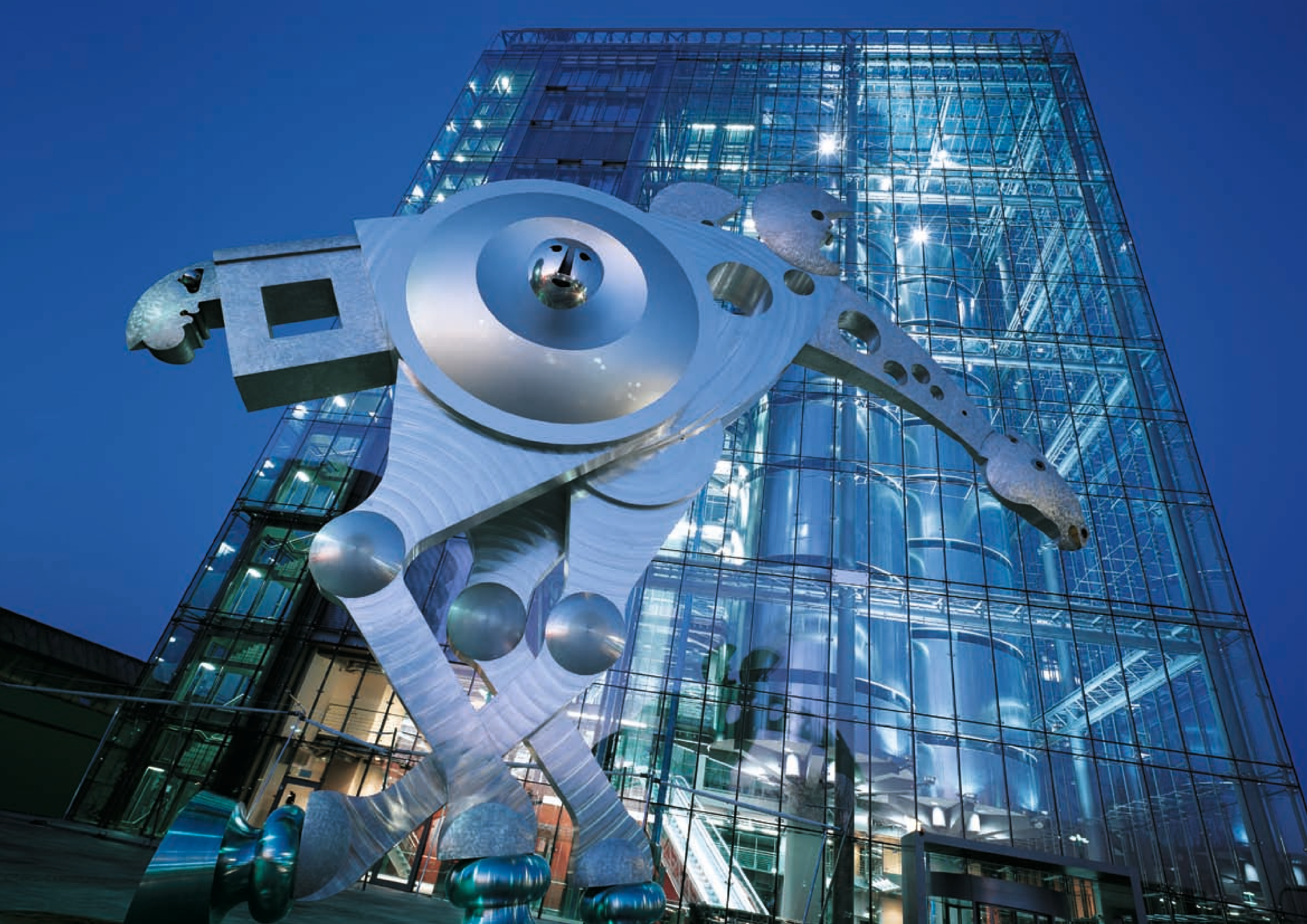
Expert Guide

HEIDELBERG

Color & Quality



Content

1 Light and Color

1.1 Light is Color

We live in a world of color. We use colors to liven up our living space, so we feel good in it. Space and color have a direct influence on our senses and the way we feel. Properly coordinated colors evoke a feeling of harmony, which puts us in a good mood.

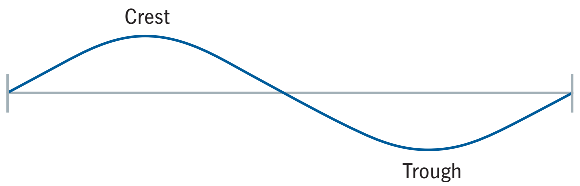
The printing industry also uses color to enhance its products and supply consistent quality to customers.

One of the prerequisites for this is established standards for measuring quality. And to be able to assess colors we need to be able to “see” them. This requires light.

The Sun emits light that it generates itself and is therefore a luminous object. In contrast, most of the objects surrounding us do not emit any light of their own and are therefore known as non-luminous objects. Consequently, we can only see them when they are illuminated by another light source.

Light is radiation that travels in waves at a speed of 300,000 km/s. It consists of electromagnetic oscillations that propagate in wave form. Just like a wave of water, each light wave has a crest and a trough.

Waves can be described using either their wavelength or the number of oscillations they make per second. Wavelengths are specified in everyday units such as kilometers, meters, centimeters, millimeters or nanometers.

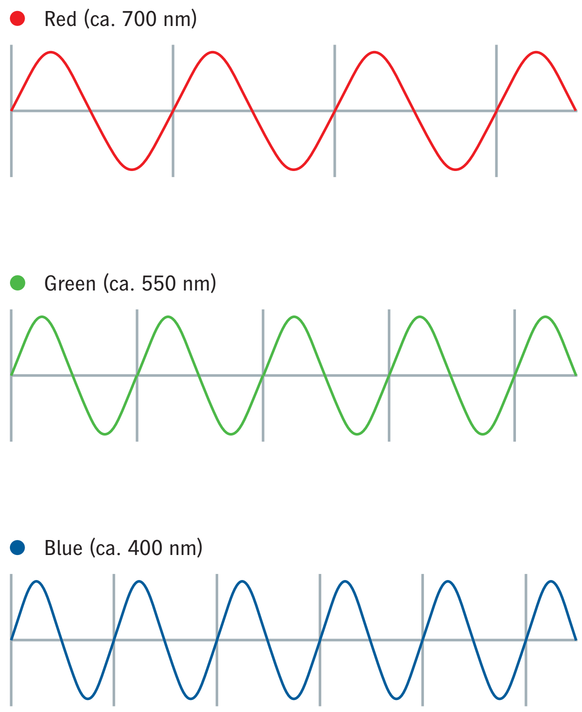


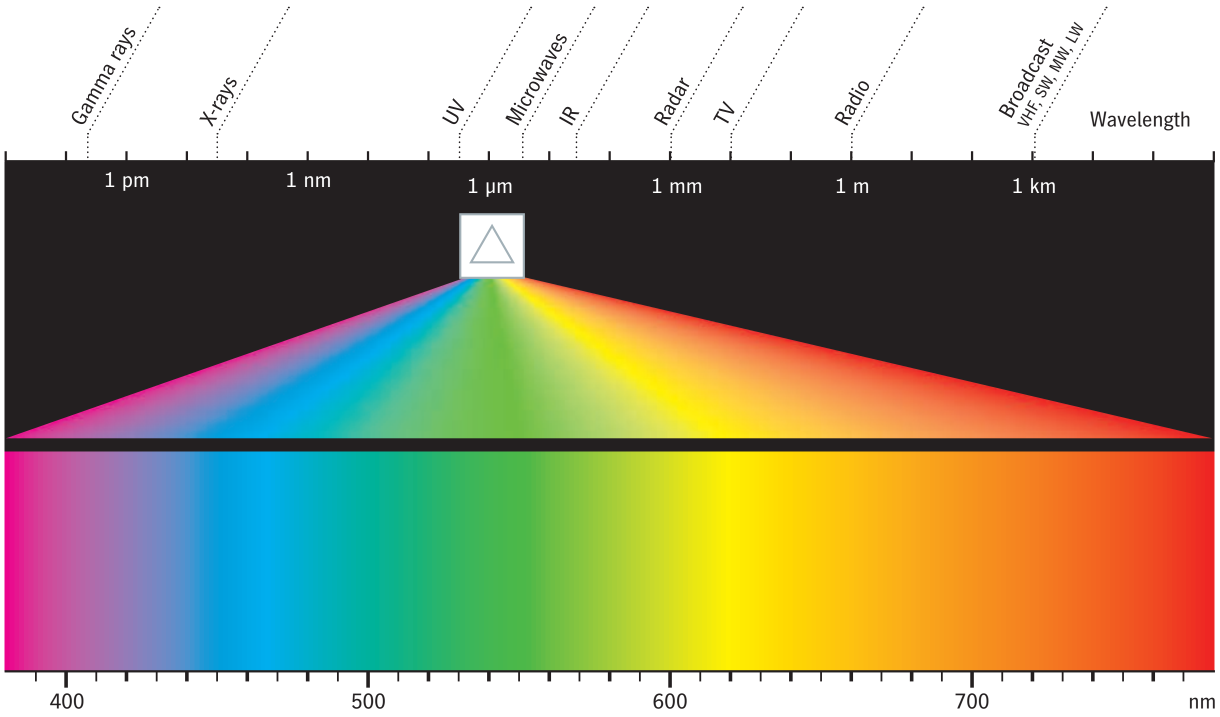
The number of oscillations per second – the frequency – is specified in Hertz.

Different wavelengths have different characteristics. X-rays, for example, are used in medical diagnostics, while microwaves find a home in many people‘s kitchens. Other wavelengths are used to transmit telephone conversations or radio and television broadcasts.

Only a very small range of the electromagnetic waves is actually visible to us in the form of light. This visible range lies between 380 nanometers (blue light) and 780 nanometers (red light). We can split light into its various color components using a prism. Because white light consists of a mix of colors across the whole visible spectrum, it contains all of the colors of the rainbow (figure on page 6).

