can then be pieced together seamlessly. The fourth screen angle at −18.43494882292...° is then generated accordingly.

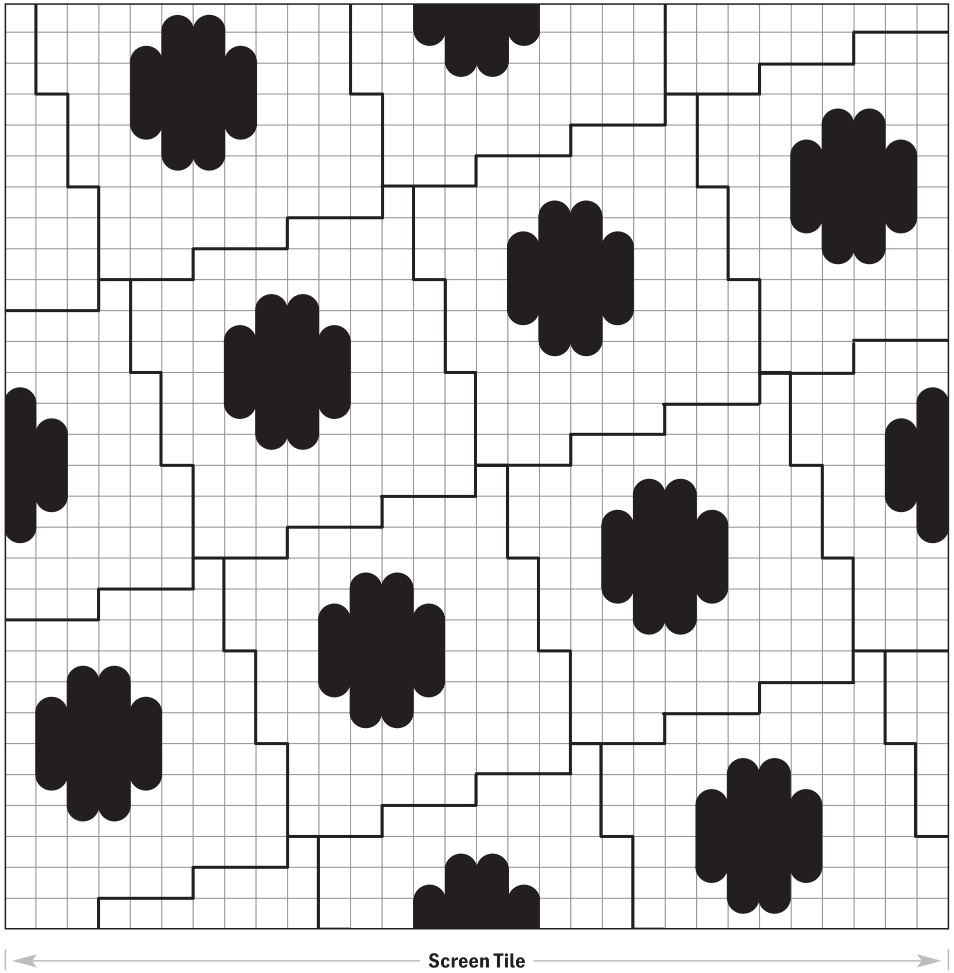


Figure 10: Diagram of an 18.4° screen tile. The pattern is repeated every three screen dots in both directions.

Looking at the diagrams, you will not only notice that the single color separations are composed of screen tiles. You will also notice that all four color separations together are made up of screen tiles, each with 3 × 3 screen dots set at 0°. The great advantage of this is that, when you create an overprint, any moirés there will have a maximum of three screen dots in one period. Consequently, moiré will rarely be viewed as a disturbance since the period is so small.

Accuracy requirements cannot be derived mathematically, unlike with conventional screens. Our experience shows that this screening method is clearly less sensitive to misregistration.

This method is a solution that can be easily implemented and that has very good overprint qualities (see Chapter 4.3 on RT Screening).

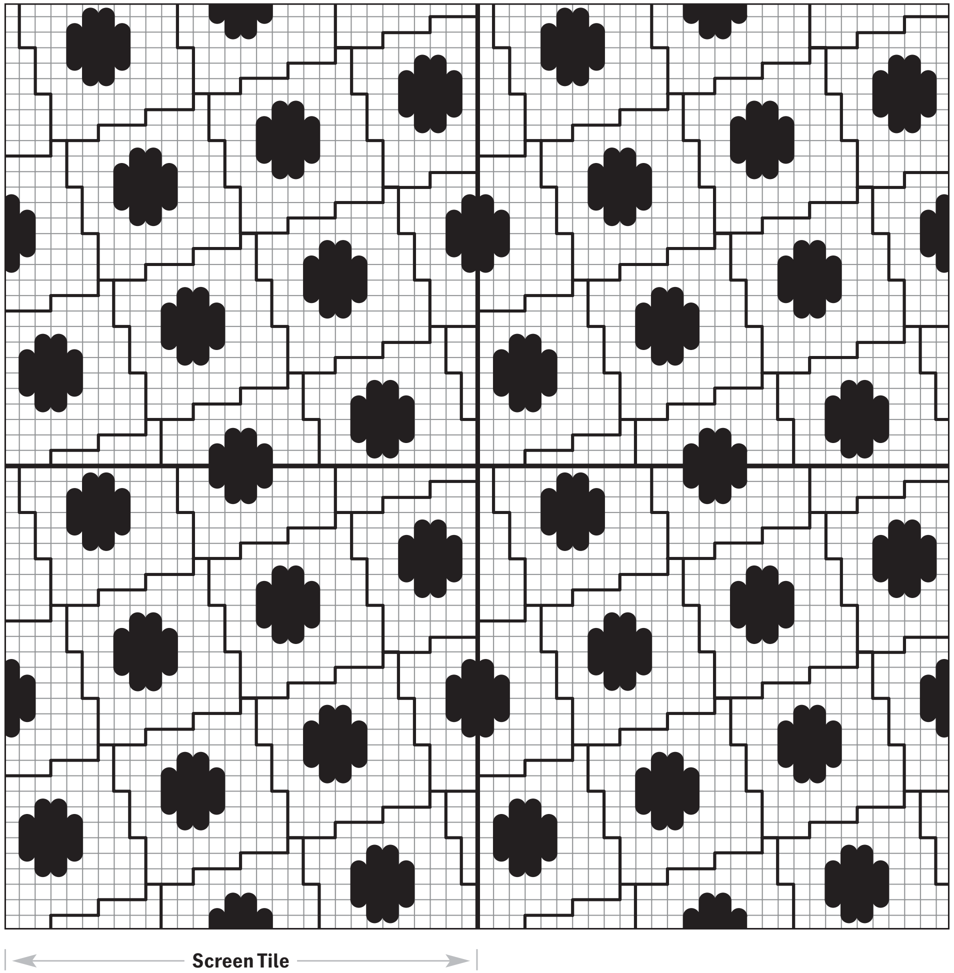


Figure 11: Diagram of a screen composed of screen tiles.

2.3 Frequency-Modulated Screening

A conventional screen is composed of compact screen dots arranged at regular intervals. The individual screen dots get larger as the density[8] increases, whereas their screen period and, consequently, their frequency remain constant. In frequency-modulated screening on the other hand, the frequency of the dots is varied, while their size remains constant. Frequency-modulated screens are composed of a number of tiny, finely distributed dots. As their density increases, the number of dots increase until they touch each other and eventually blend in together. To summarize, what changes in this screening method is mainly the frequency.

To learn more about what factors should be taken into consideration when using a frequency-modulated screening process, see Chapter 4.7 on Diamond Screening.

2.3.1 Dithering

Dithering[9] has mainly been used for laser and inkjet printers. The individual laser dots are distributed as finely as possible in an orderly pattern, as you can see in the following example. Today, error diffusion is usually used (see Chapter 2.3.2).

You will notice that these images become considerably darker when they are copied and are not really suited for further processing. The laser dots are not distributed well enough for this purpose, with a border line that is much too long appearing between the black and white elements (see Chapter 1.5, Laser Dots and Screen Dots). As described in Chapter 7 on screens in print, errors occur mainly at the borders of screen dots when film is copied to the printing plate and as a result of dot gain in print. For that reason, screen dots should be placed as compactly as possible to minimize the size of the border line as much as possible.

2.3.2 Error Diffusion

Several kinds of error diffusion are also used for laser and inkjet printers. These methods decide whether a pixel will be exposed or not by comparing the current pixel with some type of dot matrix and by taking into account the adjacent pixels. Usually, intermediate tints are approximated by distributing white and solid pixels. Each of these pixels will give you a difference to the nominal density, and you are basically making an 'error' that you are attempting to rectify. This principle will be explained briefly using the classic Floyd-Steinberg filter.

The 'errors' that originate when four adjacent pixels are screened are added up with the statistic weightings shown in the following diagram. In this procedure, the current pixel density, marked by an asterisk, is added up with the statistical weighting of 16 (the sum of the other statistical weightings) and divided by the sum of all statistical weightings. The result is then compared with a threshold value and if the result is larger than the threshold, the pixel is then exposed. It is not exposed if the result is smaller or equal to the threshold.

Naturally, this method only calculates those adjacent pixels that are actually set. The 'errors' that were made when each pixel was set continue to diffuse (hence error diffusion) until the current pixel is corrected.

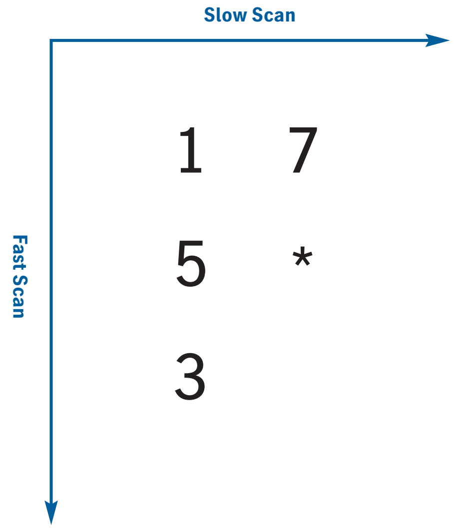


Figure 13: Statistical weighting in fast scan[10] and slow scan directions using error diffusion.

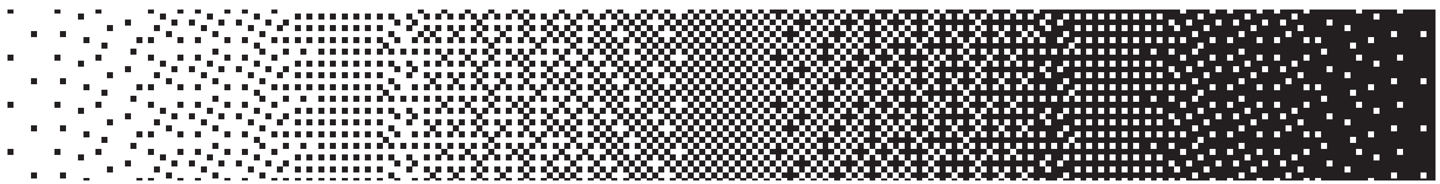


Figure 12: An example of dithering.

This method tends to create artifacts[11] in an image, with the flaws depending on the image. The statistical weights can be varied at random to avoid this from happening, but then you are creating relatively uneven tints in your image. The various error diffusion methods are very popular despite several disadvantages, in particular the time-consuming mathematical computations.

2.3.3 Random Screening

As the name already implies, dots are arranged quasi randomly in this type of screening. This process, however, at the same time makes sure that tints with a constant gray tone are depicted as smoothly as possible and repeating patterns are avoided. A purely random arrangement of dots would create an image that appears very grainy.

Heidelberg's Diamond Screening is one of the quasi random screens. This screening method makes it possible for you to have a print with an almost photo-like quality, achieving a sharpness in detail that is not possible with any other screening method. The usual offset rosettes that are so disturbing do not appear with this method, but instead your result can best be compared to a color photograph.

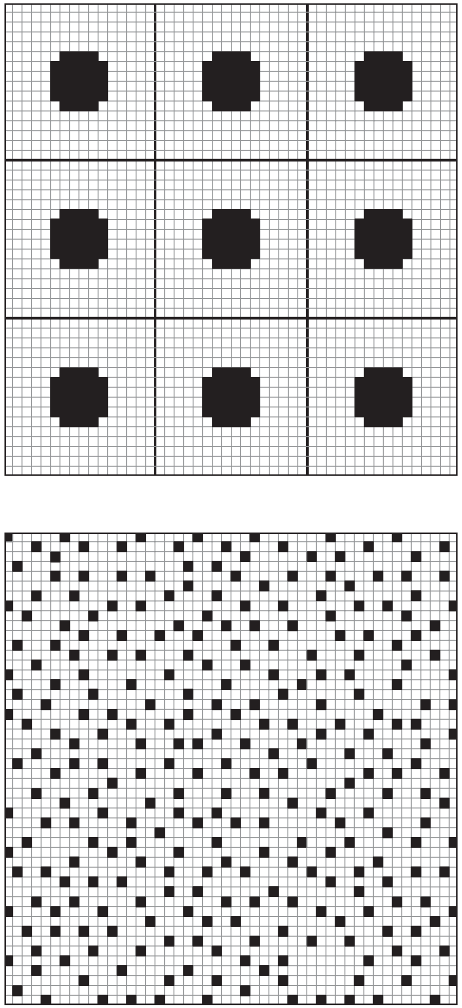


Figure 14: A comparison between a standard screen and a random screen for 12.5% ink coverage.

2.4 Line Screens

Firstly, the dot shape is what makes line screens different from conventional screens. The lines begin in the highlight area as small dots, then change to elongated ellipses that grow into lines. If lines were used instead of dots in conventional screening, the printed image would not have any advantages. Line screens do have the great advantage that two colors with a 90° angle can be overprinted without creating a color shift.

Heidelberg's recently developed Megadot and Megadot Plus make optimal use of line screen benefits. Thus, Megadot and Megadot Plus cannot be compared to the screens described so far. Megadot and Megadot Plus do not create offset rosettes, but instead produce impressively smooth color prints, where the superior type of smoothness is obvious not just with coarser screens but also when a standard 60 l/cm screen (150 lpi) is used.

Line screens have almost the same dot gain as conventional screens (see Chapter 7.2 for more information on dot gain in print). In contrast to Diamond Screening, Megadot screening does not require more care in its processing than conventional screening does. However, unlike Diamond Screening, moirés between the screen and the original cannot be avoided.

Megadot screens do well in color newspaper printing, where the rosette in the coarser screens can often be very disturbing, as well as in the production of high quality art work, where excellent smoothness in the print is possible even with relatively low screen frequencies which are easier to print. Because the typical offset rosette is missing, details can be reproduced more accurately.

Unfortunately, line screens are not that well suited for silk screen printing since lines tend to produce moiré more readily in this process than in other screening methods.

3 Screening Technologies

This chapter deals with the technical implementation and approximation of the screening methods described so far.

In PostScript®, the dot shapes can be defined through functions that are then internally transformed to matrices. Every screening technology described in this book saves screening information as matrices. There are two basic methods:

1. The threshold matrix.
2. The lookup table.

In the first method, threshold values are saved in the matrix and compared with the corresponding position in the image when it is being exposed. If the density is greater than the threshold value, the relevant position is exposed, otherwise it is not. Heidelberg's screening technologies are based on this threshold matrix method.

With lookup tables, a bitmap is saved for every possible density level. Screening is done by simply selecting the appropriate density level from the memory and by outputting the bitmap directly.

3.1 Single-Cell Screening (PostScript Level 1 Screening)

Single-cell screening was the only way to create screens at angles in PostScript Level 1. PostScript Levels 2 and 3 brought enhancements that will be described briefly after we cover HQS Screening®.

Single-cell screening is the most basic form of rational screening and will be explained first to have a better understanding of the context.

As already mentioned, rotated screen dots must be constructed into the recorder's dot matrix. This is done by using the next possible screen angle and next possible screen frequency where the corners of the screen dots fall on whole recorder pixels. A larger screen tile is then formed based on the individual screen dots, the so-called screen meshes or halftone cells. The screen is constructed by placing these tiles seamlessly side by side. The tile in our example consists of a 4 × 4 screen mesh.

Single-cell screening does not allow for many screen angles and screen frequencies. Even if the example only has a deviation of 1°, it is enough to create significantly visible moiré in the overprint. The deviation in screen angle and the different screen frequency of the screen angles both contribute to moiré.

This is a problem for color reproduction in particular because there are only very few combinations that have usable overprint properties. It is only possible to create a subset in RT screening.

Every user should note that standard PostScript screening has quite a few restrictions as to what screen frequencies and angles can be used which in turn affects the quality you can have.

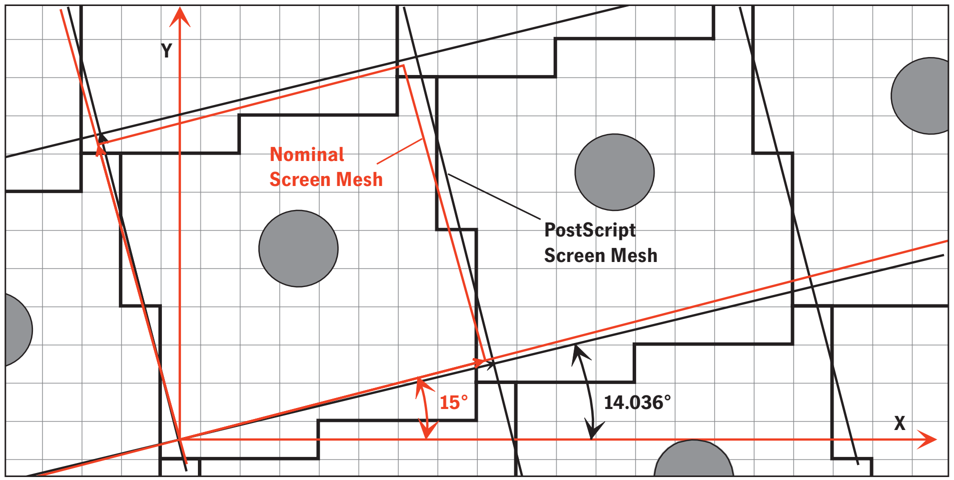


Figure 15: Standard PostScript screen cell.

3.2 HQS Screening

HQS is short for High Quality Screening. In principle, it is a rational screening technology that allows excellent approximations of irrational screen angles. In HQS, a screen cell consists of many screen dots to achieve a closer approximation. The screen dot corners only have to fall on whole recorder pixels every few screen dots. This type of screening, also known as supercell screening, allows a relatively close approximation of screen angles and screen frequencies. The supercells are then placed together to form a screen tile, similar to the example used in the previous chapter. Because screen tiles can become quite large in this process, they are not shown here graphically.

The fact that every supercell can be converted into same-sized, rectangular screen bricks can be mathematically proven. A screen is then made up of these bricks. This is not done by placing the bricks side by side as with square screen tiles but by creating a staggered wall. The screen bricks are often only the size of one row of screen tiles and since these bricks are usually pretty long, address computations rarely have to be done.

Figure 16: Standard PostScript screen tile.

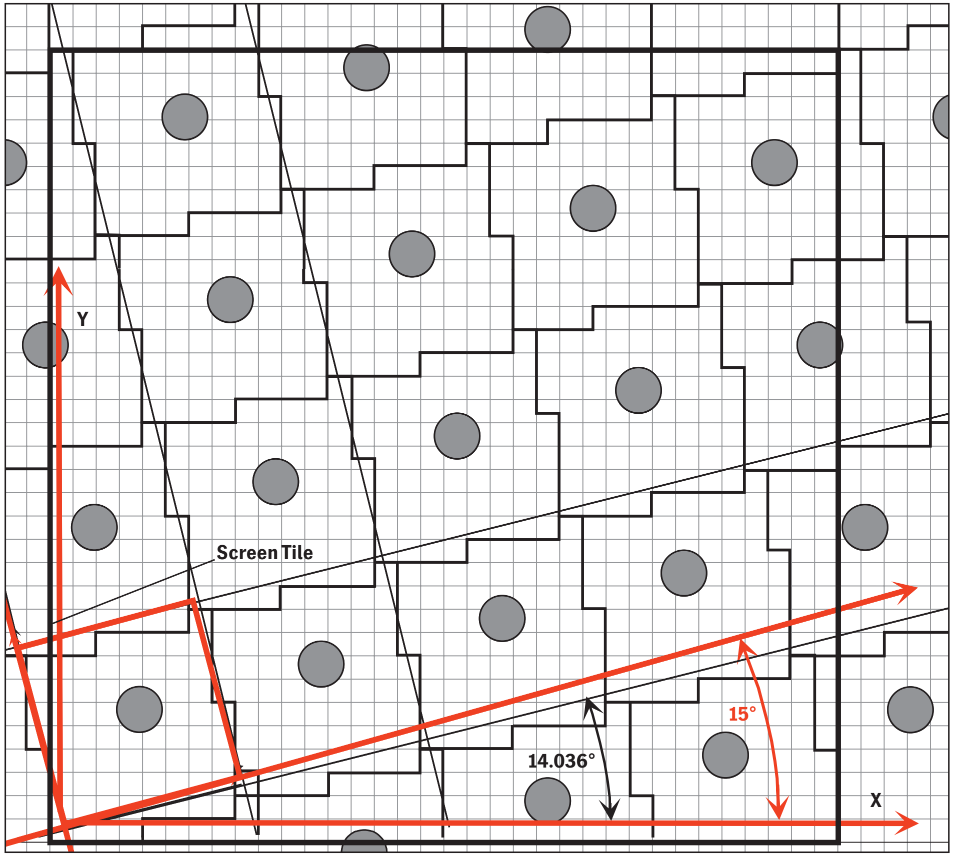
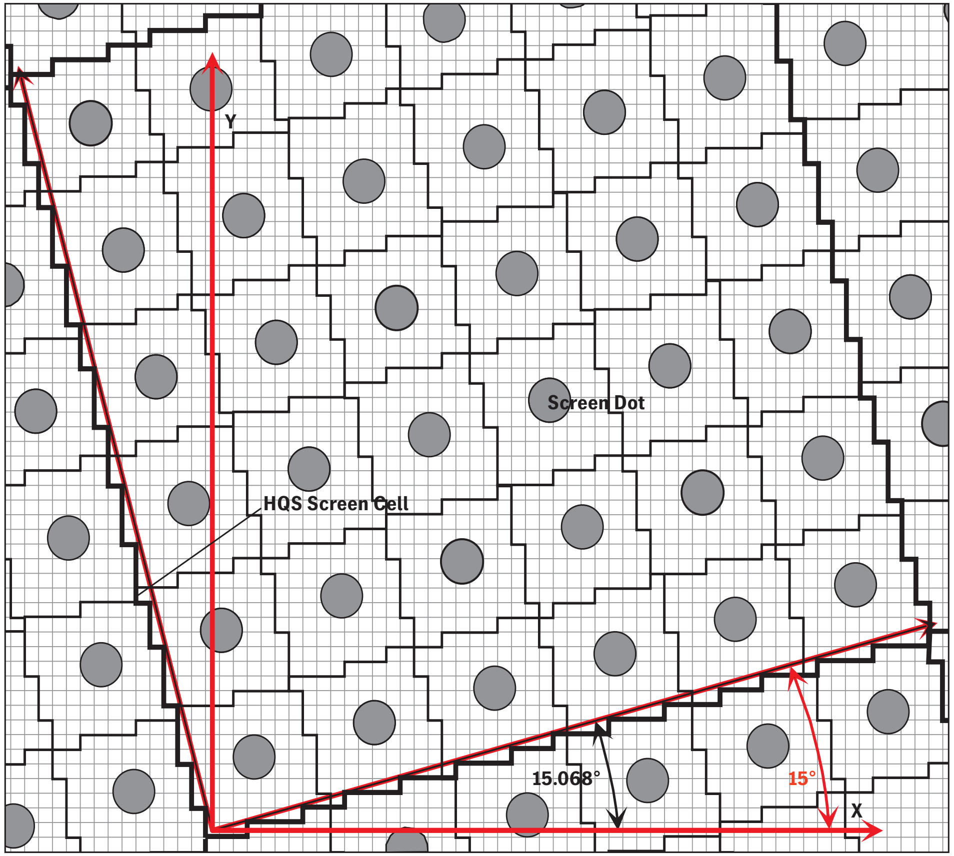


Figure 17: HQS supercell. The nominal screen mesh (red arrows) and the screen cell that was actually generated (black arrows) match quite well.

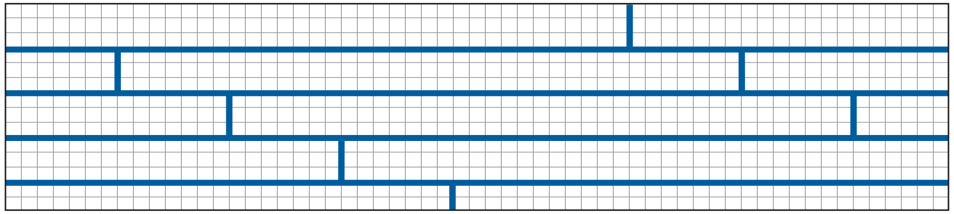


Relatively good screen angle and screen frequency approximations are also possible with smaller, easy-to-process cell sizes as well. The supercells often contain redundancies[12] that can be removed to further reduce memory requirements.

In HQS, all angles typically have slightly different screen frequencies. As a result, moiré in the overprint is a decisive criterion to remember when selecting suitable supercells for the color print. For this reason, a program was developed to calculate screen angle/screen frequency combinations without any disturbing moiré in the overprint. HQS and RT screening use supercells made from several screen dots; they are enhancements of PostScript screening.

The rational screening methods discussed this far (as also used by other manufacturers) are all bound to the dot matrix of a particular recorder. As a result, only certain screen angles and frequencies can be generated by it, something which imposes restrictions on quality as well.