The figure opposite shows how wavelengths become shorter as we move from red to green and blue.





1.2 Seeing Color

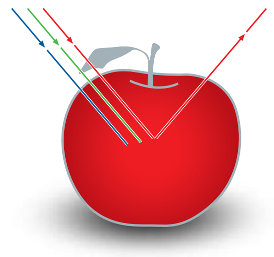
Colors only become “visible” when light is applied – but why is this so?

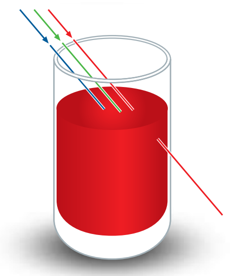
Color is not a property of an object in the same way as its shape. However, bodies have the ability to swallow (absorb) or reject (reflect) light of specific wavelengths. We can only see the colors that correspond to the reflected wavelengths. When white light strikes an object, one of the following scenarios occurs:

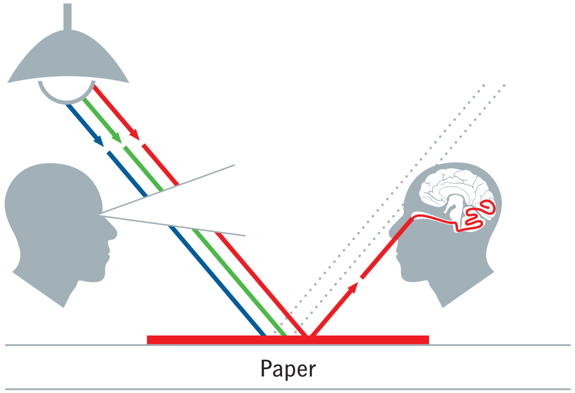
- All light is absorbed. In this case, we see the object as black.
- All light is reflected. In this case, the object appears white.
- All light passes through the object. In this case, the color of the light does not change. The object, e.g. glass, is entirely transparent.
- Part of the light is absorbed, the rest is reflected. We see a color whose tone depends on which wavelengths are reflected and which are absorbed. This applies in particular to printed matter.
- Part of the light is absorbed, the rest is transmitted (passes through). We see a color whose tone depends on which wavelengths are absorbed and which are transmitted. Part of the light is reflected, the rest is transmitted. The color of both the reflected and the transmitted light changes.

The question of which of these scenarios occurs depends on the properties of the illuminated object.

The light reflected or transmitted by an object is received by our eyes and converted into nerve signals that trigger the color sensation in our brains.







The retina in our eyes consists of light-sensitive cells. There are two types of cells – rods and cones. The rods distinguish between light and dark and the cones respond to different colors. Three different types of cones are responsible for different wavelength ranges. Some respond to light in a wavelength of 400 to 500 nanometers and are therefore sensitive to blue. Others “see” in the green range, and a third type is primarily sensitive to red light.

This structure with its different cells makes the human eye so sensitive that we can identify and distinguish several million different colors.

1.3 Color Mixing

1.3.1 Additive Color Mixing

In additive color mixing, light of different colors is superimposed. If all the colors of the spectrum are superimposed, this results in the color white.

The additive primary colors are red, green and blue. Each of these represents one-third of the visible spectrum.

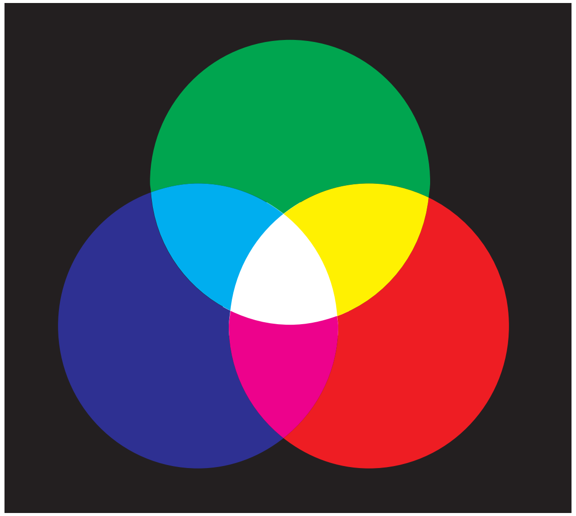
The principle of additive color mixing can be clearly illustrated using three slide projectors. Each projector generates a circle of light on a screen in one of the three additive primary colors.

Additive color mixing is used in television broadcasts.

Additive Color Mixing

Green	+	Red			= Yellow
Green	+	Blue			= Cyan
Blue	+	Red			= Magenta
Blue	+	Red	+	Green	= White
No light					= Black

Where the three circles of light overlap, the following secondary colors result:



1.3.2 Subtractive Color Mixing

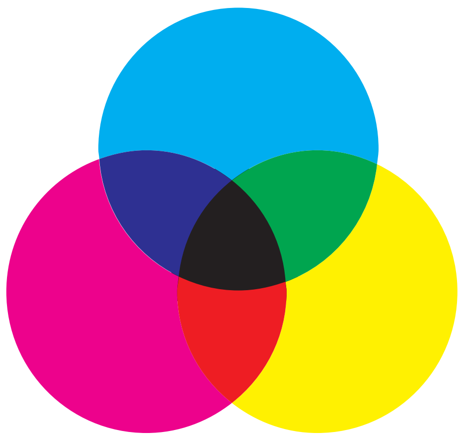
Subtractive color mixing removes different color components from white light. When all color components have been removed, the result is black.

The subtractive primary colors are cyan, magenta and yellow. Each of them represents two-thirds of the visible spectrum.

Subtractive Color Mixing

Cyan	+	Yellow			= Green
Yellow	+	Magenta			= Red
Magenta	+	Cyan			= Blue
Cyan	+	Magenta	+	Yellow	= Black
No color					= White

In subtractive color mixing, overprinting cyan, magenta and yellow yields the following secondary colors:

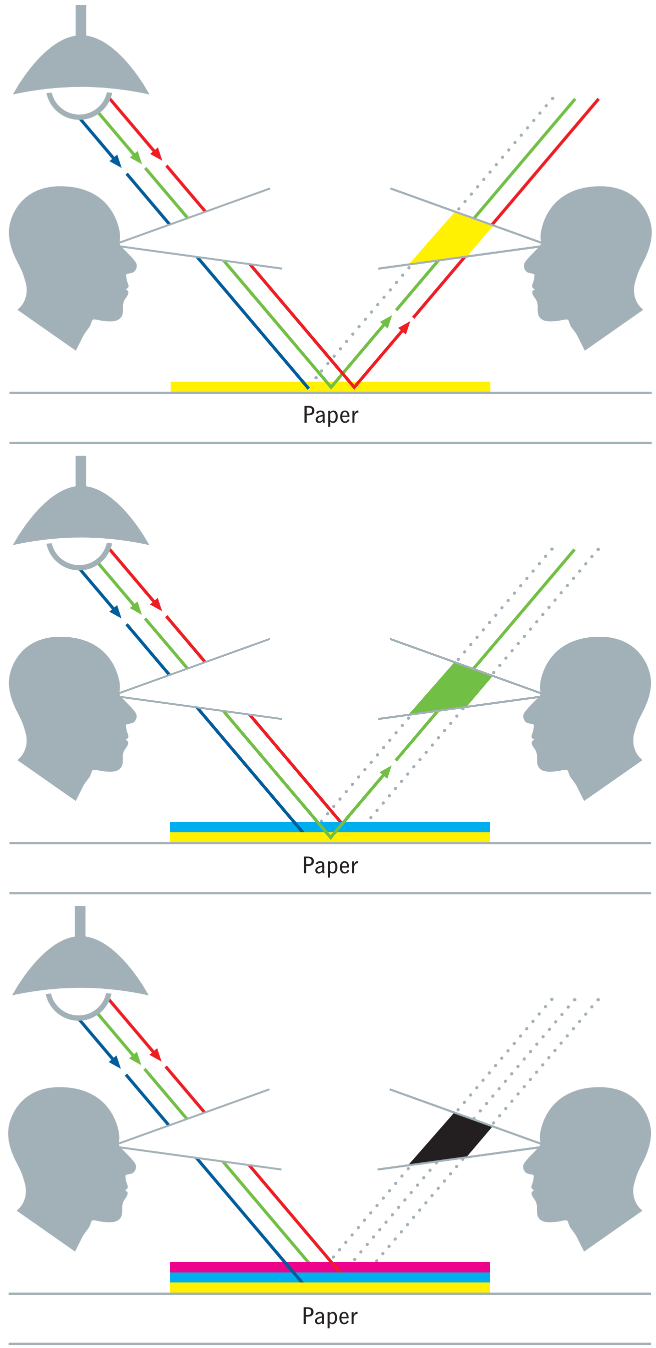


They can be generated by removing one additive primary color from white light (e.g. with a filter) or by superimposing two additive primary colors.

Printing inks are translucent substances that function as color filters. Which color do you get if you print a blue-absorbing substance on a white paper?

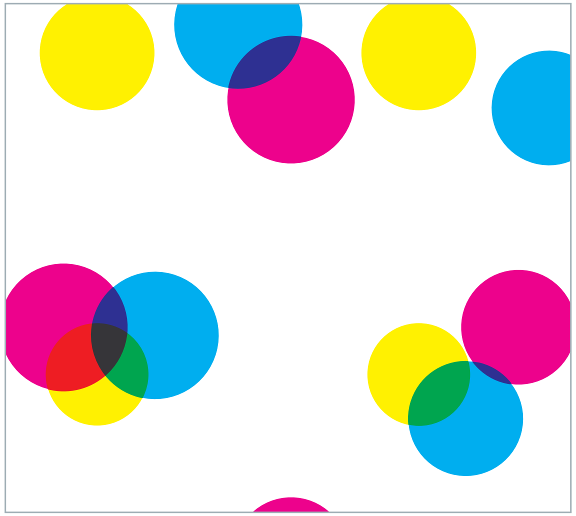
Blue is removed from the white light; the other components (green and red) are reflected. The additive combination of these two colors results in yellow: This is the color we see.