Figure 18: HQS screen 'brick'.



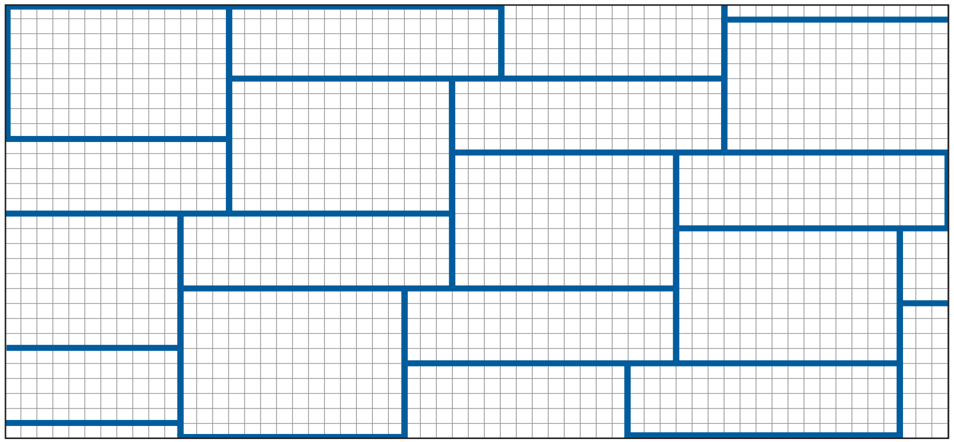


Figure 19:
PostScript Halftone Type 16 tiles: Calculating addresses in the RIP is much more complicated than with HQS screen bricks.

3.3 Supercell Screening

In this section, we will briefly go into other screening options in PostScript. A more detailed description would not fit the framework of this book and is really only of interest to software programmers.

Ten screen types are described in PostScript® 3™ (see PostScript Language Reference. Third Edition). A few of these are still based on single-cell screening (see Chapter 3.1) and the better screens are based on supercell screening which we just mentioned in the previous section. Screen tiles are saved in some screen types, but this requires quite a lot of memory. The most complex screen, the Halftone Type 16, is on par with an HQS screen with regard to its screen angles and screen frequencies. There is no advantage over HQS, and calculating a threshold matrix is more laborious. Two differently sized rectangles are taken from the screen tile and placed seamlessly side by side (see Figure 19).

With Halftone Type 16, Adobe® has opened the world of supercell technology to RIP manufacturers who do not have their own screening technology. Nevertheless, the considerable hurdle of generating threshold values still has to be overcome. There is no PostScript screening method that produces better quality results than HQS.

3.4 IS Technology

Irrational Screening (IS) has made cutting-edge technology available to PostScript RIPs. This screening method is used to create extremely precise screen angles and screen frequencies. IS is used in the names of specific screens based on IS technology.

There are two very different implementations of IS technology: one for hardware and one for software. The two different implementations achieve practically the same results for screen angles and screen frequencies, but the algorithms used to calculate the screens are very different.

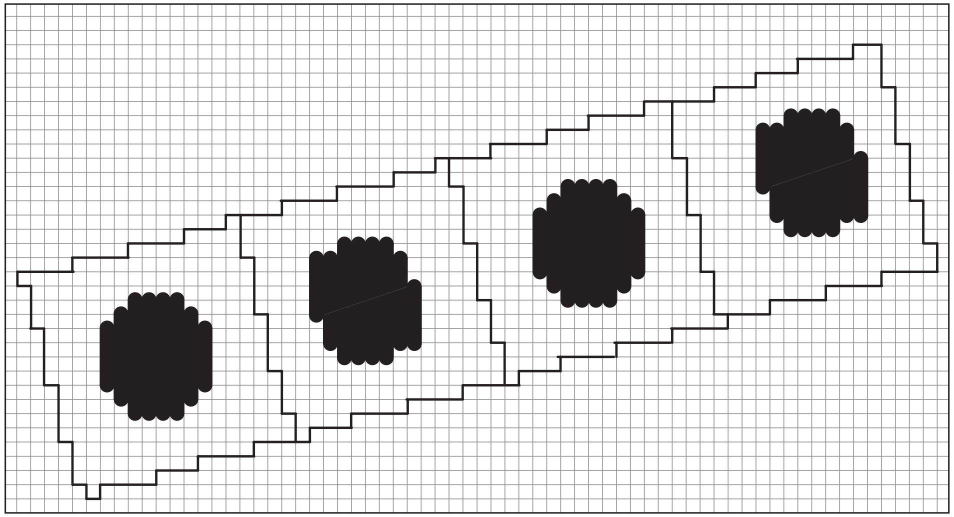


Figure 20: IS screen dots set an angle of 15°. The sequences involved in IS screening are irregular and do not repeat themselves.

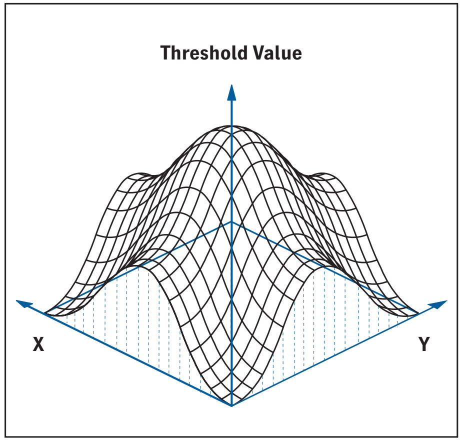


Figure 21: Diagram of a dot matrix. Gray tones, which are shaped somewhat like this if a round-square dot, is used, are stored in a matrix with an edge that is 128 elements long in x and y direction.

3.4.1 Classic IS Implementation in Hardware

Unlike the steps used in rational screening, a 15° angle can't simply be created by going three steps forward and one step to the side. Instead, the sequences involved in creating IS screen dots are irregular and do not repeat themselves.

The starting point for creating a screen is a dot matrix[13] that, in newer RIP implementations, consists of 128 × 128 elements. The dot shape is stored as a 12-bit gray tone in this matrix. We have illustrated what this dot matrix looks like when shown three-dimensionally.

The various screen angles are generated by transforming the coordinates system in the imagesetter into the mainly rotated coordinates system of the dot matrix. Technically, this transformation takes place in a RIP that calculates the dot matrix coordinates on-the-fly[14].

With one set of coordinates defined as the starting point, the address increments[15] are added up very accurately in x and y direction, and in this way the coordinates are calculated for the dot matrix. The gray tone stored in the dot matrix is compared to the density found in the image, and depending on the results of this comparison, the relevant recorder pixel is exposed. The exposed area is equivalent to a horizontal sectional plane through the dot matrix.

If the dot matrix limit is reached during calculation, the overflowing bit is simply cut off and the resulting rest of the address is used as the new coordinates. This step can be repeated as often as desired. At the end of a row, the starting point of the new row is calculated by adding those address steps to the starting point of the previous row.

The RIP does not address each element in the dot matrix during a run; different elements are used for each run for the 15° angle depicted in the example. However, it can happen that the same elements are always addressed with 0° and 45° angles. This will be described in more detail in the pages to follow.

IS screening gives you a screen period that is accurate to ±0.000000015 and a maximum angle error of ±0.0000012°. In other words, the first systematic deviation from the nominal position by just one recorder pixel will occur only on a film that is larger than 80 m × 80 m. The level of inaccuracy found in supercell processes when approximating to conventional screens varies and amounts to some screen dots in every normal recorder format (see Laser Dots and Screen Dots in Chapter 1.5).

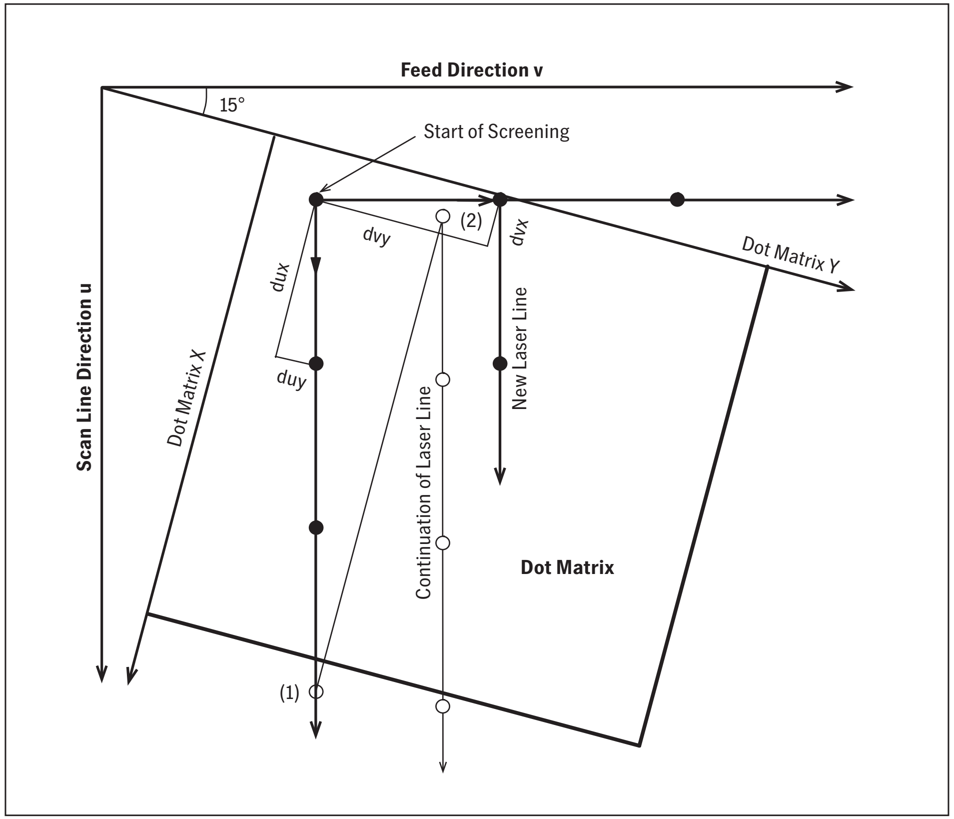


Figure 22: Transformation of coordinates in the RIP. Details can be found in the text.

This high level of precision has its price. Special hardware is needed here because the calculations must be generated quickly and yet must be exact. A software implementation would be much too slow. A further improvement in quality can be made without investing too much in hardware, namely by doubling the number of recorder pixels in fast scan direction. However, to do this, the imagesetter must support the asymmetric resolution mode and must be able to process the resulting data which is now doubled. Some imagesetters are not familiar with this mode, others must reduce their imaging speed, and others again only support asymmetric resolutions up to a certain value. Asymmetric resolution not only reproduces a better dot shape, but also increases the number of pixels per screen dot and in turn the amount of density levels that can be displayed.

It isn't hard to see the advantages in having many recorder pixels per screen dot.

An example of this: A screen dot made of eight laser lines is created if a 120 l/cm screen (300 dpi) is exposed with a recorder resolution of 1000 l/cm (2540 lpi). Only 64 (8 × 8 = 64) different density levels can be displayed using such a screen dot, which is by no means enough. Even if the imagesetter pixels are doubled in fast scan direction, 128

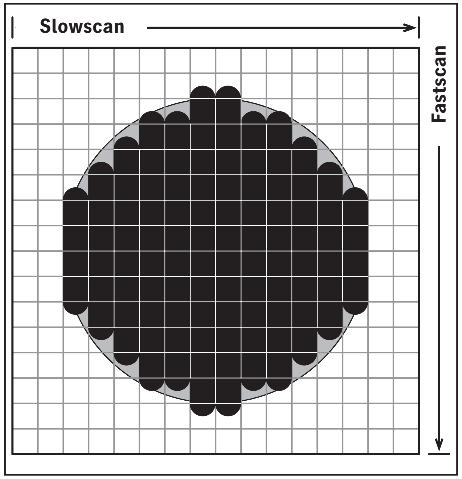


Figure 23: Diagram of a screen dot with symmetrical resolution in fast scan direction (rotational direction of laser mirror or drum) and slow scan direction (feed direction). Size: 16 × 16 pixels.

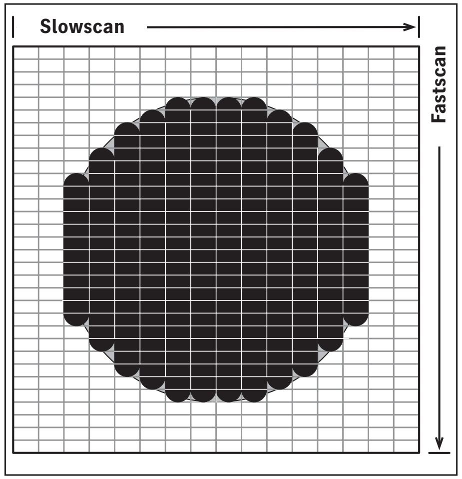


Figure 24: Diagram of a screen dot with double the resolution in fast scan direction (rotational direction of laser mirror or drum) compared to slow scan direction (feed direction). The reproduction of the dot shape is considerably better. Size: 16 × 32 pixels.

density levels are still not enough to show a gray scale smoothly in an ink coverage going from 0 % to 100 %. Breaks, or banding[16], especially in the dark end of the scale, are very noticeable.

Because the human eye is very sensitive to differences in dark areas, approximately 1000 density levels are needed to display a smooth vignette, at least if it is constructed of even tints. See Tips and Tricks in Chapter 8 for more details.

Multidot technology is implemented to achieve the greatest number of density levels possible. The dot matrix memory is no longer loaded with just one dot, but with four, nine, or even 16 dots. Each dot differs slightly from the next, and the result is that adjacent screen dots also vary slightly. The difference is so small that it is not detected by the naked eye since the eye only recognizes integral densities. The selective use of this technology, depending on the resolution and frequency, will guarantee that more than 1000 density levels are always available. However, in most cases only 256 gray levels of that can be used because of the PostScript interpreter. The only exception to this is smooth shading, which is described in Chapter 8.2, Vignettes.

Despite PostScript restrictions, the quality of vignettes, film linearization (see Chapter 6.7) and calibration (see Chapter 6.6) of the printing process benefit substantially from the minimal 1000 gray levels possible in screening.

Not all input levels can be mapped to an output level if mapping in process calibration is 8 bits to 8 bits (standard in PostScript). As a result, steps are lost and breaks occur in the vignettes (see Chapter 8.2 for Tips and Tricks – Vignettes). If mapping in process calibration is 8 bits to 12 bits, there is usually an output level for every input level. The high number of output levels reproduced is due to the higher resolution in the 12-bit dot matrix. Normally, no steps are lost during a conversion from 8 bits to 12 bits, resulting in noticeably smoother vignettes.

The principles described here for Multidot and 12-bit screen resolution can be applied to all Heidelberg screens.

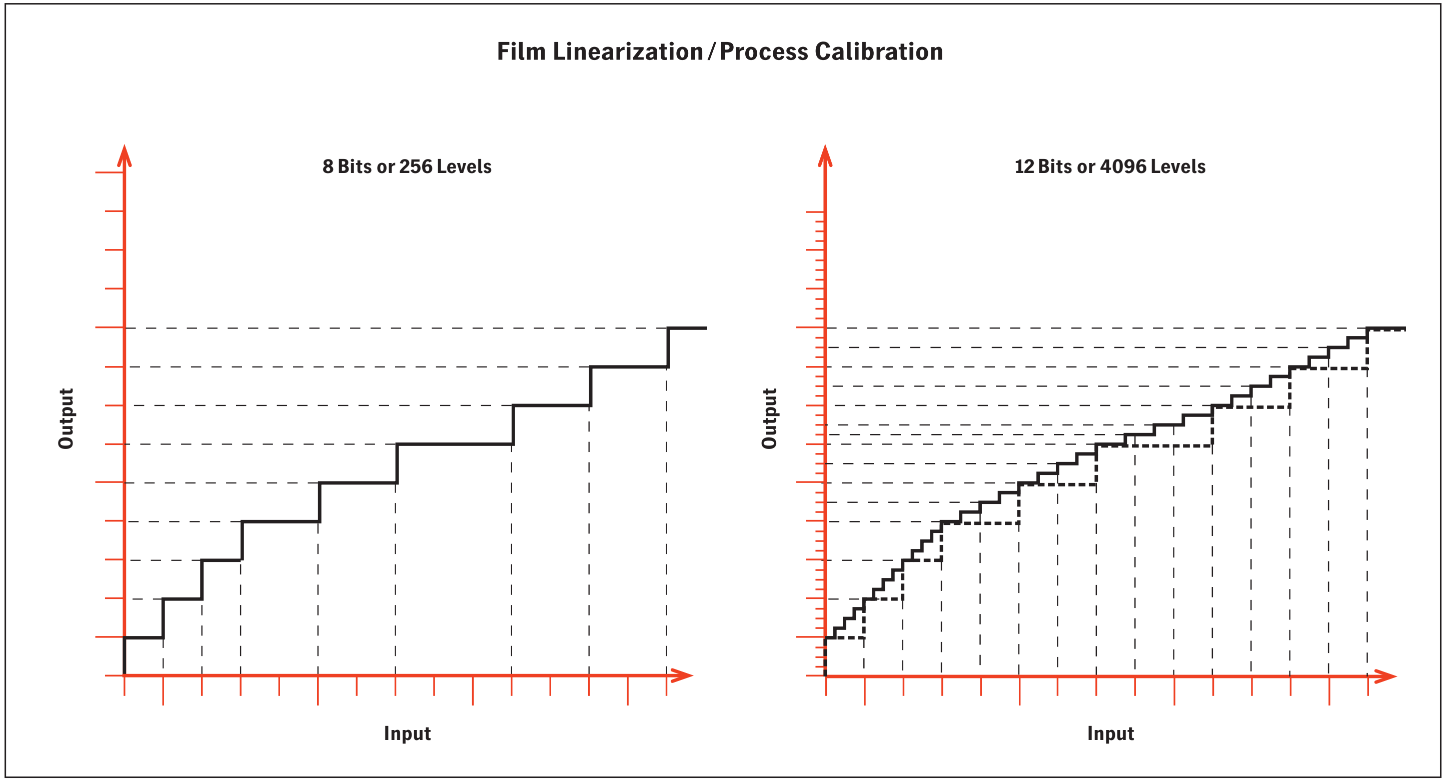


Figure 25: Comparison of a calibration with 8-bit and 12-bit resolution.

3.4.2 Modern IS Implementation in Software (Soft IS)

The software solution for irrational screening is the most recent development in a long list of screening technology innovations to come from Heidelberg.

The classic hardware IS algorithm cannot be processed quickly enough in software. This is why the software solution is based on completely different algorithms which are basically similar to the HQS process described earlier. Some crucial changes have removed the HQS restrictions and enable full screen angle and frequency compatibility with IS hardware screening.

Asymmetric resolutions are not supported in the way they are in the hardware implementation, not even when the film or plate recorder is capable of doing so. In the software solution of this technology, it takes twice as long to calculate screens when the resolution is doubled in fast scan direction, and the prolonged imaging time is unacceptable. This apparent shortcoming is compensated for in Multidot technology by expanding the dot matrices to more than 16, the result of which is a vignette quality with practically no difference between the hardware or software implementation.

The software solution does have a cost advantage because the user doesn't have to purchase special screening hardware such as the Delta™ Tower. A 500 MHz PC will have approximately the same screen performance as a Delta Tower as long as there are no other complex operations running on it.

Probably the biggest advantage of Soft IS technology is that IS, RT, HQS, Diamond Screening and Megadot can all be made available in one and the same product, so the user doesn't have to worry about whether to choose HQS or IS when buying a solution. The overall trend to software solutions makes this a future-oriented solution.

The quality of Soft IS is the same as for hardware IS, so separate print proofs are not necessary. The print samples in this book can also be used as references for Soft IS. Soft IS speaks for itself – it provides the best possible quality with the least amount of effort.

4 Screen Systems and Dots

This chapter is intended as a reference for the various screen systems and dot shapes. It does not build upon the previous chapters, so it is possible that some of the details from earlier sections are repeated here.

In color reproduction it is not a matter of just supplying black-and-white film for the four color separations, but of achieving optimal overprint properties for the repro material. There are only a few combinations of angles and screen frequencies that guarantee good results so that is why it is important to hit on exactly these combinations.

We use the term 'screen system' when talking about such a combination. A screen system always has four screen angles, although the corresponding screen frequencies may differ. The frequencies are selected to minimize moiré in the overprint, which is why you can't simply overprint any screen frequency. Most screen systems have several dot shapes with which they work optimally.

RT, IS, Megadot or Diamond Screening is strongly recommended for color work, and not the standard PostScript screening.

Several screen frequencies can be chosen for each screen system. The value shown for frequency is a nominal value, meaning that not all angles will be processed with precisely this screen frequency. The nominal value usually refers to 0° or 45°. Related to the nominal value, the relation between the screen frequencies and the various angles remains constant, which means that overprint properties do not depend on the screen frequency but only on the system used. The overprint quality of most of the screen methods that do not use IS screening technology depends on the screen frequency selected. This is also the case with HQS screen filters[17].

Many programs allow users to enter arbitrary screen angles and screen frequencies. This data is then approximated more or (usually) less accurately (see Chapter 2.1.2 on Accuracy or Chapter 3.1 on Single-Cell Screening). However, since there are only a few combinations of screen angles and frequencies that guarantee good overprint results, it makes no sense for users to enter arbitrary screen angles.

4.1 Screen Angle Direction

Screen angles were discussed in the previous chapters without explaining how they are measured. The absolute position of the angle also wasn't important in previous discussions.

The only thing that is crucial for the overprint is the relative positioning of one angle to another. This fact and the fact that PostScript has no specifications in this respect meant there was never a uniform standard in the past. The zero position was almost always 12 o'clock, but the counting direction was either clockwise or counter-clockwise, depending on the output system. The development of digital screen proofing systems created a new scenario. To get a proof with the exact same screen, film and plate recorders must act the same as the proofing system.

That is why new products implement screen angles in a standardized form, irrespective of the output system. This is based on DIN 16547. The angles are counted as on a compass. Zero degrees is north and the counting direction is clockwise. These approaches always refer to the finished print. On an offset film, it means that the type must be right-reading, and the emulsion side is usually face down. The examples used follow this principle.

In practice the user must clarify whether the system will follow the standard or be device-specific.

The dot shape also plays an important role in establishing the screen angle. Because of the symmetry in round and round-square dots, there are no clear-cut angles, but instead there are always two equally good angles staggered by 90°. The elliptical dot and the line screen are in contrast to this as they both have clearly defined angles that are measured in the direction of the first dot chain or the line. All of the following systems are defined for elliptical dots. Angles rotated by 90° also occur if the dots show symmetric properties.

The above rules are not valid, or only to a certain extent, for situations in which Heidelberg screens are deactivated and PostScript screens are activated. Such cases depend on how the application sets up screening. A deviating dot shape can cause a 90° angle rotation even if angles that are compatible with Heidelberg screens are specified. A reverse counting direction is also possible.

This chapter will now describe the screen systems in the same order used for screening methods in Chapter 2 and then the dot shapes that are suitable for each of these systems.

4.1.1 Print Results

Colors in the overprint can seem different as a result of the varied overprint properties of rosettes, line screens and frequency-modulated screens.

This happens although the dot gains in the single separations are identical and cannot be avoided even if you calibrate your plate or film output device. Further optimization of the printed result in all tonal values can only be achieved by using color management on the basis of ICC profiles. This reference book was printed intentionally without ICC profiles.

4.2 Irrational Screening (IS)

IS systems are conventional screen systems where the defining colors, cyan, magenta and black, are spaced at angles of 60°. This large distance between the angles produces better overprint results, especially when using the standard elliptical dot.

IS systems are not approximations, but exactly conventional screens with excellent quality. Irrational screening achieves a quality unattainable with any other screening method.

4.2.1 IS Classic

IS Classic is the classic, conventional offset screen system.

The position of the angles in this system can be seen in the diagram opposite. As can be seen in the table of relative screen frequencies, the yellow separation at 0° is somewhat finer than the other screens. This reduces the moiré that can appear in yellow in conventional screening methods (see Chapter 2.1, Conventional Screening).

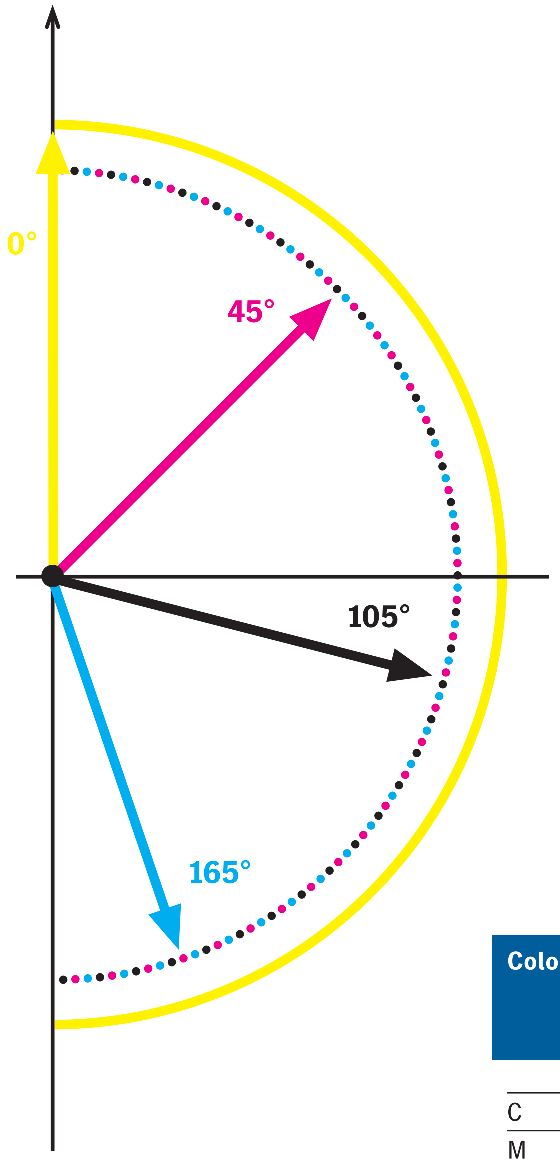


Figure 26: Angles in the IS Classic screen system.