The ink has thus subtracted a third (blue) from the white light (consisting of red, green and blue).



Assume two transparent substances are overprinted. For example, let us take the inks yellow and cyan. These two substance first filter the blue component from the white light and then the red component. We see the resulting light as green. The two inks have subtracted two thirds of the color components from the white light.

If cyan, magenta and yellow are overprinted, all the incident light is absorbed (i.e. there is no reflection). We see black.



1.3.3 Autotypical Color Synthesis

Color images are printed with cyan, magenta, yellow and black inks. The black ink improves the definition and feeling of depth in images.

The black that is produced by subtractively combining cyan, magenta and yellow is never really deep black due to the pigments used in the inks.

In classical offset printing, the halftone dots are sized depending on the color tone required (see Section 2.2). When overprinted, some of the dots of the individual colors are adjacent to one another, while others partially or entirely overlap. If we look at the dots with a magnifying glass (see figure), we can see colors which, with the exception of paper white, result from subtractive color mixing. If we do not use a magnifying glass and examine the print from a normal viewing distance, our eye is no longer able to distinguish the individual dots in the printed image. In this case, the colors are mixed additively.

The interplay of additive and subtractive color mixing is known as autotypical color synthesis.

1.4 Color Systems

Everyone perceives colors differently. If different people were to describe color tones, the results of these descriptions would differ very widely. However, printers require standardized criteria for assessment purposes if they are to be able to describe colors. For this purpose, different assessment systems have been created. A number of ink manufacturers create books of samples and give the colors designations such as Novavit 4F 434.

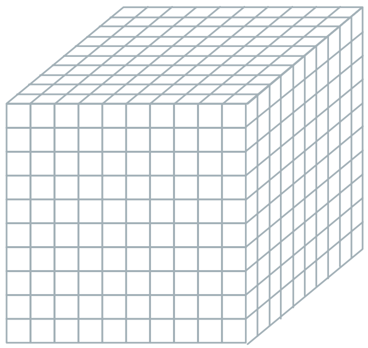
Others use color swatches such as HKS and Pantone. Another useful tool is the color circle, which can consist of 6, 12, 24 or more parts.

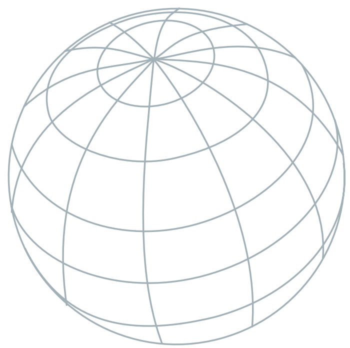
All of these systems use samples or specimens to show the individual color tones and assign names to them. However, they are never exhaustive and are rarely suitable for making calculations. As we have seen, the way we see color depends on the stimulus status of the red-, green- and blue-sensitive receptors in our eyes. Three numerical values are therefore required to unambiguously describe all possible colors.

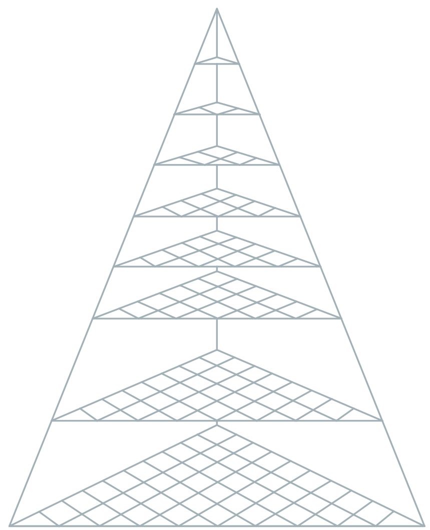
Using such a system, we could describe green, for example, as follows:
green = 0 × red + 1 × green + 0 × blue
or even shorter:
G = 0 × R + 1 × G + 0 × B.

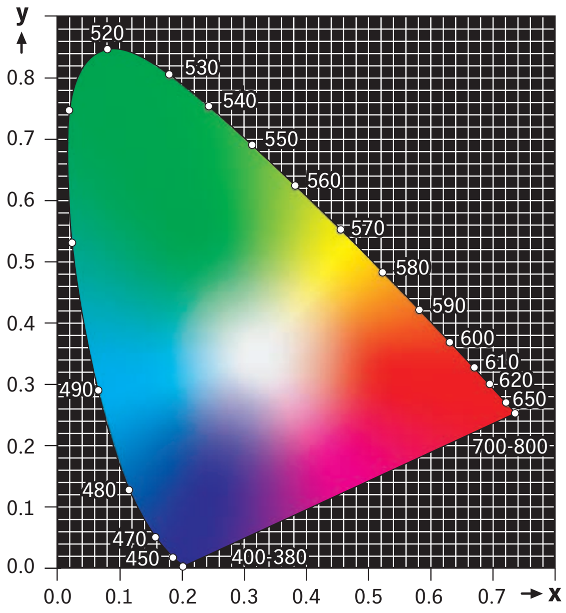
If we imagine that the primary colors are the axes of a three-dimensional system of coordinates, what we get is a color space.

Many experts have studied color systems and developed various ideas of how a color space is to be structured. Each of these color spaces has advantages and disadvantages.









Visually perceivable colors on a brightness plane of the CIE color space (CIE chromaticity diagram)

The key color spaces are standardized internationally. They are used in a wide variety of production applications, e.g. the ink and coatings industry, textile manufacturing, foodstuffs and medicine. In the print industry, the XYZ and CIELab color systems are now widespread. (The acronym CIE stands for “Commission Internationale de l’Eclairage” = International Commission on Illumination).

The XYZ color system uses the designations X, Y and Z for the color components instead of R, G and B. For practical reasons, these are used to arrive at color value components x and y and brightness reference value Y (the brightness reference value is used as a measure of brightness for body colors). A color’s location within the space (color locus) can be defined precisely using these three coordinates.

This system is often depicted as a two-dimensional graphic that resembles the sole of a shoe. The red components of a color are represented on the x-axis of the coordinate system and the green components on the y-axis. This means that each color can be assigned to a specific point within the coordinate system. However, this diagram does not take brightness into account.

One problem of this system is the fact that the measurable distances between the individual colors do not correspond to the color differences perceived. For example, if you look at the illustration on the left, you will see that a difference only becomes visible between green and yellow-green after some distance, while there is only a very small distance between blue and red.

2 Color in Print

Quality assurance in printing is geared towards ensuring correct and consistent color reproduction over the entire print run. In addition to the ink and the color of the substrate, the key influencing factors are the thickness of the ink applied, the tonal value, the color balance, ink trapping and the color sequence.

2.1 Ink Film Thickness

When using art paper in conjunction with process colors to ISO 2846-1, the correct color loci should be achieved when using ink film thicknesses of between 0.7 and 1.1 micrometers. When using unsuitable color separations, substrates or inks, the standardized corner points of the CIE chromaticity diagram cannot be achieved.

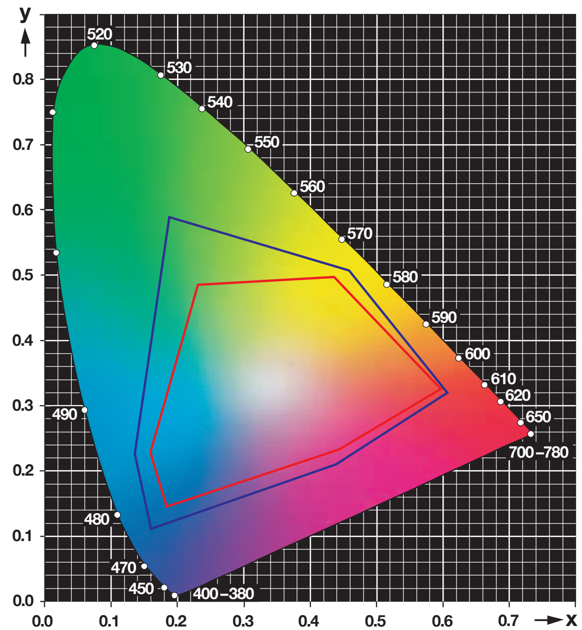
The reproducible color gamut is also reduced if saturation is not optimal. In the figure opposite, the red edged area shows a color gamut that has been reduced as a result of underinking all three process inks. The blue edged area could be achieved if saturation were optimal.

On a physical level, the influence of the ink film thickness on the visual appearance can be explained as follows:

Inks are translucent rather than opaque. Light penetrates into the ink. When passing through the ink, it strikes pigments that absorb a greater or lesser part of certain wavelengths.

Depending on the pigment concentration and thickness of the ink, the light strikes a larger or smaller number of pigments; this absorbs different portions of the light. The light beams finally reach the surface of the substrate and are reflected by it. The light must pass through the ink film again before it reaches the eye.

A thick layer of ink absorbs more light components and reflects fewer than a thin layer; the observer therefore sees a darker and more saturated color tone. The light component arriving at the viewer's eye thus forms the basis for assessing the relevant color.



2.2 Tonal Value

The tonal value is the key factor – other than the ink – affecting the visual appearance of a color nuance. In reference to a film or digital image file, the tonal value is the proportion of an area covered by halftone dots. Brighter colors have smaller tonal values. To reproduce different color nuances, classical halftone printing with constant screen ruling (aka screen frequency) uses halftone dots whose size depends on the tonal value required.

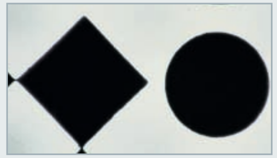
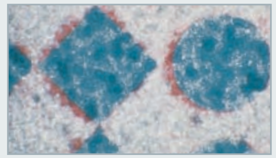
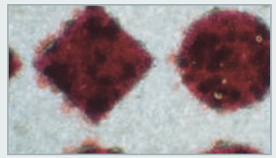
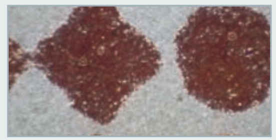
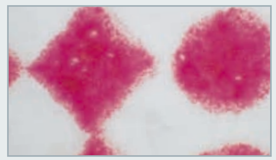
With frequency-modulated screening, on the other hand, the halftone dots are of identical size but the distances between them differ. Tonal values are usually specified as a percentage.

2.2.1 Changes in Tonal Value

When transferring a halftone dot from film to substrate via the plate and blanket, the geometric halftone dot size and thus the tonal value can change as a result of various factors.

The process-related changes in tonal value (see Section 2.2.3) can be compensated for in prepress.

Changes to tonal values caused by printing problems are unpredictable. Particular attention therefore needs to be paid to these in the print process. The most important are:

The path of a halftone dot	Factors influencing halftone dots	Appearance of halftone dots	
Film Assembly Camerawork	Film edges, adhesives		Two halftone dots on film (magnified approx. 150x)
Development	Chemicals, development times		
Plate	Materials, wear during printing		Halftone dots on the plate
Platemaking	Exposure time, vacuum, undercutting		
Dampening	Amount of dampening solution, pH, surface tension, water hardness, temperature		
Inking	Ink film thickness, consistency, temperature		Halftone dots on the plate after inking
Blanket	Material, condition, surface		Dots on the blanket
Printing Blanket/substrate	Cylinder rolling		
Substrate	Surface, paper grade		High magnification clearly shows the first-class results on the substrate.
Sheet transport	Transfer register		
Delivery	Smearing		

Dot gain / dot loss

Dot gain • When halftone dots grow in size relative to the film or digital image, this is called “dot gain” or occasionally also “dot spread”. This can be caused in part by the printing process, materials or equipment, factors that are relatively difficult for the operator to influence, and in part by the inking, which the operator can manipulate.

Fill-in • Fill-in can result from non-printing areas in the shadows being reduced or even disappearing completely. This can be caused by e.g. slurring and doubling.

Sharpening • Sharpening refers to a decrease in the tonal value as compared to the film or digital image. In practice, the term is always used to describe a reduction in dot gain, even when the dots are still fuller than on the film or in the digital image.

Halftone dot deformation

Slurring • When slurring occurs, the shape of the halftone dot during printing changes as a result of relative movements between the printing plate and blanket and/or between the blanket and the print sheet, e.g. a circular dot changes into an oval one. Slurring in print direction is known as circumferential slurring, while slurring at right angles to this is termed lateral slurring. If both types of slurring occur at the same time, the direction of slurring is diagonal.

Doubling • In the context of offset printing, doubling is when a second, typically smaller, shadow-like ink dot is unintentionally printed next to the intended dot. It is caused by ink being transferred back to the blanket out of register.

What the printer needs to look out for

Dot gain can be monitored (by means of measurement and inspection) using color control bars and the increase can be quantified. Control bars are particularly useful for a purely visual assessment. Fill-in can be easily monitored using measurement targets with high tonal values.

Right Wrong

Dot gain and fill-in are generally the result of excessive inking, insufficient dampening solution feed, too much pressure between the plate and blanket, or the blanket being too slack. Sometimes it can also be due to incorrect setting of the inking and dampening form rollers.

Right Wrong

Dot gain Sharpening Slurring Doubling Smearing

Even under normal conditions with correct plate copying, a certain amount of dot gain occurs. Sharpening can occur under abnormal conditions such as plate blinding or ink building up on the blanket. Countermeasures: Wash the blankets and inking units more often, possibly exchange the ink and change the ink sequence, and check the inking form rollers, printing pressure setting and the form rollers and cylinder pressure settings.

Right Wrong

Slurring is most conspicuous in line screens. In many cases, the parallel lines provide information on the slurring direction. Circumferential slurring usually indicates that the plate and blanket are slipping slightly relative to one another as they turn, or that the cylinders are pressing too hard against one another. These two factors should therefore be monitored very accurately. In many cases, the blanket may not be tight enough or too much ink may be being applied. Lateral slurring rarely occurs by itself. If it does occur, the substrate and blanket should be examined.

Right Wrong

Right Wrong

The same elements are used for monitoring doubling and slurring. A magnifying glass should also be used to inspect the halftone dots, because line patterns cannot reveal whether doubling or slurring has occurred. There are many reasons for doubling. Generally speaking, they relate to the substrate or its immediate environment.

Right Wrong

Smearing occurs very rarely on modern sheetfed presses. The areas of a sheetfed press where the sheet is supported mechanically on the freshly printed side are the most likely sources of smearing. The risk of smearing is higher if the substrate is stiff. Smearing can also occur in the delivery pile and on perfecting presses.

Right Wrong

The type of total value change can be established quickly by sight by means of printed control elements such as the SLUR strip. These elements visually amplify the printing problem so it can be easily seen.

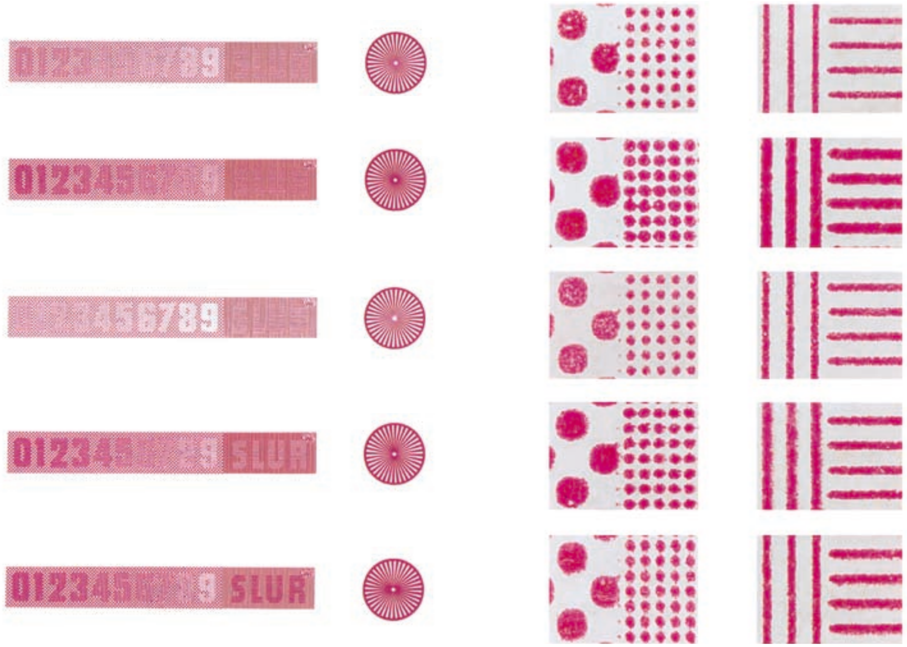
Errors such as dot gain, sharpening, slurring and doubling are more pronounced in fine halftones than in coarse ones. This is because fine halftone dots increase or decrease by the same amount as coarse ones. However, many small dots together have a total circumferential length several times that of coarse dots with the same tonal value. In printing, more ink is applied in relative terms around fine halftone dots than around coarse ones. Finely screened areas therefore appear darker. Control and measurement elements take advantage of this fact.

By way of example, let us look briefly at how the SLUR strip is made up and how it works (see figure on this page). This strip combines coarse halftone (background) and fine halftone patches (numerals).

While the coarse halftone background has a uniform tonal value, the numerals 0 to 9 have a fine screen ruling and an increasing tonal value. On a well-printed sheet, the numeral 3 and the coarse halftone patch have the same tonal value and the number is invisible. With increasing dot gain, the next-highest number disappears instead. The fuller the printed dots get, the higher the value of the invisible number.

This works in reverse when sharpening occurs. Then the number 2, 1 or even 0 becomes illegible. However, the numerals only indicate that printing is getting fuller or leaner. The causes must be ascertained by examining the plate with a magnifying glass or checking the press.

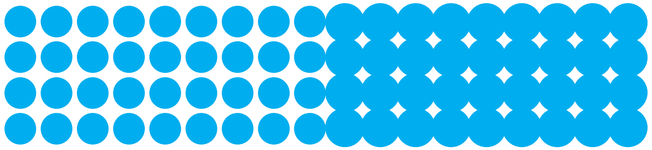
The part of the SLUR strip to the right of the numerals mainly shows whether slurring or doubling has occurred. The word SLUR is equally legible with lean, normal and full printing; the whole patch merely appears somewhat lighter or darker.



It is easy to detect the directional spread typical of slurring and doubling in the word SLUR, however. In the case of circumferential slurring, for example, the horizontal lines forming the word SLUR, which run parallel to the sheet's leading edge, become thicker. If lateral slurring has occurred, then the vertical lines forming the background of the word SLUR appear darker.

The figure at the top illustrates how changes in the halftone dots affect printing in the case of dot gain. If the dots for just one color are larger than they should be, this results in a new shade – which naturally also impacts the overall appearance of the printed image.

In offset printing, the need to transfer images from the plate to the blanket and from there to the paper usually results in a certain amount of dot gain. Control strips can tell you whether the results of printing are good or bad, but they cannot provide any absolute figures or indicate the exact nature of the problem. An objective method is therefore needed for assessing the quality of the tonal values.



Right Wrong

2.2.2 Dot Gain

Dot gain is the difference between the tonal values of a screened film or digital image on the one hand and the print on the other. The following text refers only to data but this covers film and data. Differences can result from geometric changes in the halftone dots or the phenomenon known as the “light trap effect” (see Section 3.4.4).

The dot gain, like the tonal value, is specified as a percentage (the calculation formulae are set out in Section 3.5). Because the dot gain can vary depending on the tonal value range, when making statements on dot gain it is important to also provide the corresponding reference value.

Example: 13 % dot gain with = 40 %. Cutting-edge measuring instruments show the dot gain directly.

Important: The dot gain Z indicates the difference between the tonal value in print FD and the tonal value in the film FF or in the data in absolute figures. The above example results in a 53 % tonal value in print, whereas the data/film had 40 %.

2.2.3 Characteristic Curve

The deviation of the tonal value in print from the tonal value in the data can be clearly represented in a “print characteristic” or “characteristic curve”, which can then be directly used to optimize reproduction quality.