Color	Screen angle	Relative screen frequency
C	165.0°	0.943
M	45.0°	0.943
Y	0.0°	1.000
K	105.0°	0.943

Table 2: Properties of IS Classic.

4.2.1 IS Classic

Screen System:	IS Classic	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

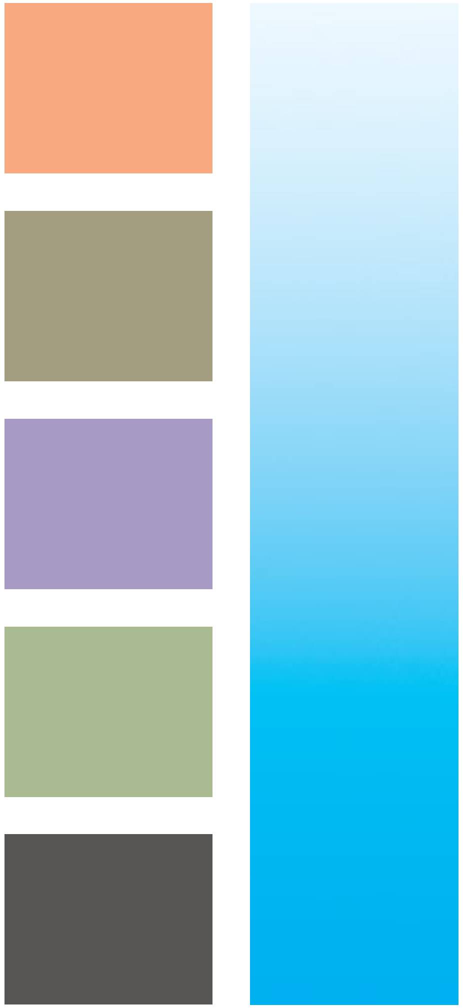


Figure 27

4.2.2 IS Y fine

The IS Y fine screen system is only available with Soft IS. It is modeled on the conventional offset IS Classic screen system. Yellow is generated as a fine screen in order to avoid yellow moiré found in conventional screening.

As can be clearly seen in the table of relative screen frequencies, the yellow separation set at 0° is finer than the other screens.

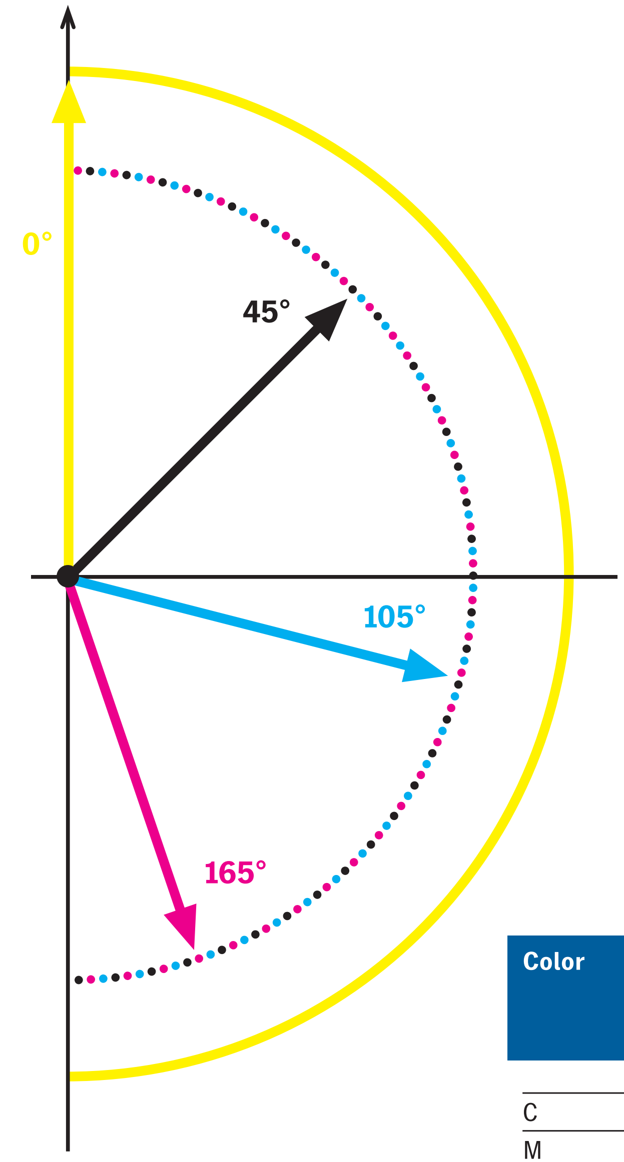


Figure 28: Angles in the IS Y fine screen system.

Color	Screen angle	Relative screen frequency
C	105.0°	0.943
M	165.0°	0.943
Y	0.0°	1.414
K	45.0°	0.943

Table 3: Properties of IS Y fine.

4.2.2 IS Y fine

Screen System:	IS Y fine	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

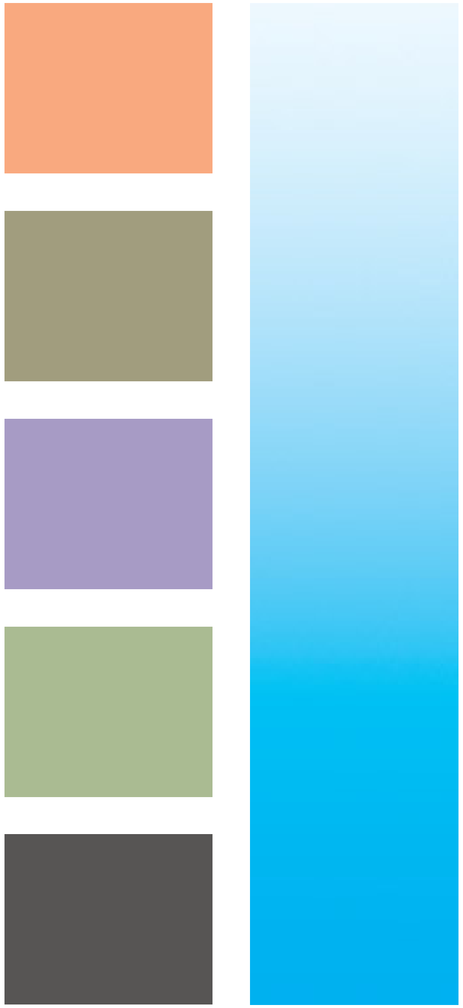


Figure 29

4.2.3 IS Y60

IS Y60 is a conventional screen system in which yellow is set at 60° and all colors have exactly the same screen frequency.

This screen system is more suited for flexography or silk screen printing than the IS Classic screen system. Moirés between the screen and the silk screen or screen roller that inks the flexographic form are minimized as the system does not have an angle of 0°.

Some customers expect to benefit in printing, for example, with slurs and doubling[18], by avoiding the 0° angle and for that reason use this screen system. However, since yellow shows up very light anyway, avoiding the 0° angle for yellow does not make any difference in screen visibility.

The table shows the allocation of colors to the screen angles and relative screen frequencies.

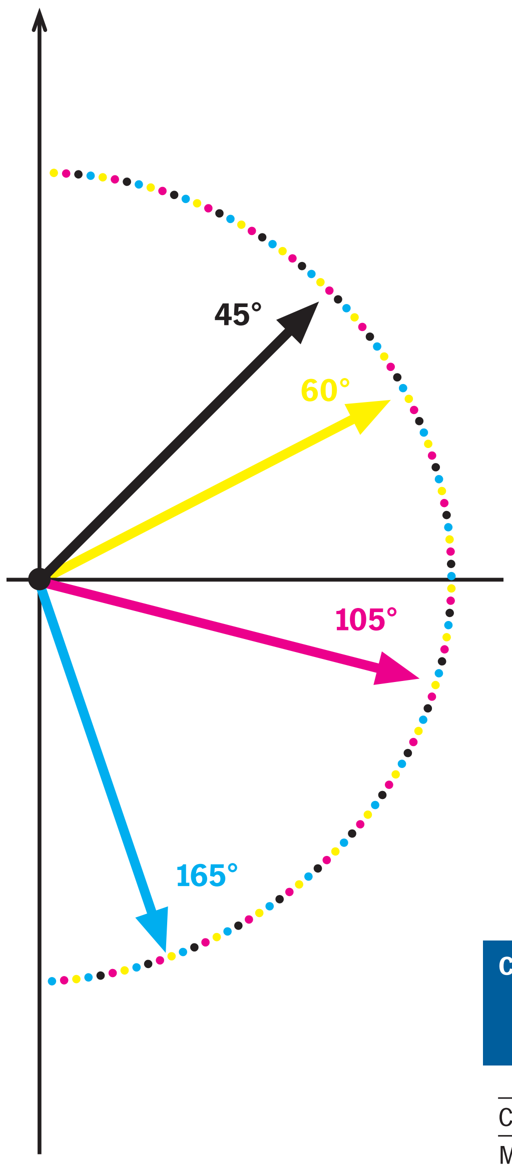


Figure 30: Angles in the IS Y60 screen system.

Color	Screen angle	Relative screen frequency
C	165.0°	0.943
M	105.0°	0.943
Y	60.0°	0.943
K	45.0°	0.943

Table 4: Properties of IS Y60.

4.2.3 IS Y60

Screen System:	IS Y60	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

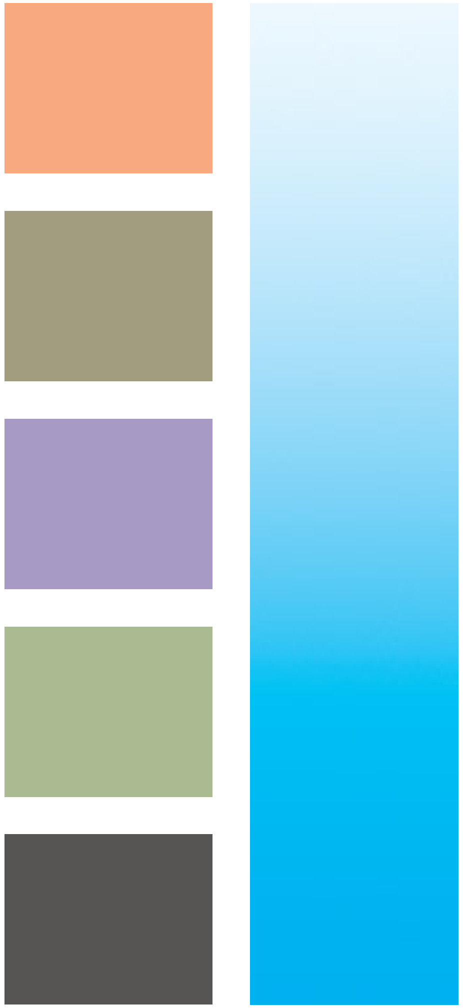


Figure 31

4.2.4 IS Y30

IS Y30 is a conventional screen system in which yellow is set at 30° and all colors have the same screen frequency. It is the counterpart to the IS Y60 screen system for the processing of negative films.

This screen system has the same properties as the IS Y60 system. It is more suited for flexography or silk screen printing than the IS Classic screen system. Moirés between the screen and the silk screen or screen roller that inks the flexographic form are minimized as the system does not have an angle of 0°.

Some customers expect to benefit in printing, for example, with slurs and doubling[18], by avoiding the 0° angle and for that reason use this screen system. However, since yellow shows up very light anyway, avoiding the 0° angle for yellow does not make any difference in screen visibility.

The table shows the allocation of colors to the screen angles and relative screen frequencies.

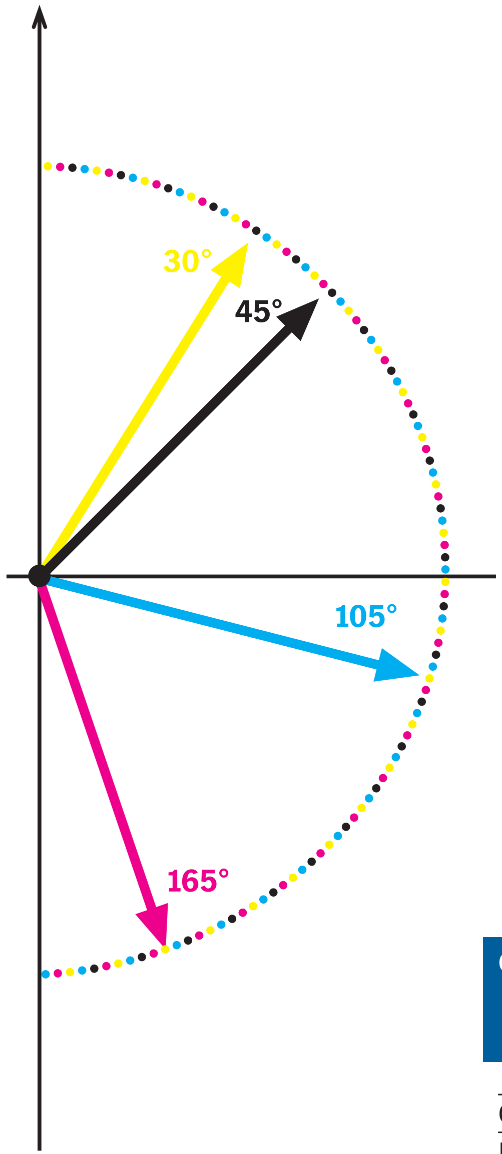


Figure 32: Angles in the IS Y30 screen system.

Color	Screen angle	Relative screen frequency
C	105.0°	0.943
M	165.0°	0.943
Y	30.0°	0.943
K	45.0°	0.943

Table 5: Properties of IS Y30.

4.2.4 IS Y30

Screen System:	IS Y30	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

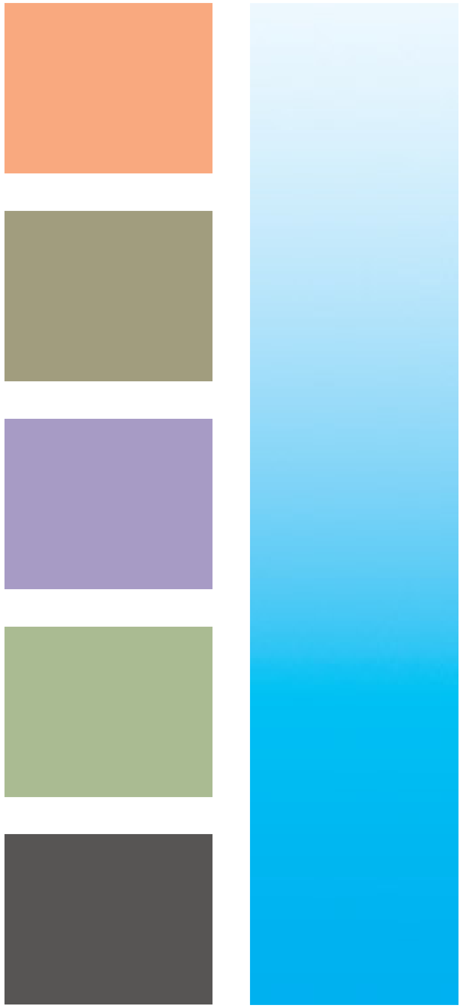


Figure 33

4.2.5 IS CMYK+7.5°

IS CMYK+7.5° is a conventional screen system that has been rotated by 7.5°. All colors have exactly the same screen frequency.

This screen system was developed especially for flexography and silk screen printing. The 7.5° angle minimizes moiré between the screen and the silk screen or screen roller that inks the flexographic form.

For this reason, this screen system is especially well suited for offset-gravure (OG) conversions with a HelioKlischograph®.

In offset-gravure conversions, a lith film is descreened in the scanning head so that there are no moirés between the litho screen and the HelioKlischograph's gravure screen.

The HelioKlischograph can only engrave circumferential lines. The IS CMYK+7.5° screen system is very compatible with gravure screens when descreening originals as it does not have 0° or 45° angles.

We will not go into offset-gravure conversion any further as gravure printers have the necessary know-how anyway and working directly with Computer-to-Cylinder (CtC) in the meantime has become commonplace.

This screen system is extremely well-suited for conventional offset printing. It has the best overprint properties of all conventional screen systems.

The table shows the allocation of colors to the screen angles and relative screen frequencies.

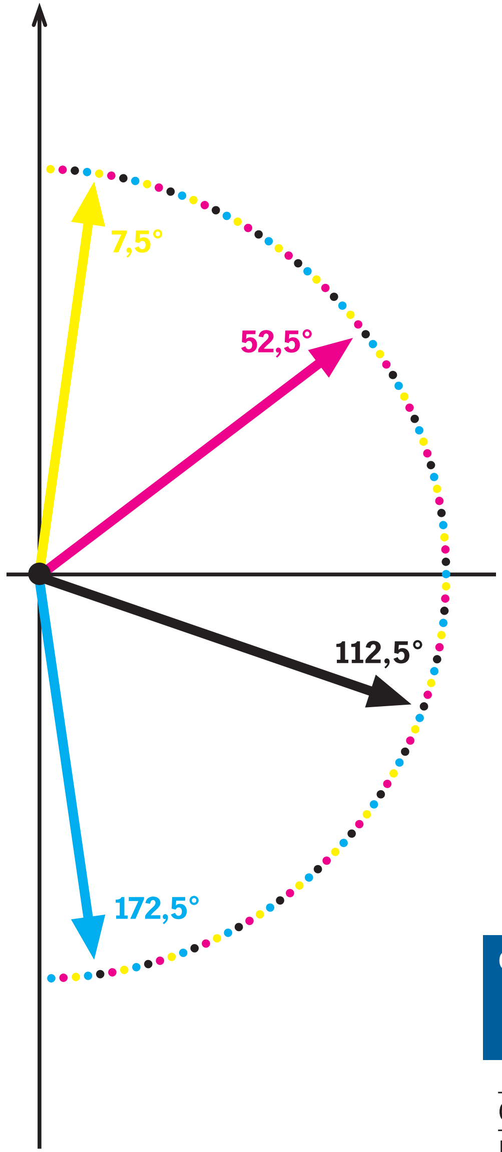


Figure 34: Angles in the CMYK+7.5° screen system.

Color	Screen angle	Relative screen frequency
C	172.5°	1.0
M	52.5°	1.0
Y	7.5°	1.0
K	112.5°	1.0

Table 6: Properties of CMYK+7.5°.

4.2.5 IS CMYK+7.5°

Screen System:	IS CMYK+7.5°	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

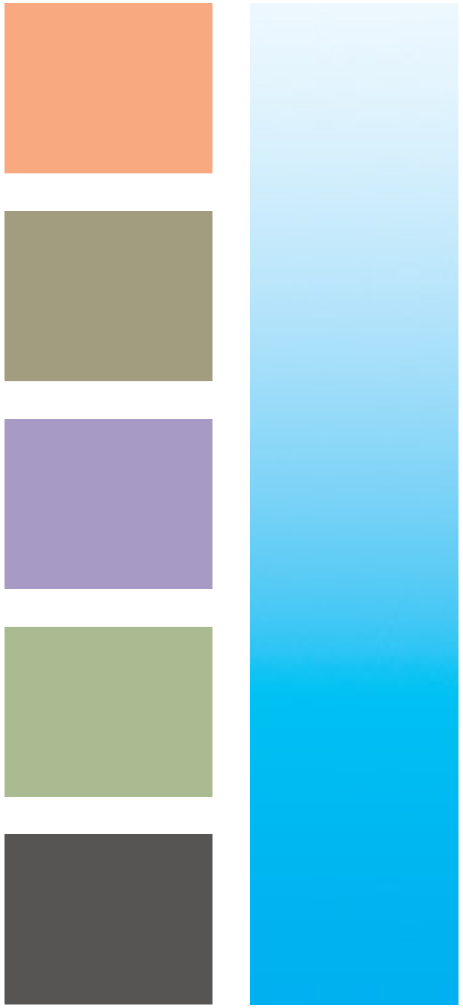


Figure 35

4.3 Rational Tangent (RT) Screening

These screen systems are ones in which all the angles have a rational tangent. (Of course, all 'rational' screen angles can be generated exactly with IS Screening).

There are differences, some of them great, in the relative screen frequencies for the various color separations of these screen systems.

RT Screening was developed for the first scanners and recorders that could screen electronically. The overprint qualities are nevertheless much better than those in the PostScript Level 1 screens that were developed much later.

4.3.1 RT Classic

An example of rational screening was described in Chapter 2.2.2. The overprint shows a weak, square structure instead of the usual offset rosette pattern.

The table shows the allocation of colors to the screen angles and relative screen frequencies.

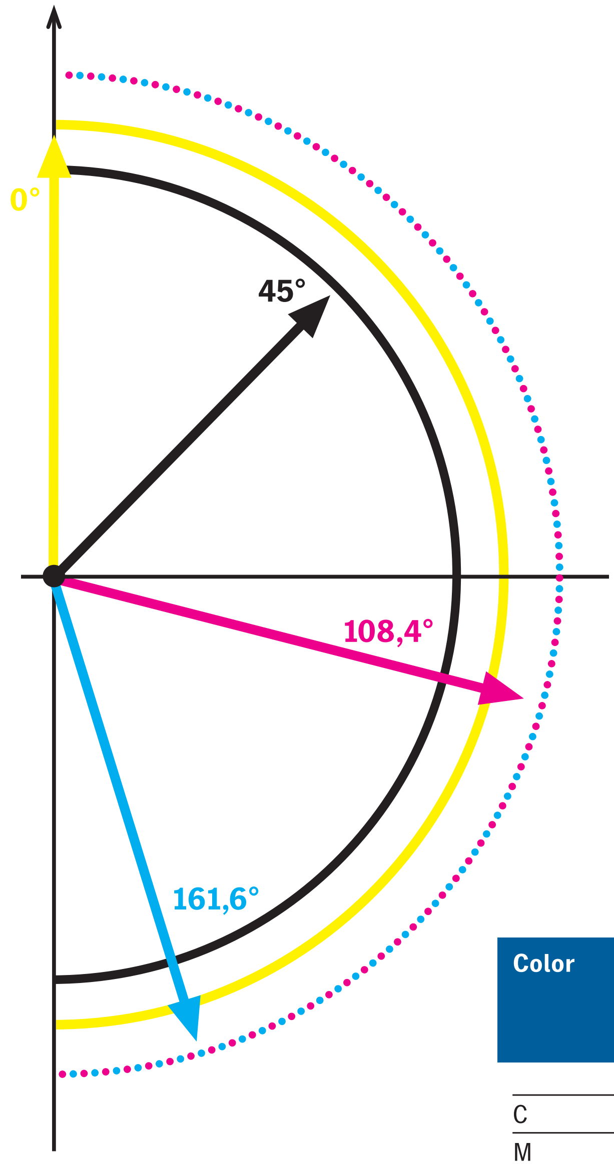


Figure 36: Angles in the RT Classic screen system.

Color	Screen angle	Relative screen frequency
C	161.6°	1.054
M	108.4°	1.054
Y	0.0°	1.000
K	45.0°	0.943

Table 7: Properties of RT Classic.

4.3.1 RT Classic

Screen System:	RT Classic	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

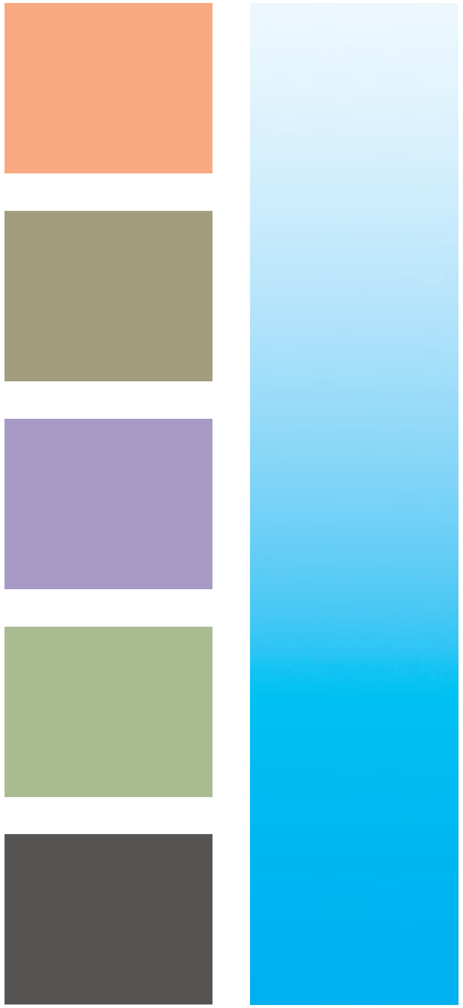


Figure 37

4.3.2 RT Y45° K fine

The RT Y45° K fine screen system was a further development of the RT Classic screen system. Yellow is set at 45° and a fine black of 1.4 times the screen frequency is used, which results in an extremely smooth overprint. The yellow moiré that shows up sometimes when conventional screening is used cannot appear here.

RT Y45° K fine is well-suited for reproducing skin tones.

This screen system is more suited for flexography and silk screen printing than RT Classic. Moirés between the screen and the silk screen or screen roller that inks the flexographic form are minimized as the system does not have an angle of 0°.

The fine black used usually has a different dot gain than the other colors have when printed. This point should be remembered when generating the process calibration/film linearization (for more details, see Chapter 6.7 and 7.4).

The table shows the allocation of colors to the screen angles and relative screen frequencies.

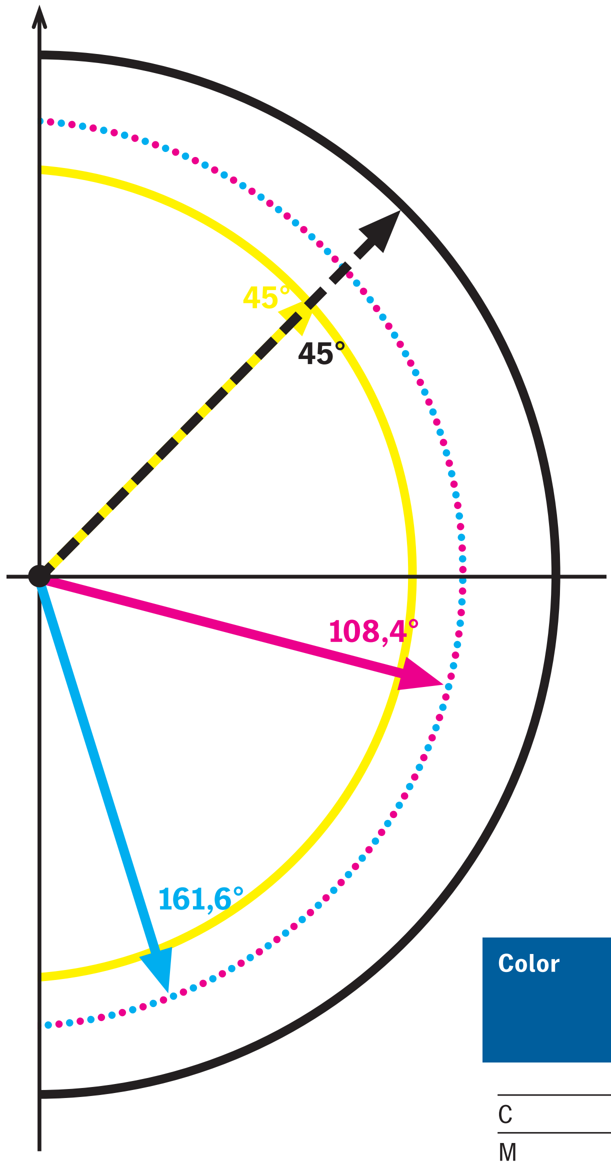


Figure 38: Angles in the RT Y45° K fine screen system.

Color	Screen angle	Relative screen frequency
C	161.6°	1.054
M	108.4°	1.054
Y	45.0°	0.943
K	45.0°	1.414

Table 8: Properties of RT Y45° K fine.

4.3.2 RT Y45° K fine

Screen System:	RT Y45° K fine	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

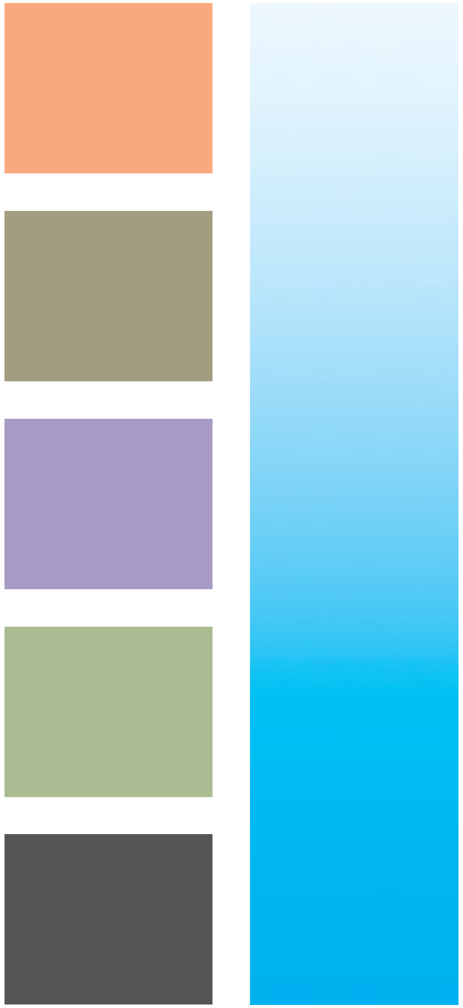


Figure 39

4.4 High Quality Screening (HQS)

High Quality Screening (HQS) is, in principle, a rational screening technology that allows very close approximations of irrational angles. All the IS screen systems and dot shapes have a counterpart in HQS. Nevertheless, there are a few small differences. The various screen frequencies can have different relative screen frequencies in these screen systems, something which also influences the overprint properties.

PostScript functions can be used to generate screen dots in addition to the dot matrices used for IS screening. As a result, there are more dot shapes available, but a dot produced with PostScript does not have the same quality as an IS screen dot.

4.5 Dot Shapes

Different dot shapes are used for different purposes, and we will discuss their use in this section. All screen dots are optimized using a program that implements methods of artificial intelligence and fuzzy logic[19]. Screen dots are created along design rules so to speak, resulting always in top quality.

One or two other points to note when creating screen dots. They should have a short border line, in this way making them as compact as possible. The reason for this is that effects such as blooming in platemaking and dot gain in print affect the border areas. A study conducted by FOGRA[20] has shown that it is better to create dots that are as sharply delineated as possible as you get better results when reproducing and processing them.

The dot shapes in the following sections can be used in all the screen systems presented earlier.

4.5.1 Elliptical Dot

Smooth Elliptical is the dot shape that is recommended for offset printing.

This dot starts off almost round in the highlight area and then becomes increasingly elliptical. When the dots join[21] the first time at 44%, the dot takes on a rhombic shape. After the dots join the second time, at 61%, rhombic shapes are first created, then elliptical ones, and finally round holes appear again in the shadows.

In offset printing, there is a density jump when the dots join. In the case of elliptical dots, the density jump is split into two steps reducing the jump effect and making it easier to control with gradation curves[22].

This is the ideal dot shape for offset printing.

This dot shape is also recommended for silk screen printing, letterpress printing and offset/gravure conversion.

This dot shape also has its elliptical counterpart in HQS. This HQS dot has the habit of turning into a round-square dot with certain screen frequencies, especially at 0° and 45°.

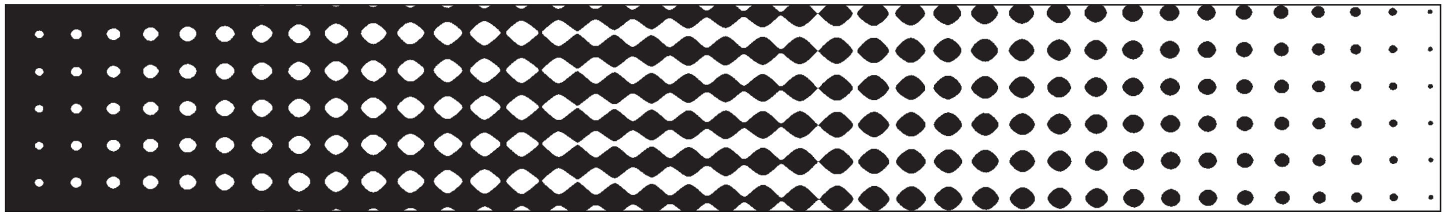


Figure 40:
Dot shape: Smooth Elliptical
Screen frequency: 2 l/cm.

4.5.1 Elliptical Dot

Screen System:	IS Classic	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

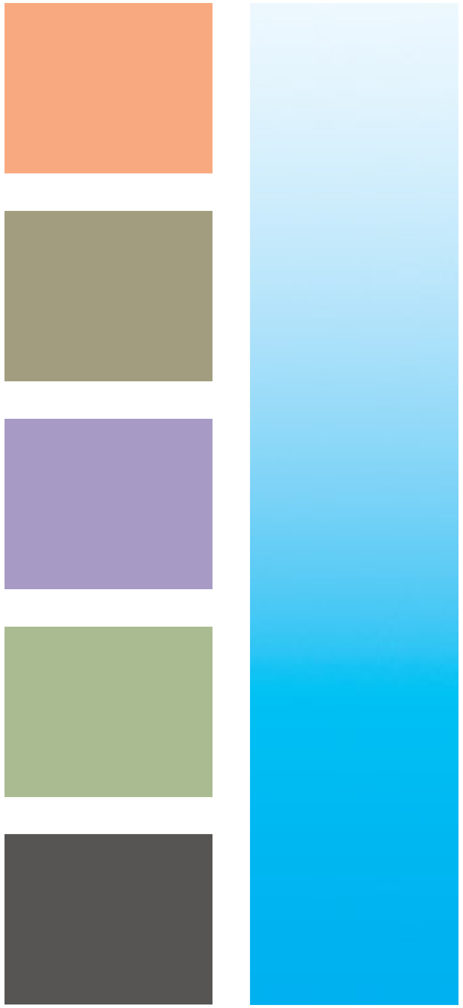


Figure 41

4.5.2 Round-Square Dot

The Round-Square dot shape is the classic dot shape used in offset printing, originating from the glass engraving screen mentioned at the beginning of this book. In PostScript, this dot shape is also known as a Euclidian[23] dot.

The round-square dot begins as a virtually round dot in the highlight area and becomes increasingly square in the midtones until it reaches the shadows, where round holes appear. The dots join together at 50 % and are slightly staggered to smoothen the density jump and to make it easier to control with the gradation curve.

This dot shape is frequently used for motifs like the one in the example (e.g. metal surfaces etc.) in which the density jump caused by printing is used to increase the midtone contrast. However, it is better to set the contrast by changing the gradation curve in the image editing system and to use the elliptical dot during exposure.

This dot is also used to a certain extent in traditional printing houses that want to avoid the organizational complications involved in changing their production process, such as changing their process calibration or their quality control, something that wouldn't be necessary anyway as this dot shape produces very smooth vignettes.

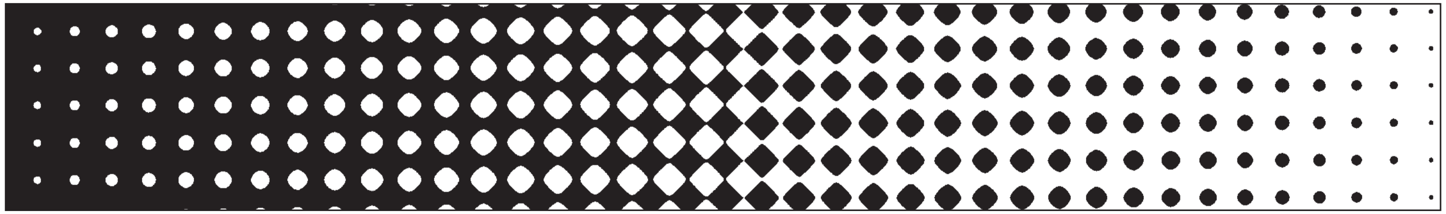


Figure 42:
Dot shape: Round-Square
Screen frequency: 2 l/cm.

4.5.2 Round-Square Dot

Screen System:	IS Classic	
Dot Shape:	Round-Square	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

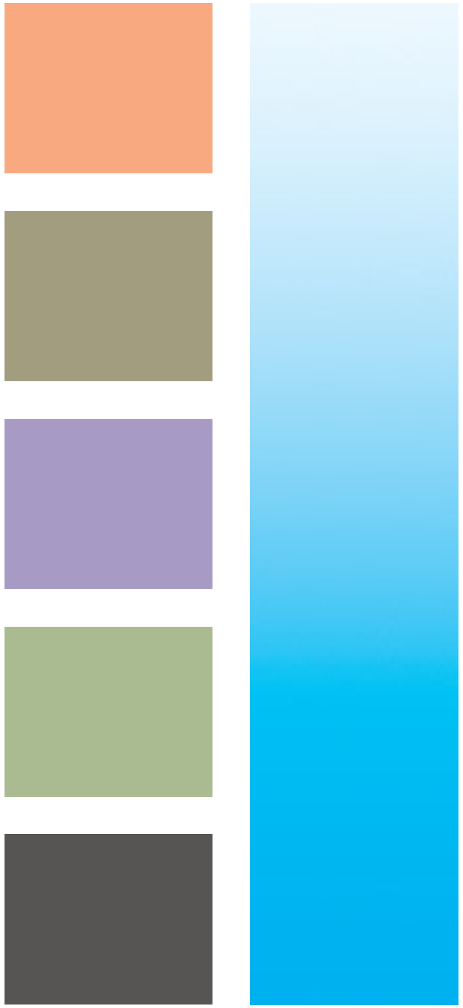


Figure 43

4.5.3 Round Dot

The round dot shape was developed for flexographic printing. The dots join at 78% with this completely round dot, after which pincushion-shaped holes appear, which then become round in the shadows.

In flexographic printing, a letterpress printing method with elastic print forms, the screen dots are squashed and, as a result, there is considerably more dot gain here than in offset printing. With this dot shape, the dots join together at a point where the dots are already smudged. A density jump that normally occurs is avoided as a result of this late dot joint.

Flexographic printing is mainly used in the packaging industry (plastic carrier bags, etc.).

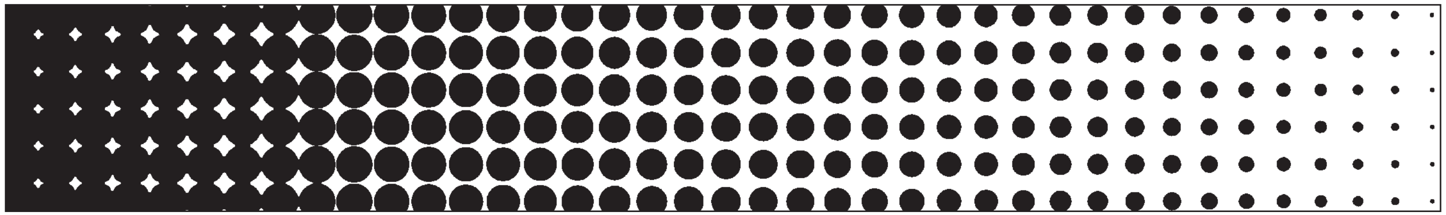


Figure 44:
Dot shape: Round
Screen frequency: 2 l/cm.

4.5.3 Round Dot

Screen System:	IS Classic	
Dot Shape:	Round	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

Figure 45

4.6 Gravure Screens

Gravure screens were developed as an option for photogravure (or rotogravure) where the dots in the cylinders are chemically etched. Nowadays, this process is rarely used in the packaging industry in Europe but is still widely used in Asia and Latin America, for one reason due to the less stringent environmental regulations in those countries.

In Europe, gravure forms are almost always engraved, usually on a HelioKlischograph from Hell Gravure Systems. Some aspects of photogravure will be explained briefly in Chapter 4.6.3 wherever more background information about screens seems appropriate.

These gravure screens provide you with a gravure tool that lets you restrict the maximum ink coverage to between 51 % and 79 % or the ratio of gutter to cell to between 1 : 2.5 and 1 : 8. You have to be able to set these limits because the values differ from printing house to printing house. Four dots, each with a different cell-to-gutter ratio, can be set with this tool. More details on this topic are offered in the tool's help function. These gravure screens are not available for all RIPs.

4.6.1 Pincushion Gravure Dot

This dot shape can only be used with special gravure screen systems. These systems are equivalent to the ones covered so far, except that the screen frequency is limited in the upper range since it makes no sense to create a pincushion gravure dot with an insufficient number of laser lines.

The pincushion dot starts in the highlight area as a small, basically round dot, which becomes square in the midtone and then later assumes its pincushion shape. The pincushion shape was selected to off-balance undercutting, which is described in more detail in Chapter 4.6.3.

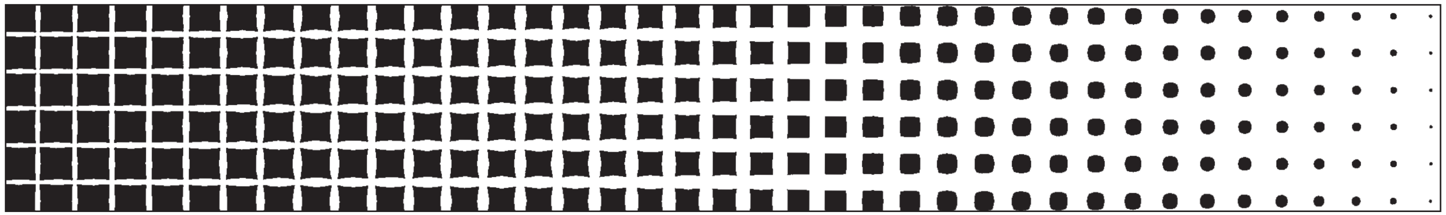


Figure 46:
Dot shape: Pincushion
Screen frequency: 2 l/cm.

4.6.2 Classic Gravure Dot

This dot shape can only be used with special gravure screen systems. These systems are equivalent to the ones covered so far, except that the screen frequency is limited in the upper range since it makes no sense to create a gravure dot with an insufficient number of laser lines. The square dot starts off as a small, basically round dot, becomes square in the midtone and remains square in the shadows.

This classic gravure dot was created in response to market demand because changing routine production processes from using a square gravure dot to using a pincushion one does not pay off for some printers.

4.6.3 Brief Excursion into Photogravure

The recesses in a printing form (or just simply 'form') do the actual printing in gravure printing. In this process, highly fluid ink is sprayed or rolled on to the recessed cells of the printing cylinder. A blade wipes off any excess ink from the cylinder so that the ink is only in the cells. The web that will be printed absorbs the ink from the cells as it passes between the cylinder and the pressure roller. The gutter between the cells should be even and stable so that the blade can sit properly.

In photogravure with etching, the cells are created by applying photoresist[24] to an approx. 0.3 mm thick copper surface. The layer is then exposed with a screen film and the appropriate dot shape so that the imaged areas are hardened and the unexposed areas are later washed away. The form is then etched in a ferric chloride solution, and the cylinder is then galvanized with hard chromium so it will withstand long periods in the press.

During etching, material is removed not only from under the washed areas but also from under the gutters. This undercutting, as it is known, is more dominant in the center of the gutters than at the corners. Without the pincushion shape to off-balance these undercutting effects, the cells would be rounder and would not be able to hold as much ink.

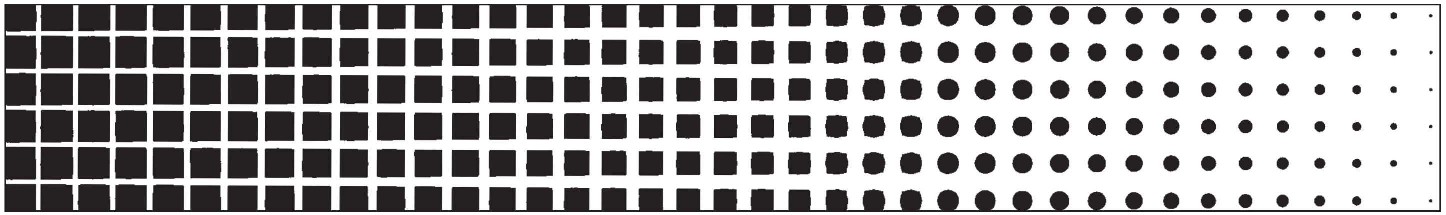


Figure 47:
Dot shape: Square
Screen frequency: 2 l/cm.

The cross-section of an etched gravure cell shown opposite illustrates the undercutting effects.

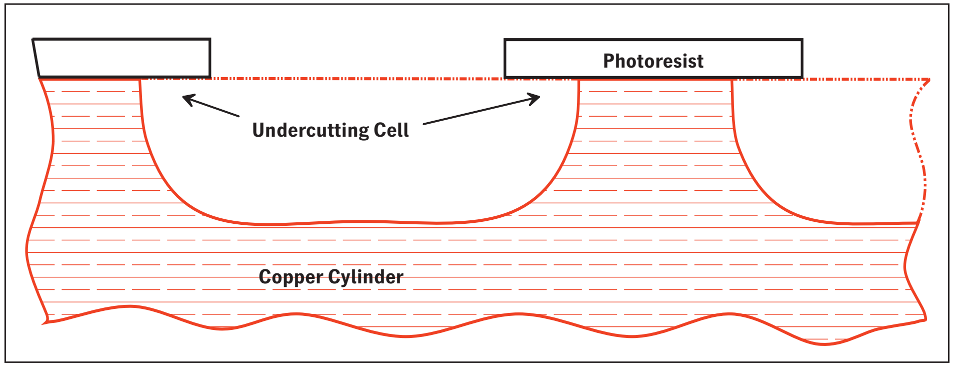


Figure 48: Gravure cell cross-section.

Viewed from above, you can see that the size of the cells can be larger since the pincushion dot cells cover a larger area and yet still have stable gutters. This is what the cells look like:

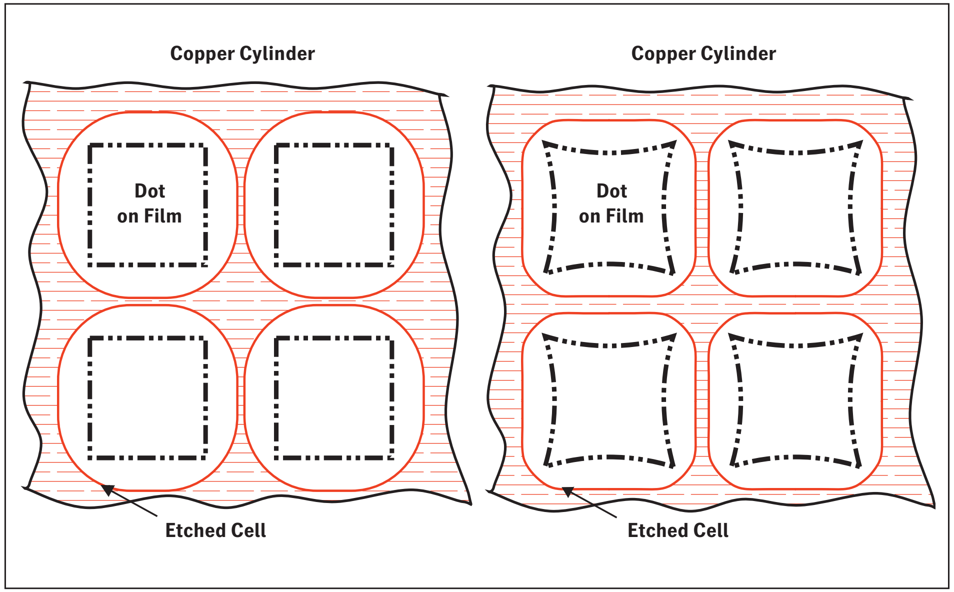


Figure 49: Square dots (left) and pincushion dots (right) in etched gravure cells.

4.7 Diamond Screening

Diamond Screening is a frequency-modulated screen in which the number of exposed dots increases as density increases, increasing in turn the screen frequency as well. In Diamond Screening, these dots join and grow together as the dot percentage increases. The individual dot itself (i.e. its amplitude) does not get bigger, but there is an increasing number of dots, and, in turn, a higher screen frequency.

The dots appear to be arranged randomly, but attention is paid that smooth areas are depicted as smoothly as possible while at the same time repetitive patterns are avoided. Images would appear very grainy if the dots were actually distributed at random.

Diamond Screening gives you a print with an almost photo-like quality. It produces a sharpness in detail that is unsurpassed by any other screening method. The usual offset rosette, so often a disturbing element, does not crop up in this screening method. Instead, you have a print that comes closest to the quality of a color photograph.

To demonstrate the excellent level of detail Diamond Screening provides, the image overleaf was reproduced using both Diamond Screening and IS Classic with a smooth elliptical dot shape.

Another important advantage of Diamond Screening can be seen in this example: there is no moiré between the fine pattern of the textiles and the screen. Diamond Screening is especially well-suited for technically demanding reproductions that entail many fine details, such as loudspeakers, textiles, wood grains and satellite pictures, etc.

A point to note in passing: No screen system will help you subsequently remove any moiré that appears between the original and the scanning screen of your scanner. In this case, you just have to rescan the original using a finer resolution.