To determine the characteristic curve, graduated halftone patches and a full tone (solid) patch are printed under repeatable conditions. The halftone and solid patches are then measured with a densitometer or spectrophotometer. When the values obtained in this way are plotted in a diagram against the relevant data values, the result is the characteristic curve.

This curve is only valid for the specific combination of ink, paper, print pressure, blanket and printing plate for which it was originally calculated. If the same work is printed on another press, using different ink or paper, the characteristic curve can differ significantly.

The figure on page 18 shows characteristic curve 1 at an angle of 45 degrees. This line is not normally attainable; it represents the ideal state in which the print and data deliver identical measurements. Characteristic 2 shows the tonal values actually measured in print. The area shown between the two lines is the dot gain.

The midtones are most useful for determining dot gain in print. The characteristic curve shows that the tonal value deviations are most pronounced here. Using characteristic curve 2, the CtP system or filmsetter can be set so that the required tonal values are achieved in print (with the usual dot gain).

It is important to ensure in advance that the imagesetter is set so that the dot size on the plate corresponds exactly to the dot size in the data. This also applies to filmsetters. In other words, a tonal value of 50 % in the file must also be 50 % on the plate (film). This operation is known as linearization. The second step then consists of adapting the dot size to match the printing trial. This is known as process calibration. With simple RIPs, linearization and process calibration are combined in a single curve. This means that every change to the linearization (e.g. resulting from new plates) also affects process calibration and vice versa.

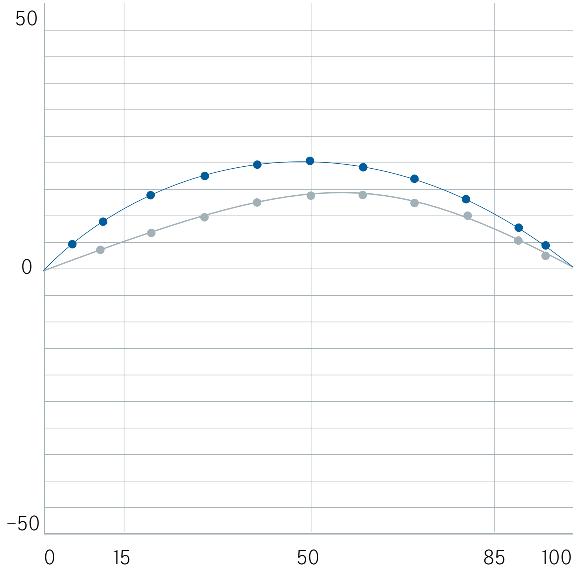
The Heidelberg Prinect workflow keeps both these calibrations separate from each other.

If conventional plate copy and CtP are used side by side, it is only possible to adapt the CtP to the results of the conventional plate copy. If plate copy is replaced by CtP, process calibration must be performed. Plates that are imaged linearly will always change the print result. This is because changes to the dots in the plate copy are no longer an issue (leaner dots with positive copy, fuller dots for negative copy).

The figure opposite shows the deviation in dot gain between the required tonal value (here ISO 12647-2, gray) and the actual print result (blue).

The Calibration Manager of Prinect® MetaDimension® depicts all tonal values clearly. The difference between the target and actual values is used to calculate the dot size required on the plate.

Nominal	=	tonal values in the data
Process	=	required target values in print (here ISO 12647-2)
Measurement	=	actual values in print
Calibration	=	corrected tonal values on the plate

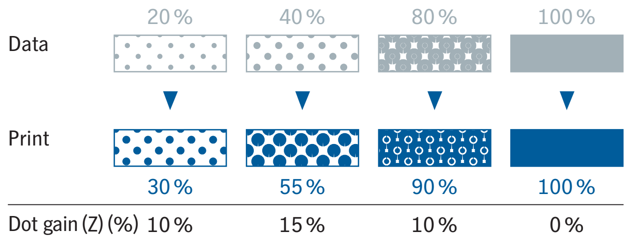


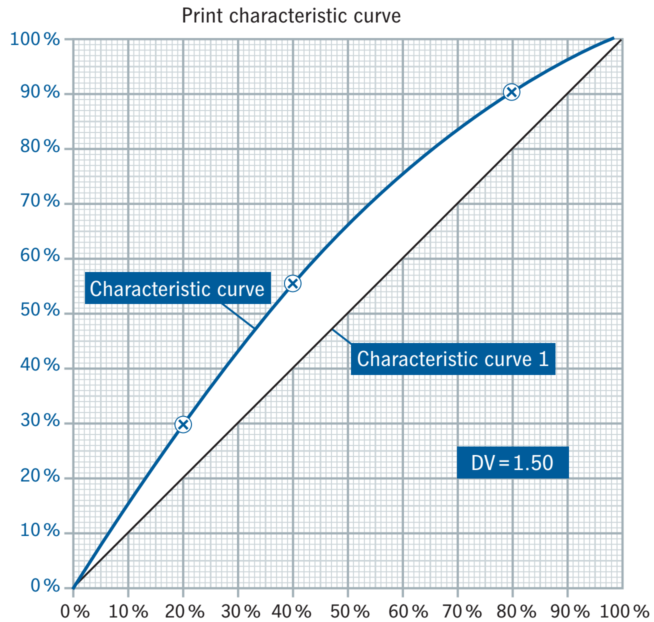
Tonal value deviation between target (gray) and actual value (blue).

Nominal %	Process %	Meas. %	Calibr. %
0.0	0.0	0.0	0.0
5.0	6.72	9.83	3.4
10.0	13.37	19.35	6.79
20.0	26.69	34.25	14.74
30.0	40.01	47.44	24.23
40.0	53.0	59.39	34.58
50.0	64.3	71.35	44.03
60.0	74.19	91.31	52.62
70.0	83.4	88.15	62.67
80.0	90.7	93.48	74.51
90.0	95.68	97.05	84.54
95.0	97.9	99.38	89.62
100.0	100.0	100.0	100.0

Tonal values in Calibration Manager.

Minor deviations always occur in practice due to process fluctuations. Tolerances are therefore specified for the dot gain. To keep the print quality as consistent as possible, it is vital to constantly monitor the tonal values using a color control bar and Mini Spots® from Heidelberg.





Characteristic curve 1: Tonal value in data; characteristic curve 2: Tonal value in print

2.3 Relative Print Contrast

As an alternative to dot gain, it is possible to calculate the relative print contrast Krel. (%); this is particularly useful for monitoring the three-quarter tones.

A print should be as contrast-rich as possible. To achieve this, the full tones must have a high ink density, but the screen must be as open as possible in print (optimum tonal value difference). Increasing the ink feed results in a greater density of the halftone dots and this enhances the contrast. However, this process is only expedient up to a certain limit, after which the dots become fuller and - particularly in the shadow areas - join up with each other. This reduces the proportion of paper white and the contrast falls away again.

If none of the measuring instruments is able to show the contrast value directly, the relative print contrast can be determined through calculation or using the corresponding FOGRA chart. The calculation formulae can be found in Section 3.5.3. Should the contrast in the production run worsen despite the consistent full tone density, this can suggest that the blankets need washing. If the full tone density is correct, the contrast value can be used to assess various factors that can influence the print result, e.g.:

- Cylinder pressure and rolling
- Blankets and packing
- Dampening
- Inks and additives

The relative print contrast is no longer specified in ISO 12647-2. Instead, values are given for solids and the dot gain of the individual colors. This provides the basis for arriving at the relative print contrast. However, if this standard is not used, e.g. because an FM screen is employed, the relative print contrast remains an important variable.

2.4 Color Balance / Image Synthesis

As mentioned earlier, color tones in four-color printing are reproduced using specific components of cyan, magenta, yellow and black. Changes in these components result in a color deviation. To prevent this from happening, the color components must be maintained in the balance needed for the required color tone.

If only the black component changes, the color tone becomes brighter or darker, which the observer will not find particularly disturbing. The same thing happens if all chromatic colors change by the same amount in the same direction. The situation is much more critical when the color tone itself changes. This happens when the color components change by different amounts, and especially if the individual chromatic colors change in opposite directions. These kinds of changes in the color balance are easiest to detect in gray patches. The term gray balance is therefore often used in this context.

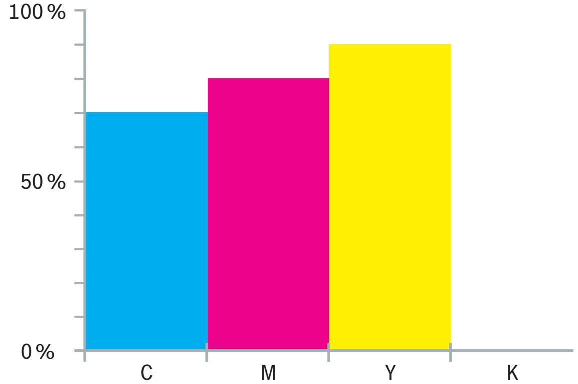
The extent of the unavoidable fluctuations in the individual inks in the print process depends first and foremost on the image synthesis principle selected in prepress. The questions that are relevant to the print process in this regard are as follows:

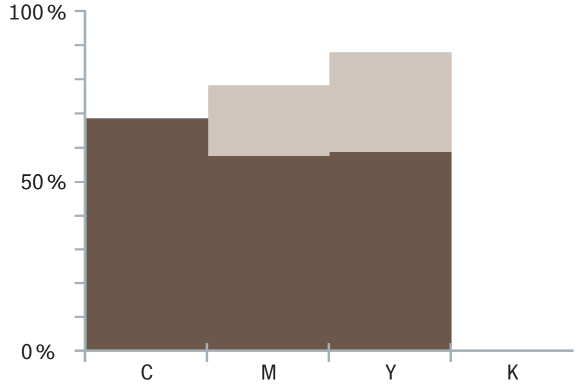
- Which inks make up the gray areas?
- What mechanism is used to darken color image areas?
- How is the shadow definition generated?

In short: What do the gray and achromatic components consist of and what is the resulting maximum total area coverage?
By way of reminder: Gray and achromatic values can be generated from cyan, magenta and yellow or by using black ink. A combination of these is also possible.

2.4.1 Chromatic Synthesis

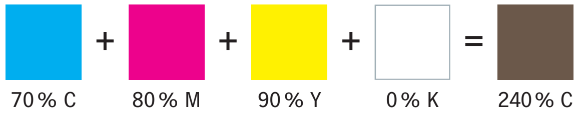
With chromatic synthesis, all achromatic values essentially consist of subsets of the chromatic inks cyan (C), magenta (M) and yellow (Y), i.e. all gray image areas, all tertiary tones, and the shadow definition contain the three chromatic inks. Black (K) is only used to support the image shadows and to enhance the shadow definition (skeleton black).





The brown shown in the illustration is formed from 70 % cyan, 80 % magenta, 90 % yellow and 0 % black using chromatic synthesis. The total area coverage is therefore 240 %.

The effect of the color components can be seen opposite. The brown consists of an achromatic, gray component and a chromatic component.
According to ISO 12647-2, 70 % cyan, 60 % magenta and 60 % yellow should produce gray when overprinted. Only the remaining 20 % magenta and 30 % yellow form the light brown component. This becomes dark brown with the addition of the gray component.

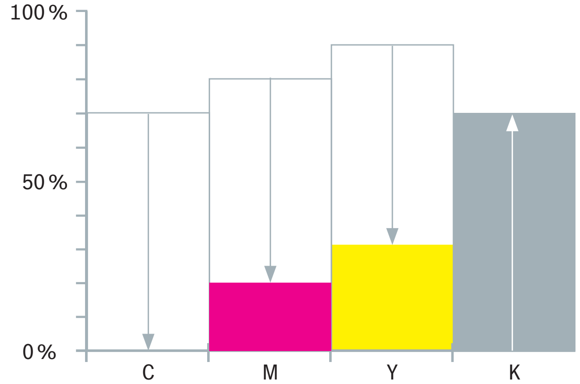


The chromatic synthesis results in a high total area coverage, which could theoretically amount to 400 %. Such totals would not allow any sensible color balance in practice. The neutral gray tones in particular would tend to result in color casts in various directions. But there would also be a negative impact on ink trapping, drying behavior, powder consumption and even the postpress stage.

2.4.2 Achromatic Synthesis

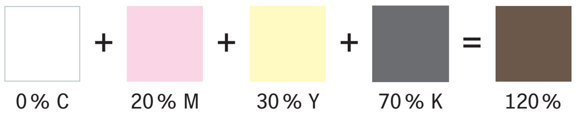
Unlike chromatic synthesis, achromatic synthesis essentially involves replacing all achromatic components with the color black in multicolor print images. Neutral tones therefore consist solely of the color black, while black is also used for shadow definition and to darken chromatic tones. All color tones consist of a maximum of two chromatic colors plus black. This makes the color balance more stable.
In theory, the brown from Section 2.4.1 is made up of the following when working with achromatic synthesis: 0 % C + 20 % M + 30 % Y + 70 % K. However, as the figure shows, merely replacing an achromatic shade produced with CMY by black does not yield an identical color.

This is primarily due to the shortcomings of actual printing inks. To obtain truly similar results, it is necessary to modify the proportions, e.g. to 62 % M, 80 % Y and 67 % K. The achromatic synthesis corresponds to 100 % GCR (Section 2.4.6).



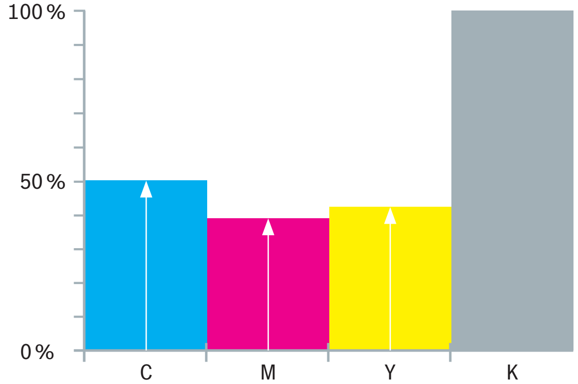
2.4.3 Achromatic Synthesis with Under Color Addition (UCA)

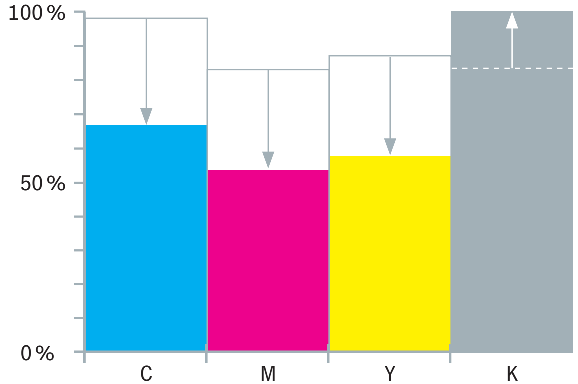
Process black by itself does not always provide sufficient definition in the darker portion of the gray axis. When this is the case, this range and, to a lesser extent, the neighboring chromatic tones can be enhanced by adding an achromatic component of CMY. UCA depends in particular on the combination of substrate and ink. The illustration opposite illustrates UCA to neutrally enhance the image shadows.



2.4.4 Chromatic Synthesis with Under Color Removal (UCR)

The highest area coverages result from using chromatic synthesis for the neutral three-quarter tones all the way to black. This drawback is offset by Under Color Removal. The achromatic component made up of CMY is reduced in the neutral shadows and in the neighboring chromatic tones, while the amount of process black is increased. In the example opposite, the initial area coverage consisting of 98 % cyan + 86 % magenta + 87 % yellow + 84 % black = 355 % is reduced by 78 % to 68 % cyan + 56 % magenta + 57 % yellow + 96 % black = 277 % by UCR.
This has a positive effect on ink trapping, drying and color balance.





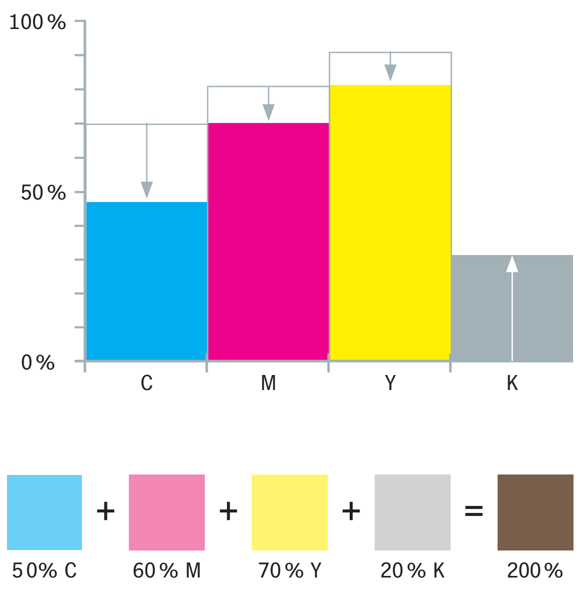
2.4.5 Chromatic Synthesis with Gray Stabilization

Gray tones generated with chromatic synthesis are difficult to keep balanced in the print process. Color casts readily occur, but can be counteracted by means of gray stabilization. Achromatic components generated with C + M + Y are partially or entirely replaced along the entire gray axis and to a lesser extent in the neighboring color ranges – i.e., not just at the darker end of the gray axis like with UCR – by an equivalent amount of black. This is known as “long black” in practice.

2.4.6 Chromatic Synthesis with Gray Component Replacement (GCR)

Gray Component Replacement involves using achromatic process black to replace CMY components neutralizing to gray in both chromatic and neutral image areas. GCR can be used for all intermediate stages between chromatic and achromatic synthesis in all image areas – and is not, like UCR, UCA and gray stabilization, limited to the gray areas. Gray Component Replacement is sometimes also referred to as complementary color reduction.

The brown from Sections 2.4.1 and 2.4.3, for example, could theoretically be built up as follows using GCR: As with achromatic synthesis (Section 2.4.2), the colors obtained with the two methods are not identical if black is merely substituted for part of the achromatic CMY without adjusting the chromatic component as well. Similar colors are achieved with, for example, 49 % C + 70 % M + 80 % Y + 30 % K.



2.4.7 Five-, Six- and Seven-Color Printing

The modern four-color process ensures high-quality image reproduction. However, with some originals and when extremely high quality is needed, it can be necessary to use special color separations. The reproducible range of colors can be extended by using additional colors (in addition to the four primary colors) or special process colors. The values measured for a seven-color print are plotted in the CIE chromaticity diagram in the figure above.

The hexagon on the inside shows the color gamut reproducible with the process colors cyan, magenta and yellow (as measured). The surrounding dodecagon shows the extended color gamut obtained using the additional colors green (G), red (R) and blue (B).

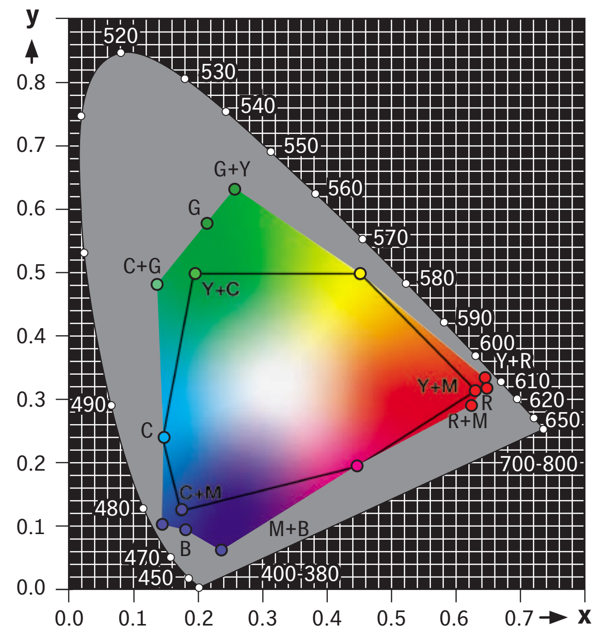
2.5 Ink Trapping and Color Sequence

2.5.1 Ink Trapping

Ink trapping is another variable influencing color reproduction. This is a measure of an ink's ability to transfer equally well to unprinted substrate and a previously printed ink film. It is important here to distinguish between printing wet on dry and printing wet in wet.