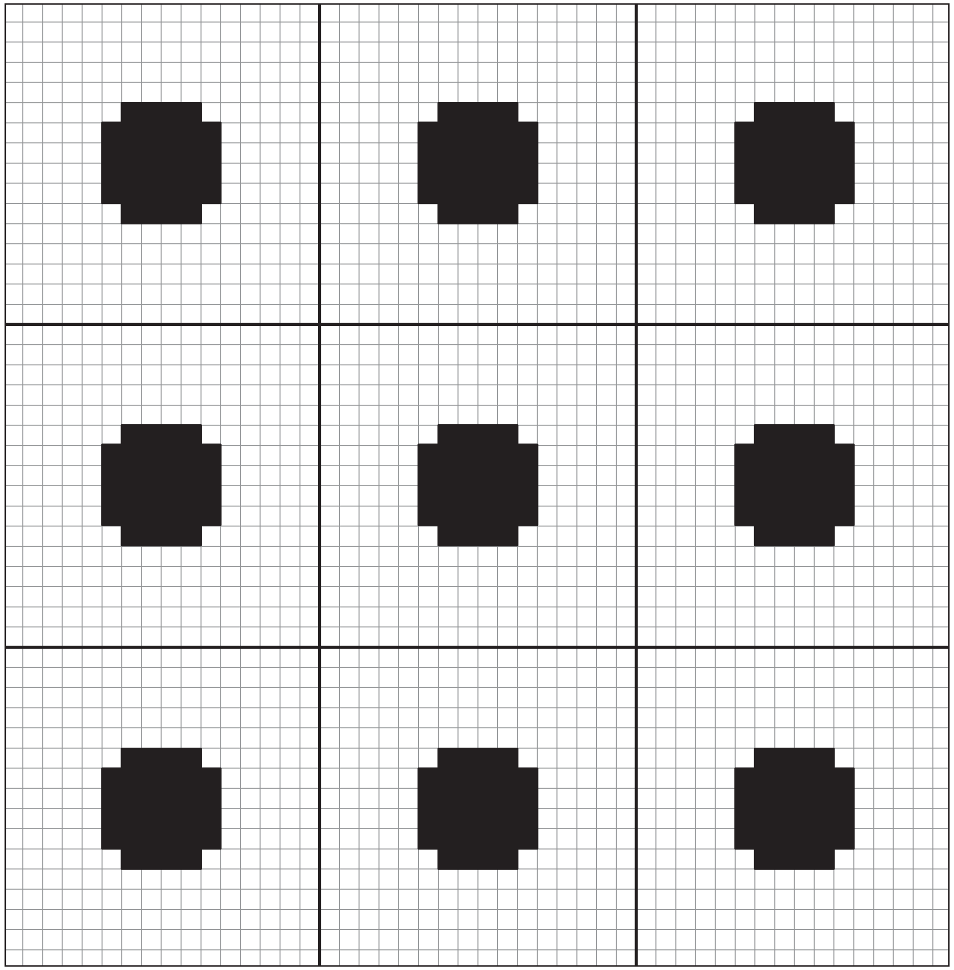
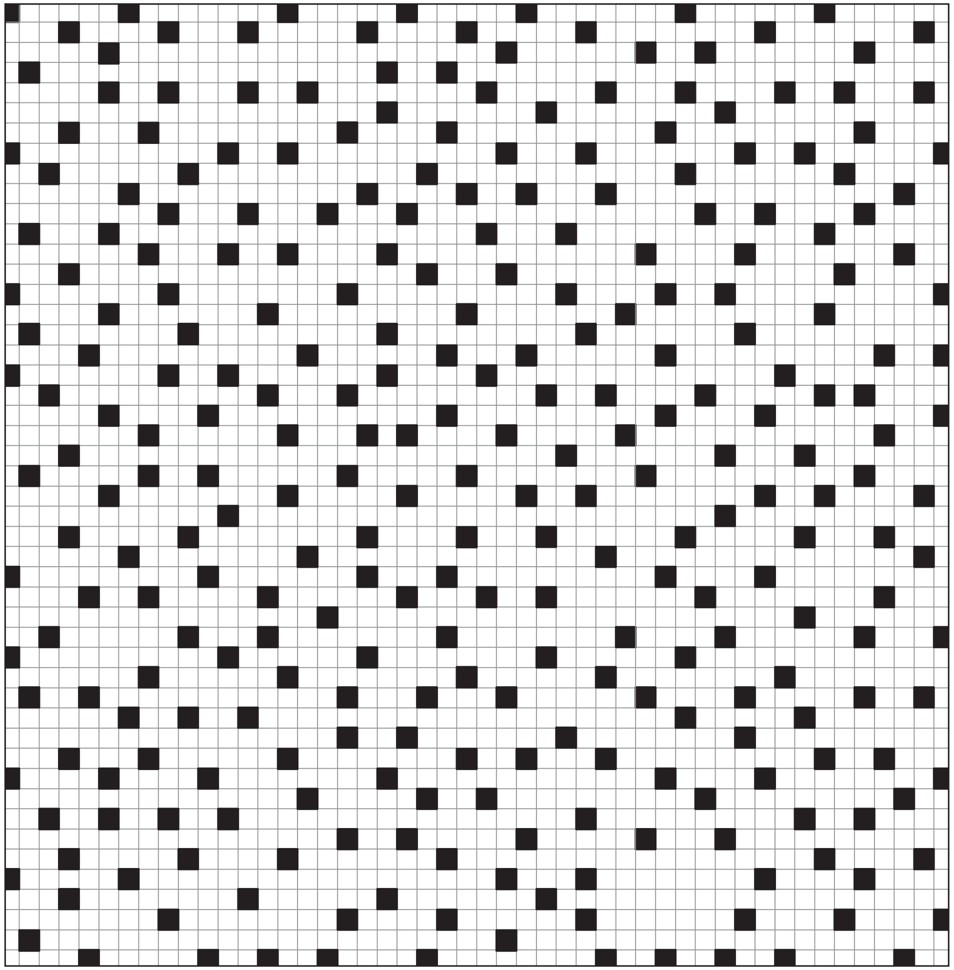


Figure 50: Standard screen dots compared with …



Diamond Screening.

For comparison with Diamond Screening: IS Classic

Screen System:	IS Classic	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

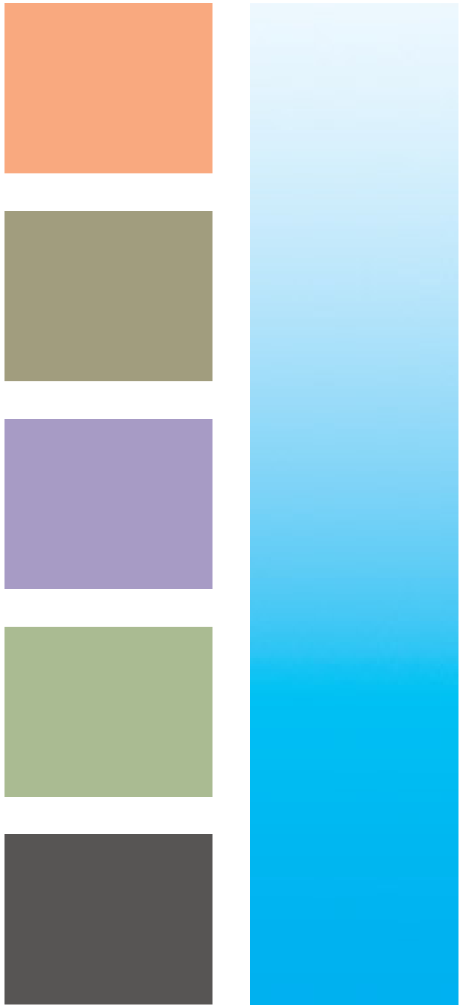


Figure 51

Figure 52: A comparison of IS Classic 70 screen …

and Diamond Screening. Diamond Screening's fine distribution of dots produces excellent details.

4.7.1 Diamond Screening Dot Shapes

Diamond Screening comes with Diamond 1 and Diamond 2 dot shapes. Diamond 2 was developed for drysetters and is more compact than Diamond 1. That is why there is less dot gain in platemaking and in printing, making further processing more stable.

Effects such as blooming during platemaking or dot gain in print are found for the most part at the borders of the dots (more details can be found in Chapter 7). Diamond Screening's larger border line in dots compared to that in normal screen dots means that certain points must be remembered in processing.

Extremely hard film, such as Kodak S 2000, is recommended for imaging, and the recorder should be carefully set. The larger dot gain in print should be counterbalanced with process calibration.

Alternatively, gradation corrections can be made during scanning. More details are available in Heidelberg's 'Diamond Screening User's Guide'.

Diamond Screening demands careful, clean work during platemaking. Because of the tiny pixels used, cutting edges cannot be covered up, and dispersion foil[25] cannot be used. In particular, films where contact is poor should be avoided, and no shortcuts in time should be taken when creating the vacuum that fixes the mounting film to the vacuum frame. The plate copier should be set so that line strengths of 6 μ to 8 μ can still be copied.

Working with dry offset technology[26], such as a Torray plate, is recommended. The general rule of thumb is that printing conditions should be closely monitored to keep them stable. Common printing errors, such as dot slur, dot doubling or dot filling at high densities should be avoided where possible, and registration should be carefully set. Minor misregistration is first only noticed as blurring and only when it becomes large can it be seen as color blanks. It would be a shame to impair the excellent reproductive qualities of Diamond Screening with minor misregistration.

4.7.1 Diamond Screening

Screen System:	Diamond	
Dot Shape:	Diamond 1	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

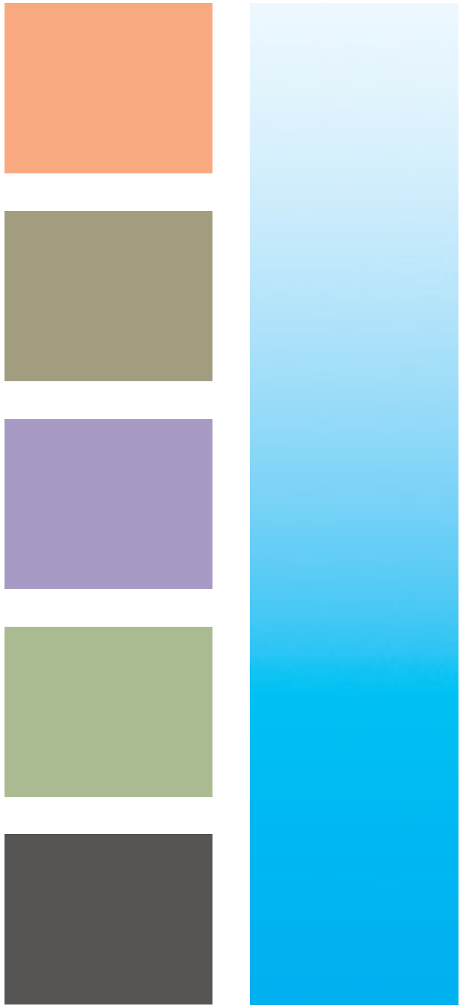


Figure 53

Figure 54: Comparison of IS Classic 70 l/cm (175 lpi) screen …

and Megadot 70 l/cm screen.

4.8 Megadot Screening

The recently developed Megadot screens cannot be compared to the other screens described so far. Megadot is mainly a line screen, and the screens in this system do not create any offset rosettes but produce impressively smooth overprints. This superior level of smoothness can be seen especially in screens that are coarser than the standard 60 l/cm screen.

Megadot screening is not only well-suited for printing color newspapers with their coarse screens, where the offset rosettes can be very disturbing, but also for printing high-quality artwork, where excellent smoothness in print can be achieved with relatively low screen frequencies, making printing easier.

The lack of a rosette results in a better reproduction of fine details.

We already mentioned earlier in the section on line screens that the main benefit of such screens is that two colors can be printed together at 90° angles apart without causing any color shift. The line screens used have almost the same dot gain in print as conventional screens. Unlike Diamond Screening, further processing with Megadot just requires the same type of care that you would take with a conventional screen. Only the fine screen for black has a slightly larger dot gain, just like the RT Y45° K fine screen system. This fact should be remembered when generating color data (see Film Linearization/Process Calibration).

Unlike Diamond Screening, moirés between the original and the screen cannot be avoided in Megadot.

Megadot screening produces an unsurpassed smoothness in the overprint, with even better definition of detail at the same time since there are none of the usual offset rosettes. Added to all this, working with this screen is also simple and uncomplicated, making it practically the ideal screening method for offset printing.

For comparison with Megadot: IS Classic

Screen System:	IS Classic	
Dot Shape:	Smooth Elliptical	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

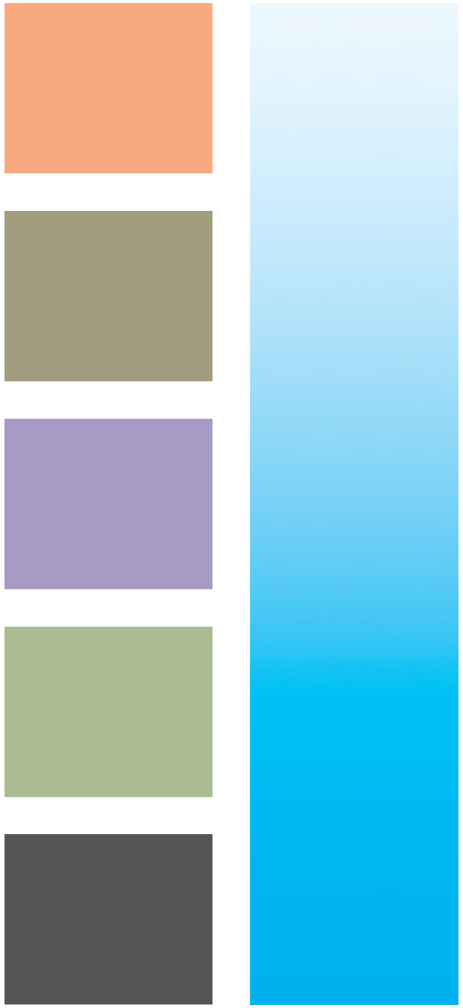


Figure 55

4.8.1 Megadot CM 0°

Cyan and magenta are set at 0° and 90° in this screen system. Yellow is set at 45° and black is generated as a fine screen at 45° as well. This screen system is characterized by its impressively smooth overprints.

4.8.2 Megadot CM 45°

Megadot CM 45° is a variation of the Megadot screen just described. It is also essentially a line screen, with the defining colors cyan and magenta set at 45° and at 135°. This screen is less visible in a single separation since the human eye perceives horizontal and vertical lines better than it perceives diagonal ones. Yellow is set at 0° and fine black is positioned at 45°. The overprint properties, however, are not as good as they are in the Megadot CM 0° screen.

4.8.3 Megadot Dot Shapes

Megadot and Megadot Flexo are the two dot shapes available in Megadot screening. The Megadot starts off as a small round dot in the highlight area, then turns into an elongated ellipse and continues on to become line-shaped. Small round holes appear again in the shadows. This dot shape was developed mainly for offset printing, although it is suited for other printing processes as well.

Megadot Flexo is an inverted Megadot. It begins as a small round dot in the highlight area and then turns into an elongated, inverse ellipse; in other words, a line dot with side supports. Once again, small round holes develop in the shadows. This dot shape was developed for flexographic printing.

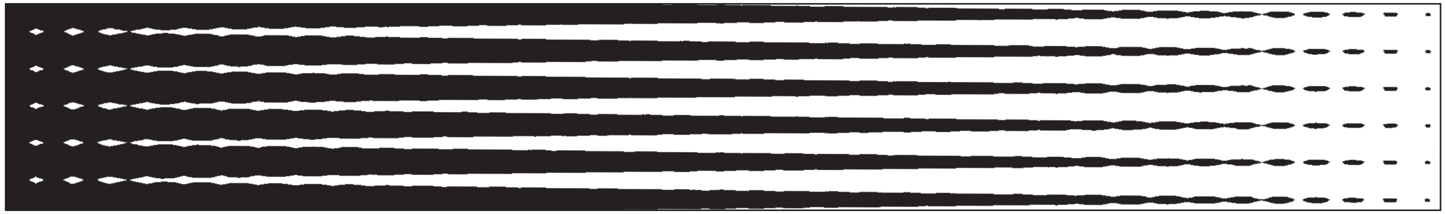


Figure 56:
Dot shape: Megadot
Screen frequency: 2 l/cm

4.8.1 Megadot Screening

Screen System:	Megadot	
Dot Shape:	Megadot	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

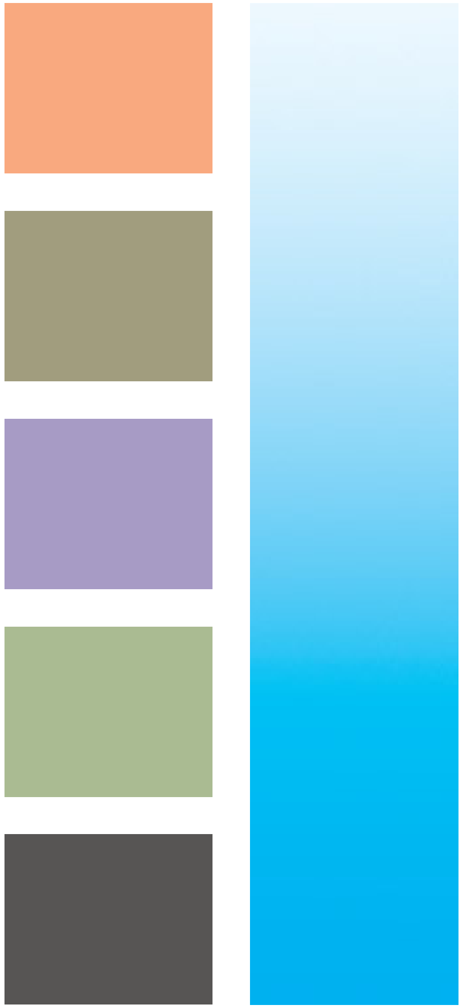


Figure 57

4.9 Megadot Plus

Megadot Plus was developed from Megadot, and it has even more benefits. The screen cells are not squares as in all other screening methods, but parallelograms. The line-like dot shapes grow along the longer baseline of the parallelogram. The following diagrams show Megadot screen examples in the highlight, midtone and shadow areas.

The colors are assigned to the screen angles and relative screen frequencies as shown in table 9.

Megadot Plus appears approximately 50 % finer than conventional screening in the overprint and approximately 20 % finer than the previous Megadot. For example, a Megadot Plus screen of 40 l/cm (100 lpi) is about as fine as a conventional screen of 60 l/cm (150 lpi) and a Megadot Plus screen of 60 l/cm is about as fine as a Megadot screen of 70 l/cm. Of course, Megadot Plus has all of the positive features of the older Megadot mentioned in the previous section, and some of them are even enhanced in Megadot Plus. Offset rosettes do not exist, and the black fine screen is not necessary, which is an additional benefit.

The line structure of this screen causes the dot gain in print to be larger than with conventional screens. For that reason, process calibration is recommended.

Color	Screen angle	Relative screen frequency
C	90.0°	1.000
M	0.0°	1.000
Y	45.0°	0.943
K	135.0°	0.943

Table 9: Properties of Megadot Plus.

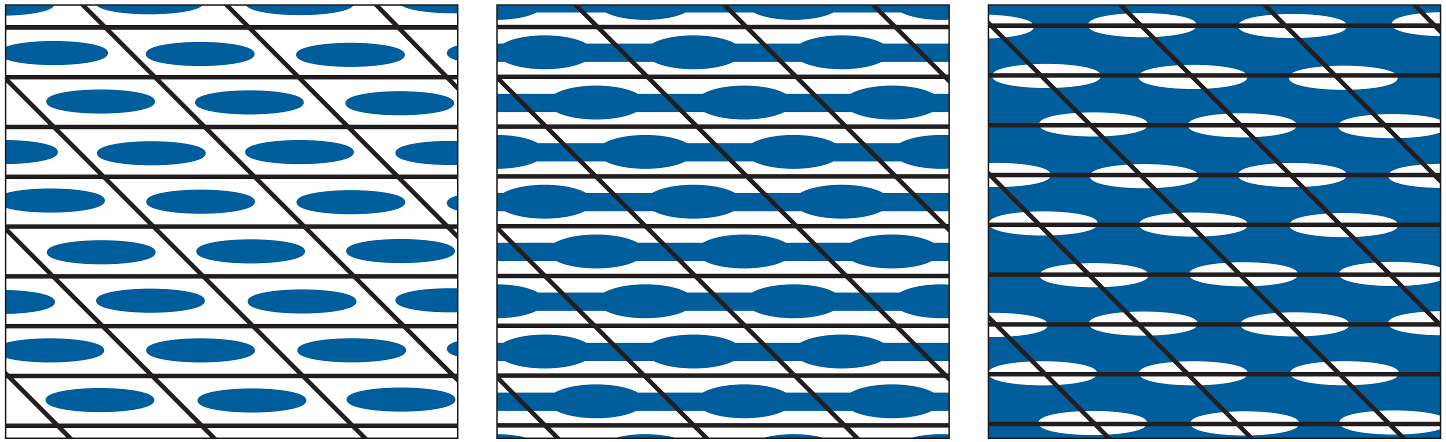


Figure 58: Megadot Plus in highlight, midtone and shadows.

4.9 Megadot Plus

Screen System:	Megadot Plus	
Dot Shape:	Megadot Plus	
Screen Frequency:	60 l/cm	150 lpi
Recorder Resolution:	1000 l/cm	2540 dpi

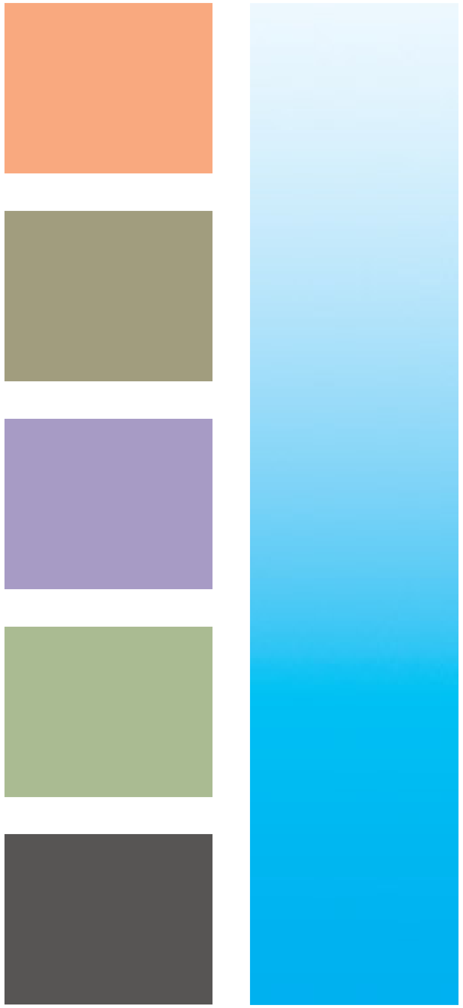


Figure 59

5 Screen Settings in a PostScript Workflow

In the previous chapters, we explained the differences between PostScript screens, which were implemented by Adobe in the interpreter, and Heidelberg screens. Now we will take a look at how these screens can be used in a PostScript workflow.

A PostScript production process is based on the interaction of a number of components that exchange data through the means defined in the PostScript page description language, and sometimes through enhancements implemented by the manufacturer.

Applications such as QuarkXPress or InDesign®, and PostScript drivers such as LaserWriter® or Adobe PS™, use these means in various ways. At the end of the production process is the RIP whose task is to communicate with all of the various products and in turn to be able to produce the correct result. However, in too many cases, not enough screen data is available in PostScript, which means the RIP is left with the thankless job of having to generate a decent screen out of the bits of information it has.

The main aspects of screening in a standard PostScript workflow will be covered in the sections below as well as how the broader functionality found with Heidelberg screening can be used within this scenario. This information is meant to assist you when a screen does not image as expected.

5.1 PostScript Screening

When the first PostScript RIPs were developed in the 1980s, there were only a few limited ways of generating screens. While it was possible to configure dot shape, screen frequencies and screen angles precisely through the Setscreen operator, PostScript screening by Adobe was implemented only as a single-cell screen. This resulted in several serious restrictions:

- Only a certain number of gray levels were available, depending on the screen frequency and resolution used.
- The angles and frequencies that were actually possible only allowed a very limited scope for color reproduction, and only a small number of RT screens was possible.

How these things were related was not clear to the user, who could not understand why his/her screen settings were ignored.

PostScript Level 2 and PostScript Level 3 brought improvements to PostScript screening, both in terms of what could be set as well as in terms of Adobe's standard implementation. Part of PostScript Level 2, with additional improvements in PostScript Level 3, is a supercell technology where the screen angles and screen frequencies can be compared to HQS. Nevertheless, HQS is still way up front in the way it creates supercells and, effectively, in producing a high-quality smoothness in print.

Even in state-of-the-art PostScript Level 3, any screen angle/screen frequency combination is not possible, although approximations can be achieved that produce relatively good results. The real 'irrational angles' found in IS technology are still not available in the Adobe implementation.

Even before PostScript Level 2 was introduced, screening technology had developed to such a stage that highly accurate supercells and even irrational screens were possible. This led to Linotype and Hell integrating their own screening technologies into the Adobe PostScript Level 1 interpreter. These developments are the basis of Heidelberg's screen solutions today, and an important part of this is the concept that users can still enjoy all the benefits of Heidelberg screening despite any restrictions in a standard PostScript workflow.

5.1.1 PostScript Halftone Types

Several screen types called halftone types are described in the PostScript specification. These screen types can be divided into two categories.

On the one hand, there are the classic halftone types, in which screen frequencies, angles and dot shapes are denoted mathematically. In the sections below, they will be called 'Setscreens'. These screens are converted to threshold matrices during the RIP process.

Then there are screen types that are supplied directly as threshold matrices where screen angles, frequency and dot shape are defined implicitly from the dimensions and content of one or two threshold matrices. In the sections below, they will be called threshold screens.

Both categories have variations designed for a monochrome (separated) or a color (composite[27]) workflow. You can read up on halftone types in the 'PostScript Language Reference' (ISBN 0-201-37922-8).

According to the PostScript specification, screens are device-specific. This means that you cannot expect to find all the different screens listed in the PostScript specification in one RIP. The screen parameter setups that the RIP understands are usually defined as part of a PPD (PostScript Printer Description File) file (see Chapter 5.2.3.1) or can be set at the RIP itself.

Modern Heidelberg RIPs with software screening give their users not only Heidelberg screen systems but also almost fully support all halftone types. Older RIPs with hardware screening are not as flexible in this respect and can only support the halftone types to a certain extent.

5.1.2 PostScript Setups and User Inputs

Some of the screen parameters found in the PostScript specification are not suited at all for user input, and some only to a certain extent. With the Setscreen operator, two of the three parameters (screen frequency and screen angle) can be taken directly from the input the user makes. Dot shape, on the other hand, always conceals quite a long PostScript program, which means that simple dot shape terms like 'elliptical' or 'round' must first be converted to the PostScript code. The PPDs contain the information needed for this that can be used by the applications or PostScript drivers.

In threshold screens, there are no direct references between the PostScript code and the description that a user can understand, so PPDs cannot help here. The application should not make these screens available in PostScript data as they are extremely device-specific. The RIP's user interface provides the better solution in such cases, with the right software setting up the link between the threshold data and a user-friendly description on the user interface.

5.1.3 PPD Screen Parameters

PostScript Printer Description (PPD) files are formalized text files that comply with the Adobe PPD specification. They are not a part of the PostScript specification. PPD files (or just PPDs) contain the specific information needed to generate PostScript for a specific output system, such as a CtP recorder. A PPD describes the properties of an output device or device family and how they can be activated using PostScript. A PPD-derived PostScript job is usually device-specific nowadays, and this can lead to errors when it is output to a different device.

PPDs are created by the manufacturer of the output device and generally are made freely available by distributing them with the widely used operating systems. Adobe places PPDs for output devices equipped with the Adobe PostScript interpreter on the Internet. The latest PPD versions can usually be found through the manufacturer (e.g. www.heidelberg.com).

PPDs are often described as printer drivers. Strictly speaking, this term isn't correct since drivers and applications only take the information they need about specific PostScript output systems and how to activate certain functions from the PPD. However, PPDs, unlike printer drivers, do not generate code which is the most basic task of a driver. Some examples of printer drivers are the Apple® LaserWriter or Adobe PS for the Macintosh® and various Windows versions.

A PPD has invariable parameters and parameter lists. The invariable parameters can be, for example, the PostScript version supported by the PPD, the name of the manufacturer and the model number of the output device. The parameter lists offer several alternatives. The best example here is the list of output formats. The user can choose from several standard formats and, if it seems appropriate, a user-defined one.

The PPD specification does not have a hierarchical screen system concept and, as a result, cannot support a full description of Heidelberg screens. The complex interaction of screen system, screen frequencies, resolutions and dot shapes cannot be portrayed. The rules on how items are to be displayed in the user interface are sometimes missing as well. The result of this has been that some applications have a very confusing way of displaying items in the user interface.

Consequently, the PPD restrictions do not allow applications and drivers to define a full, job-specific screen setup for the output run.

This is why Heidelberg developed a supplementary concept (see below). In terms of screening, the PPD concept has been kept very simple. The PPDs do not contain the angles of the different screen systems, but just the standard angles of 15°, 75°, 0° and 45° for CMYK. A list of the most common screen frequencies for the most frequently used imagesetter resolution is included as well. The resolution itself cannot be selected in the PPD, and portraying the interrelation between screen frequencies and resolutions cannot be implemented with PPDs.

5.1.4 Screen Setups for Printer Drivers and Applications

A correct PostScript job for filmsetters or platesetters must contain screen setups because these devices can only output gray levels through screens. A PostScript job for output to a non-screening contone output device, on the other hand, does not need this information. This means that the application or the driver must include the device-specific properties of the output path when the PostScript code is being generated.

Most of the applications generate the PostScript code in conjunction with the operating system's PostScript driver. The screen parameter setup is often left up to the printer driver. Similar to other device-specific properties, the driver reads the possible screens from the PPD and presents the user with comparably complex choices in the user interface. Professional prepress applications have their own support system that enables the user to choose from the PPD-based selection or to define customized screen angle and frequency settings.

The restrictions found with the drivers (LaserWriter, Adobe PS) can be relaxed by the use of driver plug-ins[28]. Heidelberg offers such a plug-in in the shape of Jobstream™. This plug-in lets the user perform a complete parameter setup of Heidelberg screens, with the same ease as on a RIP.

Applications must also tackle the subject of screen setups when they generate PostScript themselves without the support of the driver. Usually, there is a PPD-based selection to choose from, but it is also possible to define the screen angle and frequency for each color.

Fully integrated support for application-specific screens using the methods described in the PPDs is rarely found. Inputs made in the user interface are almost always converted to the Setscreen PostScript setup because threshold PostScript screens are much more complicated to use and require very specialized know-how.

5.2 Heidelberg's Concept for Screen Setups

5.2.1 Weaknesses in the Standard Workflow

On the whole, it can be said that applications, drivers and PPDs do not support screening in the way they should, and the manufacturers of prepress applications will always come up with a good reason why. The user is faced with a number of drawbacks because of this, the most important of which are listed below:

- Extreme accuracy is needed when defining the setup to get suitable color screens. Entering numbers with many digits for each color is full of pitfalls, and typos can prove to be expensive.
- Customized screen setups can result in unwelcome surprises in the overprint. Not being familiar with a screening technology or not knowing how the RIP deals with the inputs can produce bad overprints.
- PPDs are not capable of describing the complex potentials and relations screens have in a prepress workflow.
- It is practically impossible for an application manufacturer to offer optimal screens for all the different output devices that exist on the market today. However, using a screen that is not optimal involves the risk of artifacts appearing in print. For that reason, using an application's screen should be confined to monochrome ornamental screens. Screens are device-specific, and Heidelberg has invested a lot of effort into optimizing screen systems and dot shapes so that their customers can have top-of-the-scale output quality.
- The editorial or design department and production are separate units in many firms. The responsibility for quality and, consequently, for screens usually lies with production. Therefore, giving production full control over screens without involving the editorial department is something that should be considered.

For workflow quality and reliability, we recommend working only with Heidelberg screens and using the correct PPDs to define their setup. If the wrong PPDs are used, you might even end up with a PostScript job that has no screen parameters at all. If this job happens to be separated as well, an output with suitable color screens is often impossible (see Filtering Screen Angles).

5.2.2 Advantages of the Heidelberg Prepress Concept

The many restrictions in all of the components described above led to the development of a Heidelberg concept for screen setups. This concept works on the principle of only a minimum number of standard-based screen setups but yet allows flexible use of Heidelberg screening. The user can benefit from this concept as follows:

- Heidelberg screen systems can be used despite the standard PostScript language restrictions. Every PostScript file that fulfills the minimum requirements for screen parameters can be imaged with Heidelberg screens. Even non-standard PostScript can be processed in most cases.
- The user can select parameter sets from lists in the output device's user interface. The screen system concept does away with the need to enter figures for the single color separations. Specialized screen know-how is not required, and the chance of producing faulty overprints because of typing errors is slim.
- The user can decide for his/her business whether screens will be set directly during the job in the application or driver or in the RIP. Production or prepress can be involved here if desired.

The following components are included in the conversion process:

- Jobstream driver plug-in
- Printmanager in the RIP
- PPDs
- A screen filter in the RIP that the user cannot directly see
- Applied screens.

The item 'Applied screens' is only listed for completeness. It has nothing to do with the screen setups, but only with the accuracy and quality of the output screens. The settings themselves have already been defined.

5.2.3 Heidelberg Screen Setups

A RIP must have the following information to be able to expose a PostScript job for each color separation with the right screen:

- Screen system
- Dot shape
- Imagesetter resolution
- Screen frequency
- Color separation.

From the RIP's point of view, it would be ideal if all of this information were included in the PostScript data of the job, but this is usually not the case. This means, for example, that details about the screen system are only included if Heidelberg software was used when the PostScript file was being generated.

The reason for this is that PostScript does not recognize the concept of screen systems. Nevertheless, it must also be possible to use Heidelberg screens even if jobs do not have information about the screen system.

5.2.3.1 PPDs, Jobstream and Printmanager

As already mentioned, PPDs are not capable of providing a full setup for screening. Used in the framework of the Heidelberg concept, PPDs have the important job of providing the required minimum setups. Seen in this context, Heidelberg PPDs deliberately only contain 0°, 15°, 45° and 75° angles, even though there is no screen system that has exactly this combination of angles.

A filter program in the RIP assigns the angles in the PostScript code to the angles of the selected screen system. Unlike PPD-based PostScript generation, Jobstream fully supports the setup of Heidelberg screens. Heidelberg extensions overcome the deficits of PostScript, and a code that does not need any other parameter settings can be created directly while PostScript is being generated. Any settings in the RIP are ignored.

Sometimes, the enhancements that Jobstream makes in the PostScript code are not wanted because the generated PostScript is meant to be as neutral as possible. Any of the missing parameter settings required for a Heidelberg screen have to be added somewhere else.

This is what the RIP's Printmanager does. The Printmanager has numerous input channels, with each one acting as an independent output device in the network. A complete set of output parameters can be allocated to each input channel, screening being an important part of this.

Creating an input channel with the appropriate screen setup allows each job to be assigned a Heidelberg screen, providing this job has the minimum standard PostScript screen parameters.

5.2.4 Filtering Screen Angles

Filtering is a special RIP function. It evaluates the screen parameters in a PostScript job on the basis of the settings specified in the user interface.

5.2.4.1 Minimum Screen Setups in a Job

When dealing with the minimum screen setups in a PostScript job, you must keep in mind the difference between a composite and a separated PostScript.

There are no minimum requirements for a composite PostScript. Screen system, dot shape, resolution and screen frequency can be set at the RIP, and information about the color separations is created automatically with the separations.

Separated PostScript is a different matter where the separations are concerned. The information about the color separations is not contained in the actual PostScript code. The RIP regards a separation in a separated job as a black-and-white page and cannot assign it to an angle in the screen system without receiving more information first. The information it needs can be provided in two different ways:

- The screen angle acts as an alias for the color.
- The PostScript file color comments are evaluated.

5.2.4.2 Screen Angles as Color Aliases

Angles generated in the PostScript code are evaluated in a special way in Heidelberg screening. They only serve as an alias for a color separation. The color is a stepping stone in the allocation of an angle in the screen system.

Color	PostScript angle	Screen system angle
Y	0°	0°
C	15°	165°
K	45°	105°
M	75°	45°

Table 10: IS Classic example of a PostScript angle as a color alias.

The advantage of this approach is that the user doesn't have to think about screening when printing from the application but can always work with the same settings. The generated PostScript code can be output later with any screen system.

5.2.4.3 Filtering Comments

In separated PostScript, Heidelberg screens can be controlled not only by evaluating the Setscreen PostScript commands as described above but also by evaluating the PostScript comments.

Adobe defined the so-called Document Structuring Conventions (DSC comments) as a supplement to the PostScript specification. These DSC comments should not be confused with the DCS[29] (Desktop Color Separation) data format! These comments are not an obligatory part of a PostScript job, but they have turned out to be pretty reliable and are even essential for some functions. Customer-specific comments are also possible with DSC – something that is frequently used.

Probably, the most well-known use of DSC comments is OPI (Open Prepress Interface), where the PostScript code between two comments is removed and replaced by another code. This lets low-resolution images be replaced by their high-resolution versions, taking place before the PostScript code is interpreted. The PostScript interpreter cannot access these DSC comments.

Certain color comments, including customer-specific ones, are evaluated for screening. Once the color is noted, a color separation can be clearly allocated an angle of the active screen system.

The filtering of PostScript comments has become quite widespread in screening. In newer products, Setscreen parameters are now only evaluated if a job has no PostScript comments.

5.3 Selecting Screens

Screens are set in special user interfaces. The basic settings can be found in similar form in all Heidelberg RIPs, even though the graphic design or one or two minor details might be different. The screen settings in the RIP are valid for a certain input channel. The parameters only have to be selected, making any typing in of figures unnecessary.

In many cases, the various screen parameters are correlated. When one parameter is changed, the choices you have for another parameter can also change. This interaction is integrated in the user interface, and only available parameter combinations are displayed. Because of this interaction, you should always select parameters in the user interface in the given order. The screen system should always be selected first.

5.3.1 Selecting Screen Systems

All the screen systems in a RIP can be viewed in a pop-up[30] menu in the user interface. One of these systems can then be selected from the list. Using several Heidelberg screen systems within one job is only possible with a device-specific PostScript code.

One of the screen systems in the pop-up menu disables Heidelberg screening and enables PostScript screening. The system can be named 'Default' or 'Standard', depending on the product. When this system is enabled, all the RIPs can support at least PostScript screening with Setscreen setups. The generated screens are then based on original Adobe screening or, in the case of hardware RIPs, on a compatible Heidelberg implementation.

Combining PostScript screens in Setscreen setups with Heidelberg screens within one job is only possible if a special PostScript code is used.

PostScript threshold setups are supported in some of the newer software RIPs. When this functionality is available, it operates independently of the selected screen system, making it possible to combine a Heidelberg screen with a PostScript screen in a job.

Which screen systems are available in a certain product depends on three factors:

1. The product itself
2. The output device
3. The availability of an option.

The first item depends on whether the RIP used has software or hardware screening. Almost all Delta Technology[31] products have hardware screening, so it's technically not possible to generate IS screens on HQS hardware and vice versa.

The output device mainly influences screening through the resolutions it has. The screen frequencies that can actually be generated depend on this factor. Certain screen frequencies are only available with certain resolutions, their combination usually depending on the output device you use.

The third item refers to screens that aren't included in the standard scope of delivery, but which can be purchased separately, for example, Megadot and Diamond Screening.

5.3.2 Selecting Screen Dots

The user has a choice of dot shapes in almost all screen systems. The dot selected in the Heidelberg screen's dialog is not changed by the PostScript job's dot shape. This was possible for a while in older Heidelberg products, but it led to quality issues that could not be solved.

5.3.3 Selecting Resolutions and Screen Frequencies

There is a close connection between resolution and screen frequency (see Chapters 6.4 and 7.3).

Not every screen frequency is available for every recorder resolution. The selection dialog of these two parameters ensures that only available combinations can be selected. The values the user can select also depend on the screen system used.

A nominal value is selected for the screen frequency, although there are generally slight differences between the nominal value and the actual screen frequency. This is something that cannot be avoided if the user prefers to use just one value for all the separations, leaving aside the many different screen frequencies to choose from in the screen systems (see Chapter 4).

Another reason for the difference in values is that the quality-based correlation between resolution and screen frequency usually results in odd numbers for the actual screen frequency and these are not at all suitable for user interfaces. The actual values are documented in each instance. In critical cases, the user should make note of the values available in the RIP to avoid any unwelcome surprises.

The screen frequency set in the user interface can be set to default or overwrite. The job either uses the screen frequency from the Setscreen setup or ignores it, depending on what is set. The values from this job are then rounded off to the next value in the screen system. In this case, the job must have the same value for all the color separations. The user should enter these settings carefully, because the RIP cannot balance out mistakes. Screen frequencies that do not match are imaged as well.

5.3.3.1 Extremely High Screen Frequencies

An extremely high screen frequency is found whenever the ratio between resolution and actual screen frequency is less than 12. With 1000 l/cm the limit is an 80 l/cm (200 lpi) screen, and with 500 l/mm it is set at a 40 l/cm (100 lpi) screen.

In these screens, less than 12 × 12 pixels are available for a single screen dot. The dot shapes that are possible and the number of gray levels in a single dot were restricted.

In older RIPs, these high screen frequencies were implemented in special screen systems whose shortcomings, i.e. restrictions in quality, were made no secret of. Meanwhile, most of these restrictions have been removed, and extremely high screen frequencies are integrated in normal systems.

Customers with a highly trained eye can possibly still discern a difference to lower screen frequencies and if so, we recommend that they switch to a higher resolution.

The absolute highest screen frequency most screen systems support is up to 240 l/cm (600 lpi) at a 2000 l/cm (5080 dpi) recorder resolution. The naked eye can not discern any improvements in smoothness or details above a screen frequency of 120 l/cm. Great care is recommended when processing plates and prints, preferably dry offset.

Apart from the quality factor, extremely high screens can be used to boost productivity as well. An example of this would be that the most commonly used screen frequency of 60 l/cm (150 lpi) can be imaged with a recorder resolution of 500 l/cm (1270 dpi) instead of the usual 1000 l/cm, which would result in significant advantages in speed when RIPping and imaging.

5.3.4 Assigning Colors to Angles

Each screen system has a definition stating which angle belongs to which color. This can be regarded as the default setting. An appropriate dialog lets the user assign the color separations to other angles as well. However, only the four angles that are in the screen system can be used.

Only these angles are available for spot colors as well. Each spot color can be assigned one of the four angles with the help of filter comments (see Chapter 5.2.4.3).

With PostScript filtering for a separated output, the set allocation of colors and angles only works when the job in question has the color/angle allocation defined in the PPD. If not, angles could be switched unintentionally.

5.3.5 Fill Patterns

In the early days of PostScript, screening was sometimes used to create fill patterns. Consequently, provisions were made in older RIPs to attempt to recognize such patterns and to disable Heidelberg screening in such a case. This was only marginally successful. So-called patterns were introduced with PostScript Level 2, so there was no more reason to misuse screening for such purposes. Patterns are processed in the RIP totally apart from screening. All newer versions of the most common graphic programs use this function, making a special pattern analysis in screening superfluous.

In rare cases, during the output of older PostScript files, a screen will be output instead of a pattern. It is more than likely due to the misuse of the screening algorithm, and in such a case the user will have to switch over to PostScript screening. However, any color screen on that page will not be output optimally.

6 Laser Imagesetters

The vast majority of all print originals are created nowadays with laser imagesetters or plate recorders (Computer-to-Plate[32]). This chapter will describe the structure and principal properties of various types of imagesetters. Certain imagesetter properties influence what is possible in screening. These aspects will be examined below.

There are three key technologies for designing laser imagesetters:

- External drum imagesetters,
- Internal drum imagesetters,
- Capstan imagesetters.

All laser imagesetters work on the same principle, which is that one or more laser beams 'writes' image information line by line, in parallel, onto photosensitive material.

The laser is switched on in those areas where the film or printing plate is to be exposed; otherwise, it remains switched off. The laser beam is switched on and off digitally in a precisely defined cycle. The individual laser dots that can be switched on and off are known, somewhat confusingly, as pixels, derived from 'picture element'. Each screen dot is therefore made up of a certain number of pixels. This procedure is used to construct a screen within the pixel matrix of an imagesetter.

In practice, both the line spacing and the pixel frequency normally lie between 7.5 and 30 µm.

Unlike the electron beam in TV tubes, laser beams cannot be deflected by electromagnetic fields. Light can be deflected over large distances only using mechanical means. Added to this is the fact that the deflection must be bi-directional – rapidly in the direction of the laser line, and relatively slowly from laser line to laser line.

Many publications use the terms image line, scan or fast scan instead of 'laser line'. The direction perpendicular to this is the feed or slow scan.

The various types of imagesetter differ mainly in terms of the principle used for generating image lines and feed.

6.1 External Drum Imagesetters

In the repro industry, external drum imagesetters are filmsetters for color work that traditionally offer high quality. This technology also has advantages in the field of plate imaging.

The film or printing plate awaiting exposure is mounted on the outside of the drum on this type of imagesetter. Exposure takes place along the length of the rotating drum using a laser head (see below), which in turn moves along the drum with great precision by means of a spindle.

The material is moved by the drum rotating, and this writes the image lines, while the slow movement of the laser head effects the feed from image line to image line.

This type of construction requires a very stable design because of the relatively large moving masses and the imbalance created by the material clamped to the drum. Fixing the material to the drum is not an easy matter at all. To keep the centrifugal force and imbalance at an acceptable level, the rpm count must be kept relatively low. To achieve acceptable imaging times, several laser beams are used at the same time. These beams can be arranged so that different areas of the drum are exposed at the same time, or so that a 'light rake' exposes image lines lying side by side.

The principle of the light rake is a well-known one. Lasers, beam splitter and modulator are all housed in the optical head. Different designs can be used for generating parallel laser beams. The most popular one is the splitting of a single laser beam into a 'light rake' comprising parallel light beams which are then modulated individually. An acousto-optical modulator (AOM) is used for this purpose. A laser diode array is also sometimes used.

Regardless of the design of the optical head, there are two properties that can influence the quality of the screen:

1. The individual beams in a light rake may possibly have a different light intensity.
2. It is also possible that the spacing between them is not the same.

Both effects can cause a periodic 'light rake stripe', which can interfere with the screen and needs to be taken into account during screening (see last section in this chapter).

Examples of imagesetters that follow this design are Heidelberg's recorder R30X0 from the 3000 series, Heidelberg's Trendsetter and Topsetter™ plate recorders and the Kodak Approval proofer.

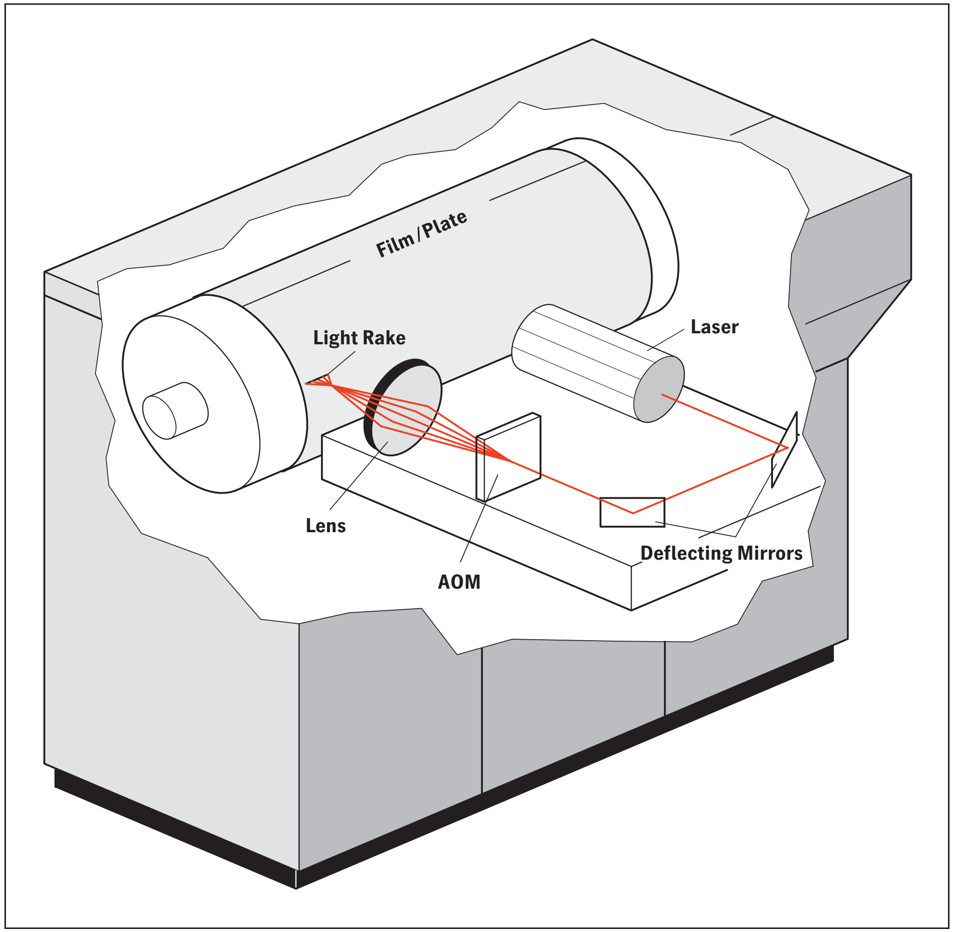


Figure 60: Schematic diagram of an external drum imagesetter.

6.2 Internal Drum Imagesetters

Internal drum imagesetters are used for both typesetting and repro. They are available on the market as both filmsetters and platesetters. The material to be exposed is held in position inside a partially open hollow cylinder. The laser is then moved along its exact center. On some units, only the deflection unit is moved. The laser beam is focused onto the material using a lens and deflected onto the film via a fast-rotating prism. The image lines and the feed are effected by moving the optical system. The material is not moved during the exposure process.

The rotating deflection unit is a small component and can rotate at high speed. This means that production can be very quick using a single laser beam. Although the optical paths are significantly longer than on external drum imagesetters, on the whole, it is easier to buffer vibration since only small masses are being moved. The optical system as a whole is kept significantly more simple.

This type of imagesetter enables maximum quality in the repro sector at very high speeds and at a moderate price. It has established itself on the market as a filmsetter and platesetter. Examples are the Herkules®, the SignaSetter®, the Primesetter™ and the Prosetter™ – all from Heidelberg.

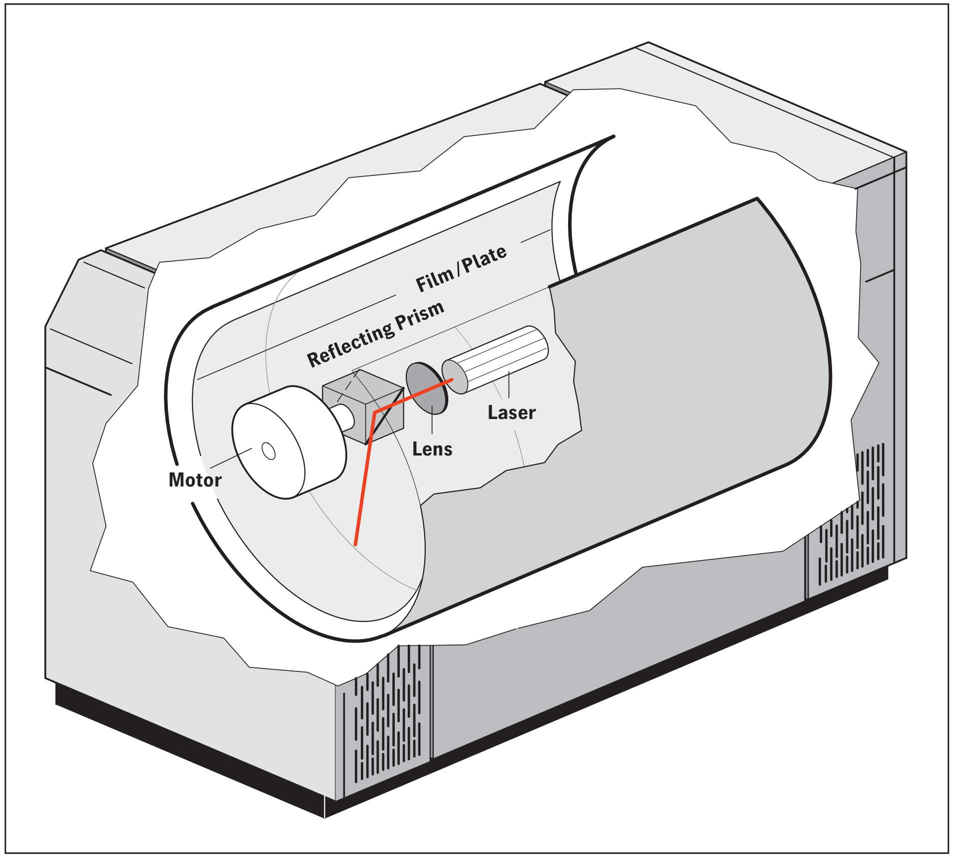


Figure 61: Schematic diagram of an internal drum imagesetter.