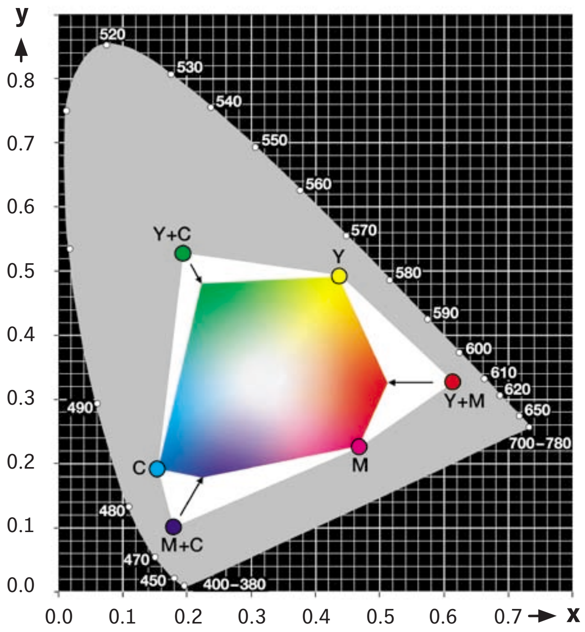
Wet on dry printing is when an ink is laid down directly on the substrate or onto a previously printed and dried ink film. If the ink is applied to an ink that is still wet, however, this is known as wet in wet printing. Wet in wet printing has become the term of choice when printing on multicolor presses.

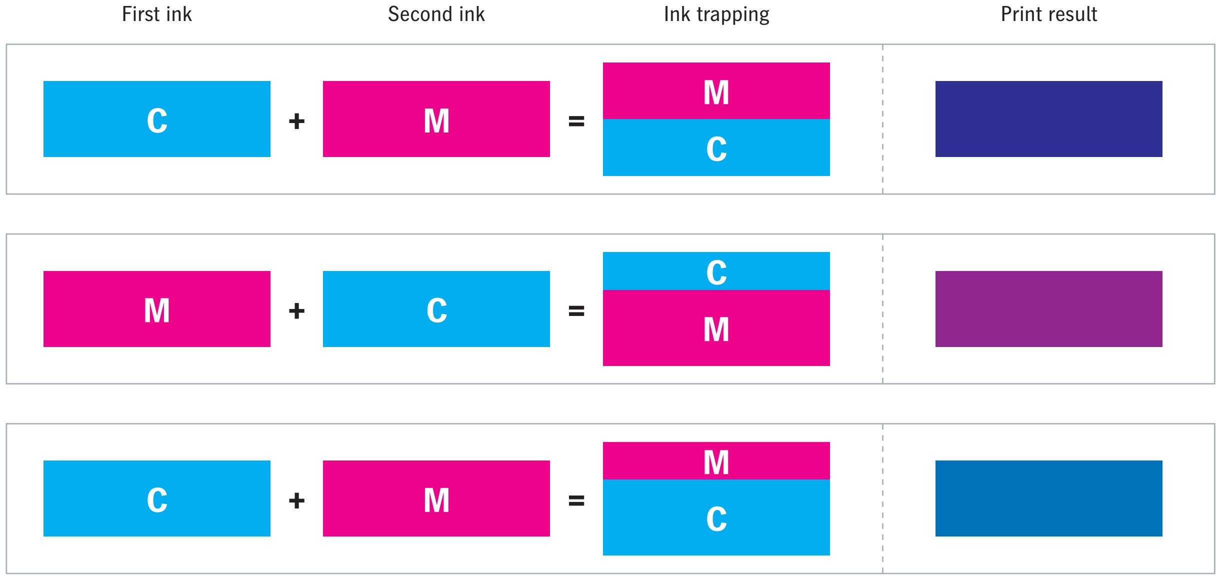
When inking is uniform and the colors are accurate, this indicates that there is good ink trapping.



In contrast, if the target color cannot be achieved, then the ink trapping is inadequate. This can be the case with all mixed colors. As a result, the color gamut is reduced and specific color nuances can no longer be reproduced.

Even if the right ink film thicknesses are printed with a given set of colors and the primary colors cyan, magenta and yellow are accurate, it can still happen that the secondary colors red, green and blue are off, due to overprinting problems.





Examples of two inks being overprinted in different ways.

The CIE chromaticity diagram above shows the effects of disturbed ink trapping or an unfavorable color sequence on the printed result. The white area illustrates the extent of the dot loss due to trapping problems.

2.5.2 Color Sequence

The schematic representation illustrates three different sequences for overprinting the colors cyan and magenta. Example 1 shows the print result on a single-color press. Firstly, cyan was printed on the white paper. Magenta was then printed on the dry cyan. The result is a saturated blue.

The second example was created on a multicolor press. Firstly, magenta was printed onto the dry paper (wet on dry), followed by cyan on the still moist magenta (wet in wet). While the trapping results for magenta on the paper were good, they were less good for cyan (due to the ink splitting that occurred during overprinting). This resulted in a blue with a red cast.

The third example was also printed wet in wet, but with the reverse color sequence (magenta on cyan). This avoids the red cast.

ISO 12647-2 lays down the color sequence black-cyan-magenta-yellow for four-color printing.

In order to reduce the effects of ink trapping problems in special cases, the original and the plates should be carefully inspected before mounting the latter on the press. It may be useful, for example, when printing solids, to print the lighter form before the heavier one.

This applies especially when overprinting halftone areas and solids. Firstly, the screen should be printed on the white paper and the solid on top of that.

2.6 Color Control Bars

So that the print quality can be assessed through measurement, color control bars (control strips) are included in the printed sheets. They are normally arranged either at the leading edge, trailing edge or center of the sheet. The central position is preferred for use with perfecting presses and imposed sheets.

Color control bars are provided by Fogra and various manufacturers in digital form. Heidelberg has been supplying its DIPCO (Digital Print Control Elements) package for several years. In addition to conventional color control bars, the DIPCO package also includes Mini Spots for color and process monitoring. In addition to use in manual assembly, all DIPCO bars can be used as “color marks” for automatic assembly in the Prinect Signa Station.

If the color control bars are used for automatic process calibration of the printing plates in CtP, they must always be located in the same position! Otherwise, the measuring results may be distorted and this can result in faulty imagings.

Which color control bars are used depends primarily on the colors used for the job. Standard bars begin from four colors. If fewer colors are printed, the remaining patches remain empty. Another important criterion is the colorimeter used. The size of measuring patches depends on the diameter of the measuring aperture. There are limits to how small this aperture can be made, however, since it must also be able to record the tonal values of the halftone patches. According to ISO 12647, the aperture should correspond to 15 times the screen frequency, and must be at least 10 times this value, i.e. 80 L/cm = 0.125 mm line definition. The minimum size of the aperture is thus 0.125 x 15 = 1.875 mm.

All color control bars consist of several different measuring patches that are described below.

2.6.1 Solid Patches

Solid (full tone) patches are used to monitor the consistency of inking. It is expedient to use one solid patch for each ink printed, spaced to correspond to the width of the ink zones (in the case of Heidelberg, 32.5 millimeters). The solid patches can then be used for automatic regulation of the solids.

2.6.2 Solid Overprint Patches

These patches are used to assess ink trapping by means of visual inspection and measurements.

2.6.3 Color Balance Patches

There are solid and halftone color balance patches.

When the colors cyan, magenta and yellow are overprinted in a solid patch, the result should be a fairly neutral black. For purposes of comparison, a solid black patch is printed alongside the overprint patch.

With the correct ink film thicknesses, the standard color sequence, and normal dot gain, the halftone patches for cyan, magenta and yellow should yield a fairly neutral gray when overprinted.

Color balance patches are intended to be visually checked; they are also used for automatic gray balance control for the colors cyan, magenta and yellow.

In the standardized process as described by ISO 12647-2, the gray balance must be mainly achieved by applying an ICC color profile to generate the separations.

2.6.4 Halftone Patches

The tonal values of the halftone patches vary depending on the manufacturer.

The values measured in the halftone and solid patches are used to calculate the dot gain and relative print contrast.

Today the FOGRA color control bars with 40% and 80% patches are most widely used.

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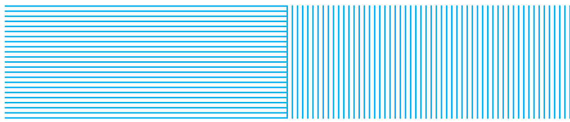
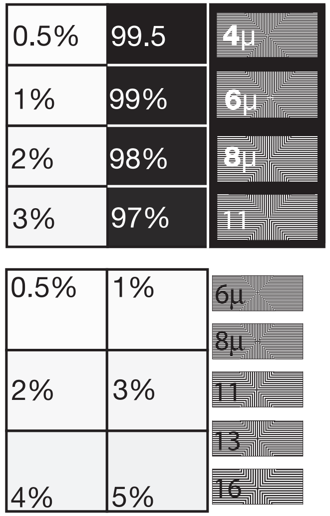
2.6.5 Slurring and Doubling Patches



Line screens with different angles are used to check for slurring and doubling by visual inspection and measurement (see Section 2.2.1).



3 Densitometry

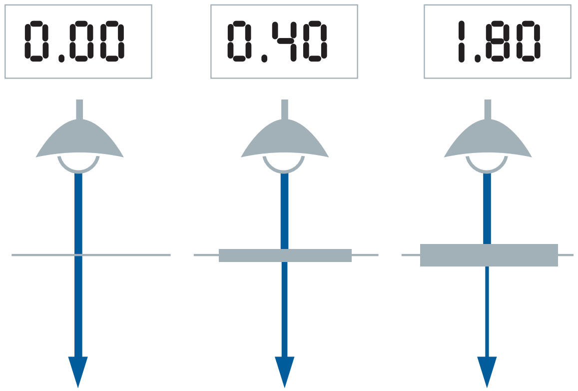
Densitometry is an effective method for monitoring solid density and tonal values in the print process. It works reliably with black-and-white reproductions and with the process colors cyan, magenta, yellow and black.