6.3 Flatbed Imagesetters/Capstan Imagesetters

Flatbed imagesetters and capstan imagesetters[33] originate from the world of typesetting. On these imagesetters, the material to be exposed is clamped onto a flat platen or slowly fed over a roller. The exposing laser beam is then generally deflected at right-angles to the feed direction of the transport platen or roller using a fast-rotating polygonal mirror or oscillating mirror, and then imaged onto the film using a large lens (scanner lens).

Capstan imagesetters allow any length of film to be exposed. The length is only limited by the actual length of the material. Specialist expertise is required to make sure that the film is transported with sufficient accuracy. Similarly, accuracy is also required when exposing color separations.

Because of the long optical routes, flatbed imagesetters in particular are constructed using vibration-absorbing materials such as synthetic concrete and are positioned on vibration absorbers. This ensures that the exposing laser beam is not deflected by ambient vibrations that could adversely affect the imaging process. The scanner lens is extremely well designed since the image lengths in the middle of the film and at the edge differ considerably and the image needs to be focused throughout.

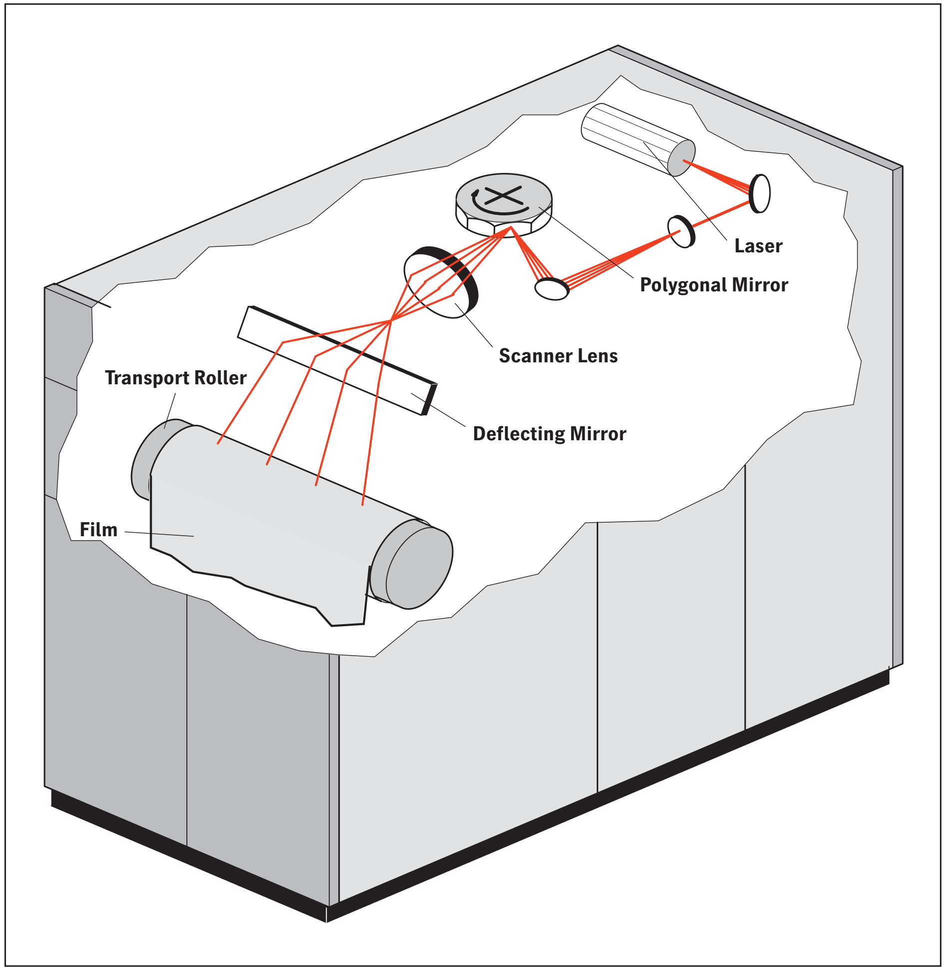


Figure 62: Schematic diagram of a capstan imagesetter.

Because of the unavoidable pyramidal errors[34] of a polygon, interference between the screen and the polygon can occur in this situation, similar to the one involving the light rake on the external drum imagesetter.

This type of imagesetter combines both good quality at reasonable costs and moderate quality at higher speeds and lower costs.

Examples of flatbed units include the recorders of the newspaper page transmission system PRESSFAX®, while the range of capstan imagesetters includes the Linotronic™ 3X0 and 5X0, plus Heidelberg's Quicksetter™.

6.4 Resolution and Addressability

Laser imagesetters feature quite a number of resolutions which are usually quantified in terms of lines per centimeter (l/cm) or dots per inch (dpi). This value is often misinterpreted, since it often doesn't describe the actual resolution, but rather the spacing between two image lines. A better term for this would be addressability. The imagesetter's resolution can be determined from the size of the laser dot ('spot size'). In ideal situations, this should be around 20 % larger than the addressability. This value is the best possible compromise between even exposure and maximum resolution.

Example: An imagesetter with an addressability of 1000 l/cm has a laser line spacing of 10 µm. The laser dot should therefore have a diameter of 12 µm. Because the intensity of the laser beam decreases towards the edge, even exposure is achieved through the nominal overlap of 2 µm. Individual laser lines without neighbors will be a fairly precise 10 µm wide. This of course only works if the intensity of the laser has been set correctly for the material that is used.

6.5 Light Rakes and Screen Dots

Light rakes can be found on both external drum and capstan imagesetters. The usual number of laser lines is between 6 and 250. The interplay with the screen period can result in interference which is mostly perceived as stripes running parallel to the image lines. Screens at 0° and 45° are particularly susceptible to this phenomenon.

At these angles, therefore, the screen dots are best made up of integral multiples of the light rake.

Example: A 60 l/cm screen at 1000 l/cm would have to be made up of 16.67 laser lines. On an imagesetter with 8 light beams, it would actually consist of 16 lines, giving an exposure result of a 62.5 screen.

This rule of using whole numbers is, wherever possible, also applied on internal drum imagesetters using just one beam, since otherwise the screen itself may contain interference structures. This limits the screen frequencies that can be achieved at specific levels of addressability.

There are also specific, preferred combinations of 0° and 45° angles for color reproduction. There are no pairs of equal 0° and 45° screen frequencies where the dots of both angles are made up of a whole number of lines. For this reason, the 0° angle often has a different screen frequency.

6.6 Imagesetter Calibration

The calibration of the imagesetter to the specific material and processor is crucial for optimizing the optical system and minimizing the effects of the light rake. Depending on the type of imagesetter used, the prescribed procedures for the light value, filter value, focus, zoom etc. have to be painstakingly carried out and repeated at regular intervals. A poorly calibrated imagesetter cannot give you good quality.

6.7 Film and Plate Linearization

The actual dot percentage achieved on the film depends on the film type and the developing conditions. Most films have a dot percentage of around 53 % at 50 % nominal density, provided the processor has been set correctly. With the correct method of working, even this deviation should be corrected by linearizing the film.

In order to linearize a film, a gray scale[35] with the appropriate density levels must be exposed, developed and measured. In the film linearization tools, the corresponding values are entered in a table with columns for desired and actual values. The 'Nominal' column lists the dot percentage the film is to have, while the 'Is' column lists the actual percentage measured. The program then calculates the correction tables so that the exposure results match straightaway.

Newer tools store the data in a database. Information about the validity range for linearizations is also kept on file so that this work does not need to be repeated from scratch for each screen combination.

Printing plates are rarely linearized since density measurement on a plate is extremely difficult and the measuring devices that are currently available are still very imprecise. It's also hard to deal with light capture effects in linearization such as those described in the Tips and Tricks chapter.

7 Screens in Print

Screening is an integral part of the overall print production process. It therefore makes sense for those in the business of print products to concern themselves with the other stages of the process, in particular print processes. The processing stages following creation of the color separation films involve a few other aspects that need to be taken into consideration when the films are first being created. Some of these stages do not apply when printing plates are being imaged directly.

This is a very broad area, and it is not possible to examine all the aspects of printing within the confines of this publication. However, the next few pages will list a few of the main ones.

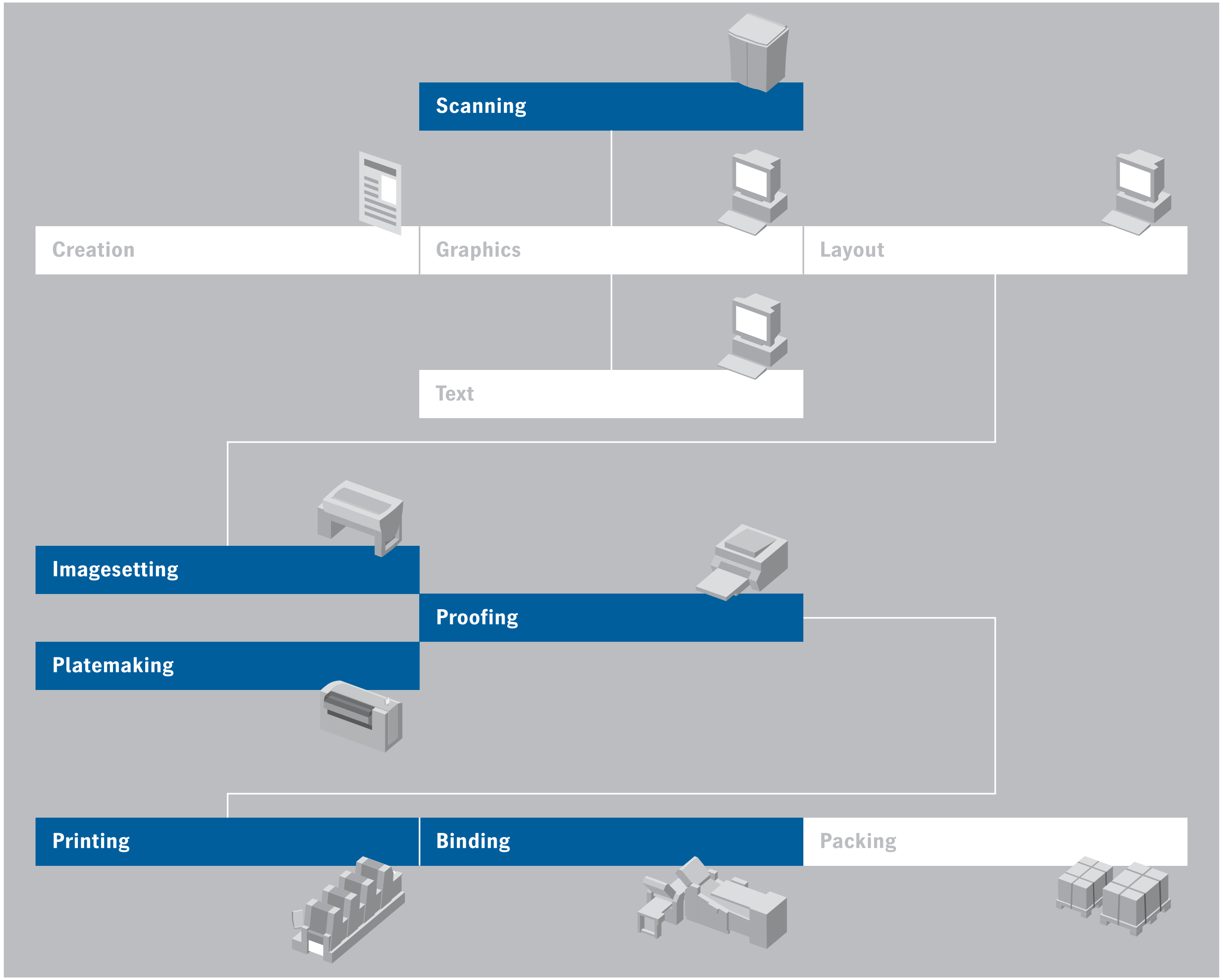


Figure 63: Printing production process.

7.1 Platemaking

By way of an example, we will look at the process for making a positive offset plate. The printing plate consists of an aluminum substrate with a light-sensitive synthetic layer. Exposure with UV light causes chemical bonds to be broken down so that the exposed sections can be washed away. The oleophilic, i.e. oil-friendly, synthetic layer absorbs the oily ink, while the hydrophilic, i.e. water-friendly, aluminum substrate is moistened in the press before each new printing run so that it cannot absorb any ink.

Blooming or side lighting influences the ink coverage when copying the films to the printing plates. In many films, the edge of the screen dot is not absolutely sharp – i.e. there is a gray zone. Blooming can occur even on extremely hard-dot[36] films with a sharp edge, since the photographic layer always is at a minimal distance from the plate and is itself approximately 1 μm thick. Reflections on the metal substrate and stray light also play a role.

Normally, printers try to cover up the cutting edges on the film. This is done using the blooming effects described and possibly even a dispersion foil[25], and the dots that are generated are generally 'pointed'[37]. A number of special points need to be observed in Diamond Screening, and these are listed in Chapter 7.4.

7.2 Dot Gain in Print

The most important effect that needs to be taken into account when creating lithos is the dot gain in print. This will be explained using offset printing as an example.

The ink is applied to the plate cylinder via an inking unit, and the water, which is mixed with alcohol, is applied via a dampening system. From there, the ink is transferred to a blanket cylinder and only then is it printed onto the printing stock. It's easy to see that the printed dots are 'squashed flat' during these transfer operations. The resulting dot gain in print can be influenced by a number of factors, including the quantity of ink, the ink/water balance and the pressure of the cylinders.

Figure 64: Blooming during platemaking.

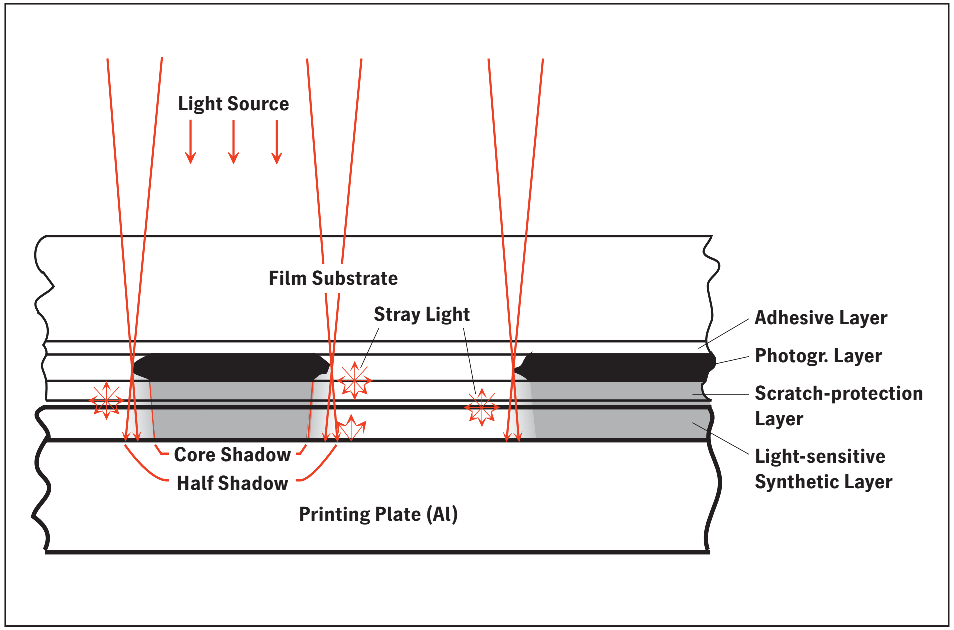
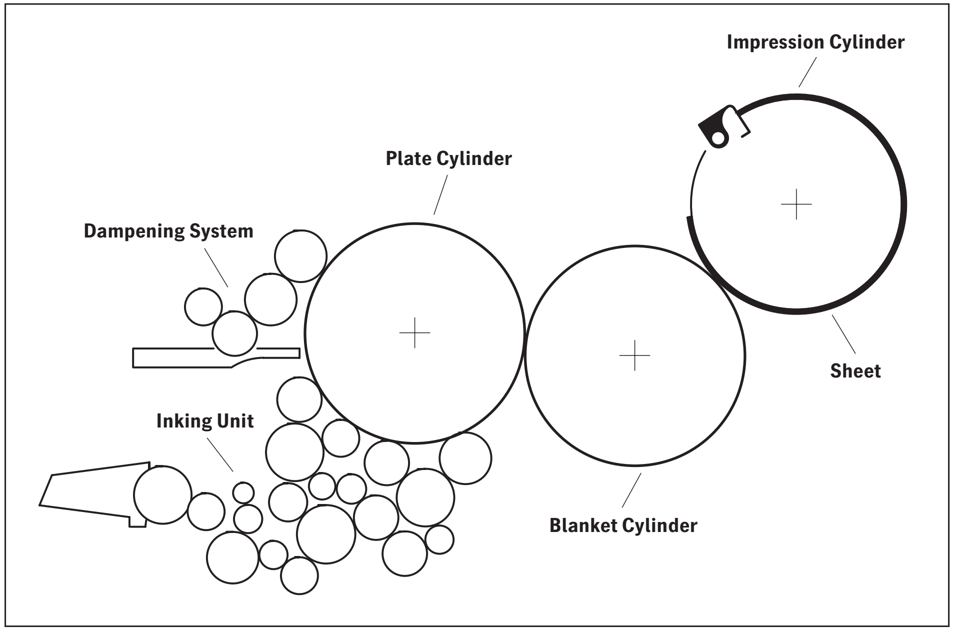


Figure 65: Diagram of an offset press.



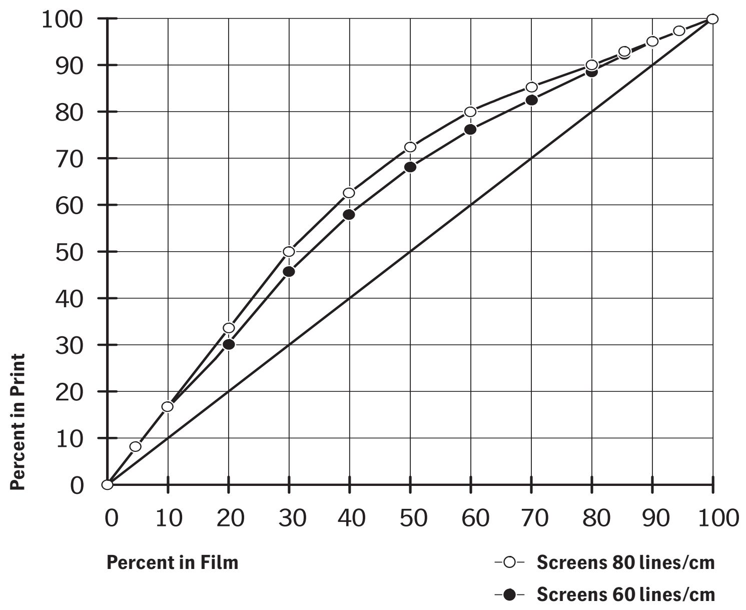


Figure 66: Example of a printing characteristic with marked dot gain in the midtone.

A further important factor for dot gain in print (around 12 %) is the light capture effects in the reflective light densitometer described in the section about density in the Tips and Tricks chapter.

The printing characteristic (curve) is obtained by plotting (or mapping) the ink coverage produced during printing against the dot percentage of the film. This shows a significant dot gain in the midtone. The dot gain can vary quite considerably, depending on the press, printing conditions, type of paper and screen frequency. If one of these factors changes, a new process calibration is usually required.

A standard dot gain is already taken into account in the color gradation during an image scan. It is then adapted to the current printing characteristic during digital screening. This requires that film linearization and process calibration were performed beforehand.

7.3 Selecting Screen Frequencies

A screen should be fine enough that it cannot be perceived by the human eye. With a 60 l/cm (150 dpi) screen, the individual screen dots are just about discernable – this is the visibility limit. For monochrome images, reproduction with 60 l/cm (150 lpi) is sufficient.

Conventional screens produce a somewhat larger rosette in the overprint, with the visibility of the rosette depending on the hue. Studies carried out by FOGRA have shown that the visibility of the rosette more or less corresponds to the visibility of a screen with a 1.5 fold period, i.e. the rosette would still be visible on an 80 l/cm (200 dpi) screen. High-quality artwork should therefore be printed using at least an 80 l/cm (200 dpi) screen.

However, printing aspects are often more important in the choice of the screen frequency. The smallest possible dot or the smallest gap that can still be printed between the dots is a crucial factor here. Because the human eye is very sensitive to densities in the shadows, it is important to print gaps that are as small as possible. The table below sets out the maximum ink coverage that can still be printed just below the full ink coverage of 100 %.

This sensitivity of the eye in the shadows means that losses of 1% are noticeable already in the shadow definition. The size of the dot that can still be printed depends on many factors, particularly the paper. It may well be possible to copy 7.5 µm, but it won't be possible to print it. Generally speaking, printing uses relatively coarse screens because they're easier to process. Experience with Diamond Screening has shown that dots with a diameter of 20 µm are still stable in print, but that difficulties are experienced with dots smaller than this.

Screen frequency l/cm	lpi	Diam. µm	Max. %	Diam. µm	Max. %	Diam. µm	Max. %
40	100	10	99.8	15	99.7	20	99.5
60	150	10	99.7	15	99.4	20	98.9
80	200	10	99.5	15	98.8	20	97.9
120	300	10	98.8	15	97.5	20	95.5
240	600	10	95.4	15	89.8	20	81.9

Table 11: Smallest printable dot and maximum ink coverage.

Screens of 34 l/cm (85 dpi) or 40 l/cm (100 dpi) are the general standard in newspaper printing. A 60 l/cm (150 dpi) screen is used in Europe for printing magazines and catalogs, although the trend is moving towards the 70 l/cm (175 dpi) screen, as is already the standard in South-East Asia. For artwork on coated[38] paper, an 80 l/cm (200 dpi) screen is recommended.

7.4 Process Calibration

Process calibration is a tool for standardizing the entire process of producing artwork masters and for allowing them to be used in different presses. Although standardization does not give a printer full artistic freedom, good results are much faster to achieve, and this means there's also less startup waste.

Process calibration is intended to balance out the deviations of individual presses from print standards. The key requirement for process calibration is that all the processes involved are standardized and stable. The press in particular must be set carefully. Your entire production depends on a good process calibration. The principle behind the process calibration workflow is the same for Computer-to-Plate (CtP) and Computer-to-Film[39] (CtF).

Process calibration is performed using a special utility in the RIP. A test page is output using the screen that is to be calibrated. A key element of the test page is the gray scales with density levels of between 0 % and 100 %. A proof print of the page is then output to the material that is to be calibrated and measured.

The user enters the data measured and the nominal values in the dialog box of the calibration tool that then calculates the calibration tables for electronic screening. These tables are saved and can be used afterwards in production. The calibration tables obtained this way are usually so good that the print results are in the tolerance range right away. Even if you make more major color corrections subsequently, i.e. you are doing the job of a lithographer at the press, a good process calibration gives you sure, centered results, providing you with a solid base for any artistic designs needed.

If the table does not already have boxes for the following density levels, it is advisable to add them: 2 %, 7 %, 93 %, 97 %, 98 % and 99 %.

Often, process calibration is the same for all colors, at least within the tolerances. It is color-dependent at least in the RT Y45° K fine and Megadot screen systems described in Chapter 4 because the screen frequencies in the color separations differ greatly in these systems. Process calibration of the other screen systems can be color-dependent, especially when caused by rheological[40] differences in the colors or press settings.

The new Heidelberg calibration manager stores the calibration data in a database. This makes color-dependent process calibration possible. Information about the validity range of calibrations is also stored so that the time-consuming calibration process does not have to be repeated from scratch for every screen combination.

7.5 Proofs

The proof basically shows you what the colors will look like in print. Because many different processes and often a number of different companies are involved in the production of a print product, it is important to make sure that you get the results you want. The proof plays an important role, especially as regards the coordination between prepress and the printshop. The proof is the template for the inks used during printing.

There are a number of very different proofing processes:

- from a straightforward output on a desktop printer,
- right through to proofs made on the printing press.

Various aspects can be assessed, depending on the method used. Common to all the methods is the fact that they all allow text, typefaces, graphics, print control elements, register and cutting marks to be checked, with varying degrees of efficacy. The presence of images can also be verified, although it is not always possible to check the correct image resolution. Screens can only be assessed by using a handful of methods. Digital proofing methods can only produce a true-color screen proof if the resolutions of the proofer and CtP/CtF recorders are the same.

Table 12 lists examples of the various proofing methods along with their differing properties. Common to all proofing methods is the fact that texts, typefaces, print control elements and the presence of all images and graphics can be checked.

With some inkjet printers and high-end proofers, an excellent approximation of the print can be achieved by carefully calculating the color transformation tables and using good color management.

Proofing method	Color fidelity	Check
Laser printers black/white	No colors, but single separations possible	Register and cutting marks, data
Blueprints black/white	No colors, but single separations possible	Register and cutting marks, data, imposition layout
Color laser printers	Not very precise, limited reproducibility, sometimes screens	Coloring (depends on color management), no imposition layout
Inkjet	Varying precision, reproducible, sometimes screens	Coloring (depends on color management), imposition layout on large-format printers
Thermal sublimation printers	Good reproducibility, no screens	Coloring (depends on color management), no imposition layout
Iris proofer (color inkjet)	Good reproducibility, no screens	Coloring (depends on color management), (possibly) imposition layout
High-end proofs (digital) e.g. Kodak Approval, Trendsetter Spectrum	Excellent, excellent reproducibility, original screens	Coloring, color balance, gray balance, moiré effects, (possibly) imposition layout
Laminate proofs (Imation, Fuji)	Excellent, excellent reproducibility, original screens	Coloring, color balance, gray balance, moiré effects, films, inaccurate registration, (possibly) imposition layout
Proof print	Good, good reproducibility, original screens	Coloring, color balance, gray balance, moiré effects, films, accurate registration, imposition layout
Chromalin	Excellent, excellent reproducibility, (with toner) original screens	Coloring, color balance, gray balance, moiré effects, films, accurate registration, (possibly) imposition layout

Table 12: Proofing process.

Chromalin and laminate proofs offer very few options for changing the reproduction characteristic and adjusting it to special printing characteristics. They can only supply proofs for a standard printing characteristic. This has both benefits and drawbacks since both methods produce proofs of excellent color constancy.

Proof printing provides users with a lot of scope for varying color reproduction, making it possible to match various printing characteristics in the production run. However, it often remains to be seen whether the satisfactory result obtained from the proof print will be produced at all on the production machine, and if it is, whether the result will be stable.

8 Tips and Tricks

This chapter deals with a number of tips and tricks that can be of assistance during your everyday work.

8.1 Angle Switchover

It can sometimes be useful to switch the screen angles in order to get better results for certain motifs. In conventional screen systems, such as the IS Classic, the colors are assigned to the screen angles as shown in the following table. Generally speaking, the applications return the input angles listed below for the corresponding colors, which are then converted by the IS Classic screen system into the output angles shown.

C, M and K, as the defining colors, are spaced 60° or 30° apart. The lightest color Y has to be sandwiched in between them so that it is only 15° away from its neighbors. When conventional screen systems are used, the smaller distance between Y and its neighboring colors can lead to a slight yellow moiré in the print. This moiré can be minimized by switching the screen angles, depending on the motif. This applies regardless of the method used to generate conventional screens or their approximations.

Color	Input angle	Output angle
C	15°	165°
M	75°	45°
Y	0°	0°
K	45°	105°

Table 13: Input and output angles for the IS Classic screen system.

If skin tones are predominant, then the angle allocation specified above is the best solution. Greens (e.g. vegetation) are generally inherently structured, so this moiré will not be visible. Alternatively, the IS Y fine or RT Y45° K fine screen systems can be used, since they have no yellow moiré.

If smooth gray-greens are predominant, then switching the screen angles of C and M is recommended to avoid any moiré between cyan and yellow.

Only the screen angles for C, M and K should be switched. Yellow should always remain at 0°. This applies not just to this screen system but to the other ones as well.

We strongly recommend that yellow is not assigned to another angle – it should retain its angle allocation.

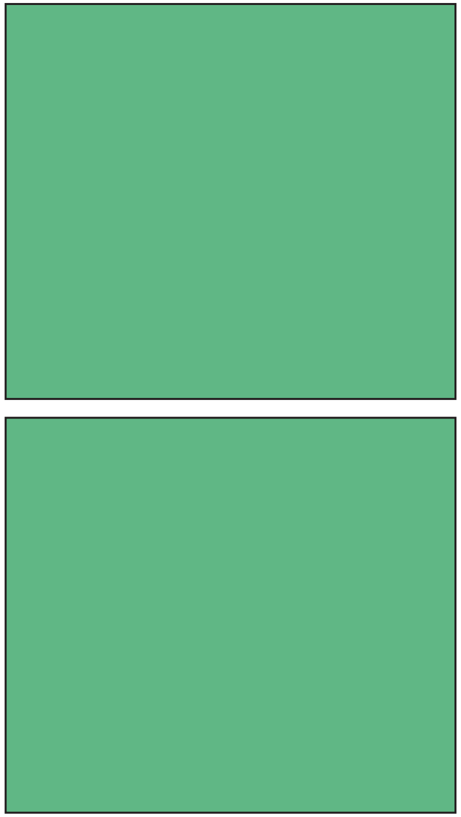


Figure 67: By switching the angle, better results can be achieved for certain motifs or critical hues (top: standard setting, bottom: cyan and magenta switched).

The relevant user manuals will describe how to switch the angles.

The illustration opposite shows two rectangles with a critical hue that were imaged in the IS Classic screen system using a 60 l/cm (150 dpi) screen and 1000 l/cm recorder resolution. In the top rectangle, the angles are not switched. On the bottom, they are.

The effects are particularly clear in generated areas. These kinds of image motifs only appear rarely in practice, however.

8.2 Vignettes

Vignettes are very suited to demonstrating the sensitivity of the human eye. In the shadows especially, the human eye is able to distinguish even very slight differences in dot percentage. To demonstrate this, the linear vignette shown below was generated with an 8-bit resolution in QuarkXPress. The dot percentage ranges from 50 % to 100 %. Over a length of 250 mm, this means that a new level begins approximately every 2 mm. The levels can be seen particularly in the shadows. An imagesetter offering premium quality reproduces such levels with utmost precision.

Another interesting aspect is the optical illusion that takes place. The brain sharpens contours in such a way that the levels on the lighter side appear darker than on the dark side of the vignette. A similar effect can also be seen in short vignettes which form the transition from a white area to a black area. Directly beside the vignette, the white parts appears whiter than white and the black ones blacker than black.

8.2.1 Generating Vignettes

How various applications generate vignettes would require a section all of its own. But first a note about PostScript. In Level 2, images are specified with 12 bit pixels, i.e. there are 2^{12} = 4096 gray levels. For performance reasons, just like in most image editing programs, PostScript only uses 8 bits internally, i.e. 256 levels, for screening. Only from PostScript 3 onwards has it been possible to generate smooth vignettes with a 16-bit resolution (65537 levels) using the 'Smooth Shading' function.

Many image editing applications do not yet use the new features and generate vignettes using the old methods, i.e. they juxtapose strips of gradually increasing density. If you're lucky, the full 256 density levels are used and the vignette's transition from 0 % to 100 % dot percentage is completed in 256 graduations. This produces useable results if the vignettes do not extend right into the shadows or they are relatively short.

Some applications try to save memory and computing time by generating vignettes from as few levels as possible. To do this, the application requests the recorder resolution set on the RIP and the screen frequency and uses this information to calculate the number of possible density levels.

An example: With a recorder resolution of 500 l/cm and a 60 l/cm screen, the application assumes that a dot will be made up of just 8 × 8 recorder pixels. This would mean that only 64 density levels could be displayed, and so the vignette is only made up of 64 levels. This is, of course, way too little, and banding can easily be seen.

In most image and graphics editing programs, there are setting options that can be used to apply 'smooth shading', or at least prevent a reduction of density levels. These setting options are often well concealed in the user interface. In view of the wide range of applications available, it is not possible to list all these options here, particularly since they often vary from version to version.

A remedy for vignettes generated using the 'old-fashioned' methods comes from the 'Idiom Recognition' facility used by Heidelberg RIPs from PostScript 3 onwards. This PostScript function enables older PostScript routines to be detected and replaced with more modern ones. For the vignettes mentioned here, this means that functions that generate vignettes using the method described above are searched for in the PostScript document. These functions are then replaced in the RIP with modern methods that generate smooth vignettes.

Unfortunately, for reasons relating to PostScript's internal configuration, it is not possible to detect or replace all inadequate vignette functions. It may be necessary to use image editing software to smoothen vignettes afterwards.

Banding may also occur in vignettes as a result of process calibration or a gradation curve. If process calibration involves particularly steep sections or bends, these can cause banding, mainly in short vignettes.

Figure 68: Vignette ranging with 50 % to 100 % dot percentage with an 8-bit density resolution. The stepping that appears when density resolution is restricted can clearly be seen.

A multidot technology is used in IS or HQS screening, as already described in the chapter on screening methods. This means that there is always a sufficient number of levels (more than 1000) to display a vignette smoothly. Even if the PostScript software reduces the number of levels to 256, they are uniform and are therefore less intrusive.

8.3 Media and Scanner Moirés

Moirés are disturbances, as described in Chapter 1.4. They can occur when unsuitable screens are overprinted, and also between the print screen and fine, uniform patterns in the original. Examples of this include certain fabrics, as shown in the Diamond Screening print example. Moirés can also occur between a striped shirt and the print screen. These types of moiré can be avoided by using Diamond Screening, which was described earlier.

Similarly, moirés can also occur between the original and the scanner's scanning screen. These moirés cannot be eliminated using a downstream process. They can usually be avoided by rescanning the original at a higher resolution.

Very pronounced moirés sometimes also occur when scanning originals that have already been screened. Reliable descreening can only be achieved in these cases by using special filtering processes. Heidelberg's NewColor® software incorporates such filters. The user can set the screen frequency that needs to be filtered out and obtains outstanding results every time.

8.4 Spot Colors

The IS Classic, IS Y60 and IS Y30 screen systems can be combined for spot colors that are not just to be printed as solid tints. To avoid overprint moirés, users should not forget that the screen angles of 60° and 30° are only 15° from the neighboring angles and that the colors are assigned accordingly. This means that the contrast to the neighboring colors should be a low as possible, or the spot colors should be light, like yellow.

The fine black of the RT Y45° K fine screen system is also fully suited for a spot color with these systems. Another option is to assign a spot color to the angle of a color with which there is as little overlap as possible.

The 60° and 30° screen angles of the IS Y60 and IS Y30 systems can be combined with the Megadot screen in every regard.

The most stylish solution is to use Diamond Screening, at the same time remembering to take into account the varying dot gain in print (see Chapter 7.4. Process Calibration).

8.5 Seven-Color Printing

Seven-color printing will only be touched upon briefly here since the process of generating the separation gradations is discussed in the scanner manuals (e.g. in the 'HiFi Color DC 3000' book). The use of enhanced GCR (Gray Component Removal[41]) is recommended. Only three different screen angles are then required for 7-color printing. Black as the dominant color is assigned to 45°, the six chromatic colors cyan, blue, magenta, red, yellow and green are alternately assigned to 165° and 105°. The IS Classic, IS Y60 and IS Y30 screen systems can be used for this.

With this method, each hue is generated using just three colors. Black provides the gray component, and any hue can be generated in combination with two neighboring colors. A maximum of 10 % of a complementary color can be added to darken the color without causing any risk of color shift. This process is practically a colored black/white print. For example, all printable hues between red and yellow can be created using black and these two process colors. The same applies for all other hues. Essentially, only three colors are printed on the same part of the image. This means that it is possible in 7-color printing to use just 3 different screen angles without running the risk of color shifts.

Color	Input angle	Output angle
Cyan	15°	165°
Blue	45°	105°
Magenta	15°	165°
Red	45°	105°
Yellow	15°	165°
Green	45°	105°
Key	75°	45°

Table 14: Color allocation in 7-color printing.

Table 14 suggests allocations of screen angles to colors. Rational screen systems, Diamond Screening or Megadot can, of course, also be used with the relevant screen angles.

8.6 Hexachrome Printing

Hexachrome printing will also only be touched upon briefly here since the process of generating the separation gradations is discussed in the scanner manuals (e.g. in the 'HiFi Color DC 3000' book). Here too, the use of enhanced GCR (Gray Component Removal) is recommended.

In contrast to 7-color printing, hexachrome printing requires more than three screen angles. Because there is an odd number of chromatic colors, they cannot be assigned alternately to just two different screen angles. The following screen combination is therefore suggested:

Black as the dominant color is assigned to 45° fine black in the RT Y45° K fine screen system. The five chromatic colors cyan, magenta, orange, yellow and green are then assigned to 165°, 45°, 105°, 165° (0°) and 45° in the IS Classic screen system. If applied accordingly, the IS Y60 and IS Y30 screen systems can also be used for the chromatic colors.

Another item to note: Cyan, magenta and yellow generally have color loci that are significantly different from those familiar from 4-color printing. With this method, each hue is generated using just three colors.

Black provides the gray component, and any hue can be generated in combination with two neighboring colors. A maximum of 10 % of a complementary color can be added to darken the color without causing any risk of color shift. This process is practically a colored black/white print. For example, all printable hues between cyan and green can be created using black and these two process colors. The same applies for all other hues. Essentially, only three colors are printed on the same part of the image.

Table 15 suggests allocations of screen angles to colors.

Color	Input angle	Output angle	
Cyan	15°	IS10	165°
Magenta	75°	IS10	45°
Orange	45°	IS10	105°
Yellow	15°/(0°)	IS10	165°/(0°)
Green	75°	IS10	45°
Key	45°	RT Y45° K fine	45° fine

Table 15: Color allocation in hexachrome printing.

8.7 Processors/Film

Premium-quality recorders require that users give some thought to choosing and using films, chemicals and processors. Each recorder has a list of films and chemicals that are suitable for that particular model. In this context, please refer to the documentation provided by the relevant manufacturers. In this section, we will just mention a few general items of interest.

Hard dot films in particular have a steep gradation, and thereby generate an exceptionally sharp, high-density dot. Of course, films with extremely sharp screen dot edges are more stable in processing than films with blurred edges.

For stable results, it is vital that the correct amount of light be set on the recorder. Just enough light (but not any more) is required to ensure that the film is no longer in the high-contrast part of the gradation curve.

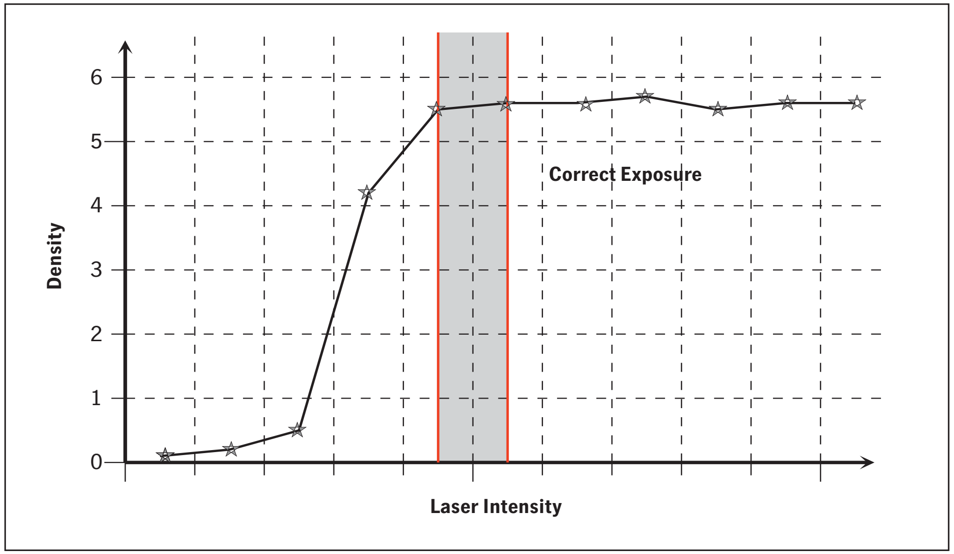
While stepping up the amount of light only increases the final density of the film slightly, blooming, on the other hand, is more pronounced. In other words, at high dot percentages, the small gaps become blurred, negatively affecting the shadow definition.

The settings depend on the recorder and the type of film used. Their job is to make work as stable and simple as possible without any overexposure.

8.7.1 Density

Transmission[42] is a key criterion when assessing films. The transmission of a film, or the reflectivity[43] of photographic paper or print can be measured as a dot percentage going from 0 % to 100 %, or as a density. Normally, the final density of a film or print is measured in logarithmic units as a density. This is recommended since light absorption is proportional to the log of the thickness of the light-absorbing ink layer. Density is, therefore, a measure of the thickness of the ink layer. Screened areas are mostly measured as a dot percentage. In densitometers, these values are simply converted using the formula below.

Figure 69: Gradation curve of a hard dot film with the correct exposure range.



Density (D) is defined as the negative logarithm to the base of 10 of transmission (T) or reflectivity:

$D = -\log_{10}(T)$.

To give an overview of these dimensions, table 16 lists the values for transmission, dot percentage and print density.

Hard dot films can achieve final densities greater than 5 on modern recorders. This means that less than $^{1}/_{100000}$th of the light is transmitted.

At light quantities as low as these, it can easily be imagined how measuring errors caused by noise in the densitometer, ambient light, stray light from dust or even the tiniest pores in the film can influence the result considerably. Some densitometers, therefore, limit the display to a maximum value. Data fluctuations should not be taken too seriously in a density range greater than 5.

Transmission (T)	Dot percentage	Print density (D)
1.000000	0.0000 %	0
0.100000	90.0000 %	1
0.010000	99.0000 %	2
0.001000	99.9000 %	3
0.000100	99.9900 %	4
0.000010	99.9990 %	5
0.000001	99.9999 %	6

Table 16: Transmission and print density.

Measurements always involve measuring errors of varying degrees.

If the reflective capacity of a print or a photographic paper is measured, then measuring errors will mainly arise from light capture effects. Figure 70 shows just how these systematic measuring errors occur. Other sources of accidental measuring errors include stray light caused by dust on the photographic paper or print.

Figure 70 shows how light reacts in the measuring head of a densitometer. The original is illuminated from the side by condenser lenses, and a centrally positioned lens transmits the diffusely reflected light onto a photocell that measures it. Light mirrored on the surface does not enter the lens in this configuration. In this diagram, the lenses displayed are far too small compared to the screen dots and too close to the paper surface.

The light capture effects mainly occur by the light not being reflected directly at the surface, but rather by it penetrating the paper and only being scattered back from this point. Part of the light is scattered below the screen dots and absorbed by the inked areas; in other words, it is 'captured' under the screen dots. A half-shadow forms around the printed dots and increases the size of the dot by a few µm. That doesn't sound like much, but on a

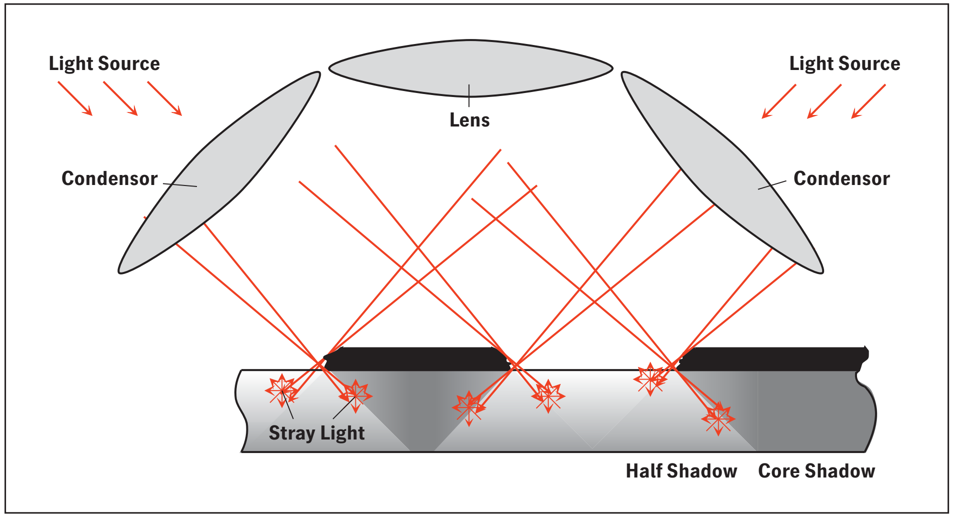


Figure 70: Light capture effects in a reflective light densitometer.

60 l/cm (150 dpi) screen, this represents a dot gain of approximately 12 % in the midtone range. If screened films are copied to photographic paper, light capture effects must be remembered when the paper is being measured.

The dot gain measured in print is mainly due to light capture effects. Light capture effects do not need to be taken into account in printing characteristics since they are already implicitly factored in there.

List of Figures

List of Tables

Footnotes

[1] PostScript is the worldwide standard device-independent page description language developed by Adobe to output text, graphics and images.

[2] A RIP is a Raster Image Processor. It translates the text, image and graphic elements defined in a page description language into a form that the output device (printer, proofer, filmsetter or plate recorder) can represent. In most cases, image, vector or other graphic information is used to generate a bitmap.

[3] Black is assigned K for Key, because B is already used by Blue.

[4] In the printing industry, the dark areas in a print or film are known as the shadows. Light areas are known as highlight and the mid-range as the midtone.

[5] When a signature runs through a printing press, slight deviations in angle or position inevitably occur from one printing unit to the next. These deviations, known as misregistration or register errors, must not be more than 1/100 mm. If misregistration is larger, the print will lose its sharpness, and color blanks will become visible around the contours of colored areas when viewed under the magnifying glass. Color blanks can be seen with the naked eye only in very low-quality prints. Misregistration also very frequently causes color shift.

[6] In case you need a math refresher: If you draw a perpendicular line from one side of an angle to another, you get a right-angled triangle. Its tangent is a ratio of side to base.

[7] Arctangent = the opposite of a tangent, it gives the tangent angle.

[8] Density is the negative logarithm to the base of ten which measures the transmission of light, i.e. its transparency (with a film) or reflection (with a print) (see Density in Tips and Tricks). This term is often misused when describing linear transmission or reflectivity.

[9] Dither = shiver, erratic movement.

[10] The term 'fast-scan direction' means the rapid movement of a laser beam over film or printing plate. It generally refers to the direction of rotation of the laser mirror or drum, in contrast to slow-scan direction which generally refers to the feed direction.

[11] Artifacts are artificial elements that are not present in the original. In the Error Diffusion method described in this book, contours are sharpened in a certain direction. Additional lines can form along these contours. Artifacts is an indirect way of saying that an image has imperfections.

[12] Redundancies are repeated or additional elements that can be used to detect or correct transmission errors.

[13] This mathematical term is loosely used to describe a two-dimensional table that assigns coordinate vector reference values for the density.

[14] On-the-fly describes calculations that are processed while the machine is in operation. With normal pages, the RIP process, including screening, operates faster than the imagesetter, so the imagesetter can image at full speed. However, a RIP interpreter can slow down an imagesetter when it is processing very computation-intensive pages.

[15] Address increments are added to the current address to obtain the next one.

[16] Banding, or shadestepping, occurs when there are too few steps in a blend or vignette. See Chapter 8.2, Tips and Tricks, to learn more about vignettes.

[17] The user input is converted in the screen filter to values that guarantee good overprints (see context).

[18] Slurs and doubling are printing press errors that become apparent through the widening or doubling of fine lines in circumferential direction. In offset printing, the printed image on the plate cylinder is printed first on a blanket cylinder and then on paper (see Chapter 7.2 Dot Gain in Print). These errors occur when the plate cylinder and the blanket cylinder are not synchronized exactly.

[19] Fuzzy logic is an approximate logic. This logic not only contains the yes/no decisions of classic logic, but also the in-between values and transitional areas. Many illogical actions that humans conduct can be simulated to carry out jobs. An example of this would be the anti-wobble feature in video cameras.

[20] FOGRA Symposium 1989.

[21] The area where individual screen dots just about join at the corners is known as dot chain.

[22] In film, gradation describes the correlation between light quantity and the resulting density. With scanners, gradation describes the correlation between the lightness of the original and its digital output value.

[23] The Greek mathematician Euclid based his Euclidean theory of geometry on a set of axioms. Axioms are basic principles from which all others are derived.

[24] Light-sensitive synthetic layer.

[25] A dispersion foil scatters light, thereby making it more diffuse. This significantly increases blooming so that cutting edges cannot be copied.

[26] Dry offset is the opposite of wet offset. Offset printing is a lithographic procedure where the printing parts are given an oleophilic (oil-friendly) synthetic layer which absorbs the oily ink. The printing plate, generally made of aluminum, is moistened by a fountain solution containing water and alcohol in order to reject the ink. With dry offset, the printing parts of the plate are also provided with an oleophilic surface, while the non-printing parts are given a coating which rejects ink (e.g. Teflon). The additional fountain solution and the dampening system are therefore not required. The dot gain in print is also significantly less and is more stable than in wet offset (see Chapter 7.2 Dot Gain in Print).

[27] In a composite workflow, the PostScript description of each page contains information about all the color separations. This is in contrast to a separated workflow, in which each page is only one color separation.

[28] A plug-in is an additional product module that performs certain functions the original program could not do or that makes certain functions available.

[29] DCS = Desktop Color Separation is an EPS file format that contains the four color separations and a file for the placement of images.

[30] Screen menu, in which the information 'pops up'.

[31] Delta Technology is a RIP and workflow product from Heidelberg.

[32] In Computer-to-Plate (CtP), the data which has been prepared for printing is imaged directly on the printing plate – i.e. without being first transferred to film.

[33] Capstan = rollers. The name capstan imagesetter refers to the roller-driven material transport.

[34] Manufacturing aspects mean that the individual reflecting surfaces of a polygon are not aligned absolutely parallel to the axis of rotation. Pyramidal errors are the slight deviations from the target direction.

[35] The gray scale or step wedge is a measuring strip with areas of gradually increasing density. It is used to check film linearizations or printing characteristics.

[36] A 'hard-dot' film has a steep gradation curve. This means that a film does not react to small quantities of light, but only after a relatively high threshold is reached. Above this threshold, only a small amount of additional light is required to expose the film to saturation.

[37] Screen dots are copied pointed if they are made smaller through overexposure and blooming.

[38] Art paper is coated with a layer of fine fillers (natural gypsum, titanium white, chalk, talcum or porcelain clay) and then reglazed. This improves the white content and the gaps between the fibers are filled in.

[39] In Computer-to-Film (CtF), the data is prepared ready for printing, impositioned to whole sheets and output on film.

[40] Rheology concerns the flow phenomena of liquids, colloidal systems and solids under the influence of external forces.

[41] Gray Component Removal (GCR) and Under Color Removal (UCR) are modern technologies for making color sets that were originally developed for 4-color printing. These technologies create the gray tones in an image mainly from black, and the chromatic colors are essentially used for coloring. This process cuts the use of expensive chromatic inks and makes color sets more stable in structure. The classic process builds the gray tones mainly from the chromatic colors and uses black essentially as a contrast enhancer. A very discerning balance of the chromatic colors is required to achieve a neutral gray. Even small errors can lead to considerable color shifts.

[42] Transmission is the ratio of transmitted light to irradiated light.

[43] Reflectivity is the ratio of reflected light to irradiated light.

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