There are two types of densitometer depending on the particular application:

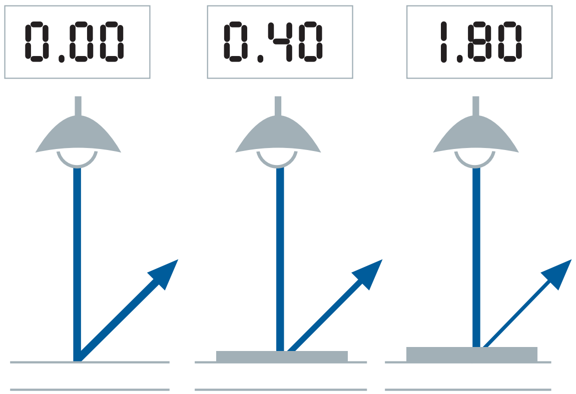
- Transmitted light densitometers are used to measure film blackening (i.e., with transparent materials).
- Reflective light densitometers are used to measure light reflected from the surface of a print (i.e., with reflective originals).

The following section looks at the technology behind reflective light densitometry.

Transmission densitometer



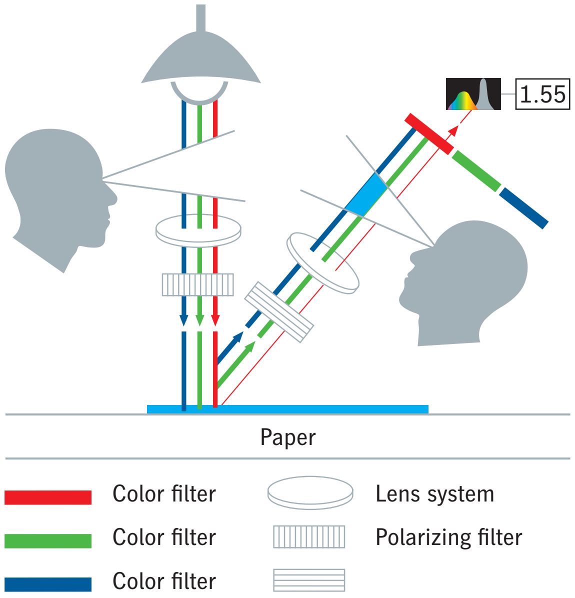
Reflection densitometer



3.1 Measuring Principle of the Reflective Light Densitometer

Reflective light densitometry uses a light source to illuminate the ink being measured. The light beam penetrates the translucent ink film and is attenuated in the process. The rest of the light is scattered by the paper substrate. Part of this scattered light travels through the ink film again and is further attenuated. The remainder of the light reaches the measuring instrument, which then converts the light into electrical energy. The result of reflective light densitometry is specified in density units.

Lens systems are used in the measurement process for bundling the light. Polarizing filters suppress the wet gloss (see Section 3.2.2); color filters are connected upstream when measuring chromatic colors (see Section 3.2.1).



The figure shows how reflection densitometry works, taking the example of a printed chromatic color. The white light which is applied will ideally consist of equal components of red, green and blue. The printed ink contains pigments that absorb red and reflect green and blue, which is why we call it cyan. We use the densitometer to measure the absorption range of the particular color, because density and ink film thickness correlate well here. The example therefore uses a red filter, which blocks blue and green and only allows red to pass.

The density of an ink depends primarily on the type of pigment, its concentration and the ink thickness. For a given ink, the ink density is a measure of the ink thickness, but provides no indication of the color tone.

3.2 Densitometer Filters

3.2.1 Color and Brightness Filters

The color filters in a densitometer are optimized to the absorption behavior of cyan, magenta and yellow.

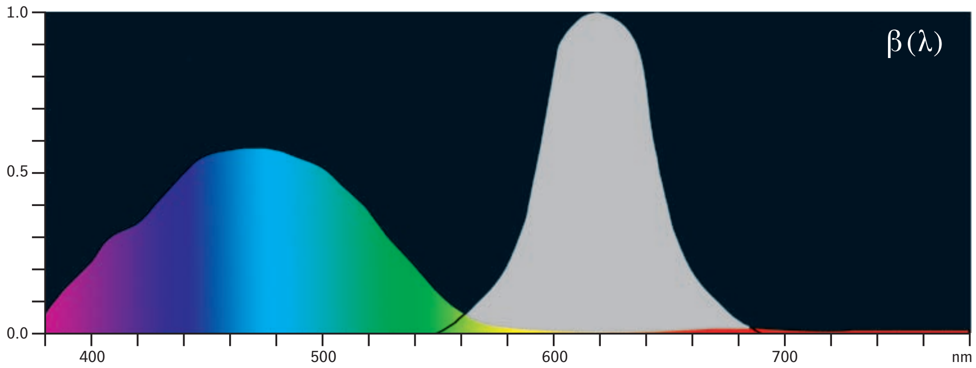
The spectral passbands and the location of the pass maxima are defined in relevant standards such as DIN 16536 and ISO / ANSI 5 / 3. Both narrow- and wide-band color filters are defined in these standards (designated A and T in the case of ANSI), but the narrow-band ones (DIN NB) are preferable.

Always choose a color filter that is the polar opposite of the colors being measured. Black is evaluated with a filter that is adapted to the spectral brightness sensitivity of the human eye. Spot colors are measured with the filter that produces the highest value.

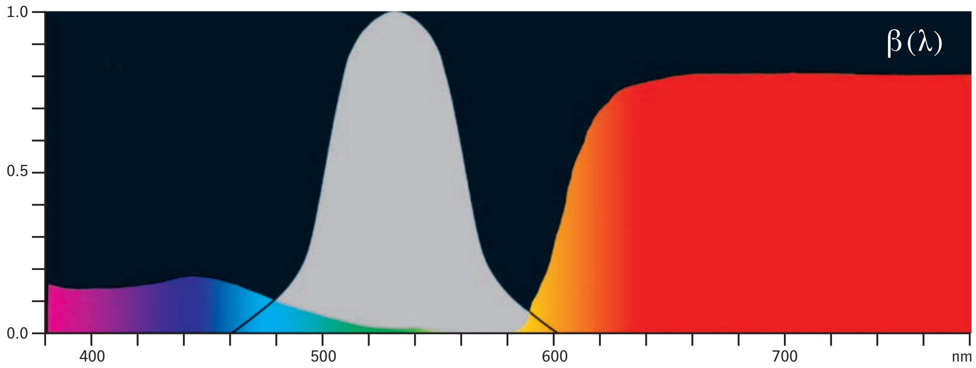
The three figures (on the next page) show the reflection curves for cyan, magenta and yellow using the corresponding color filters as defined by DIN 16536.

Printed color	Filter color
Cyan	Red
Magenta	Green
Yellow	Blue

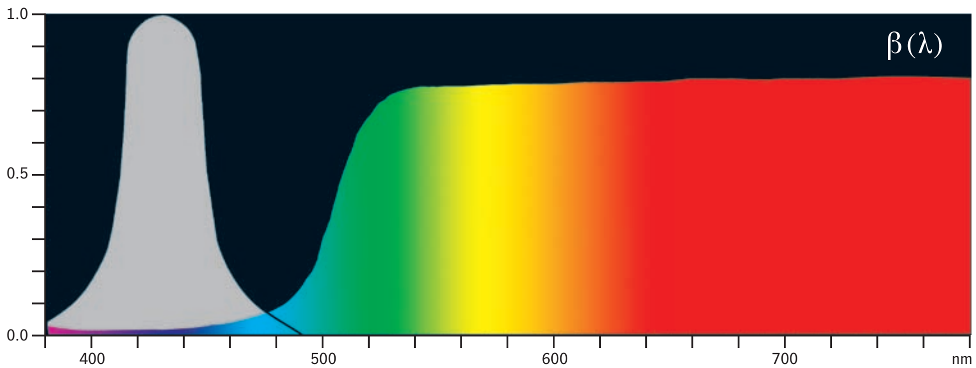
Cyan



Magenta



Yellow



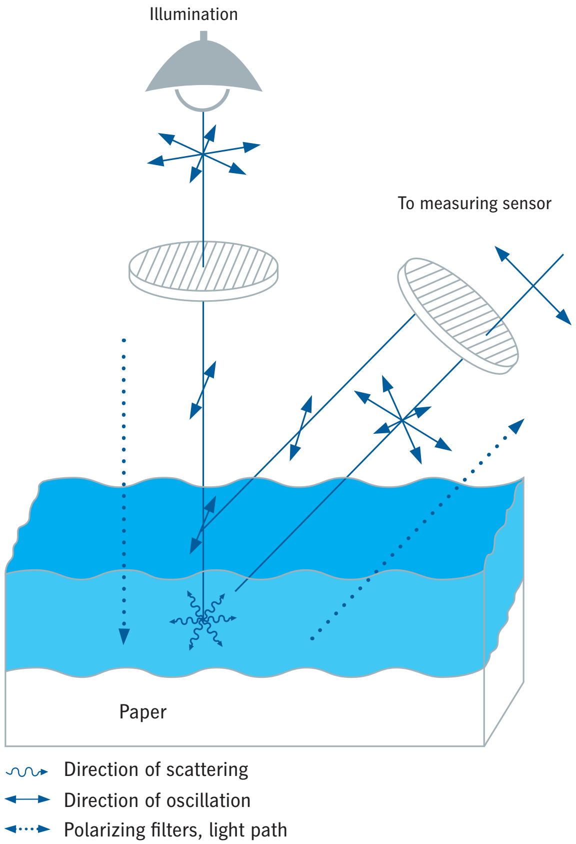
3.2.2 Polarizing Filters

If sheets are pulled freshly printed from the delivery and measured, the ink is still wet and has a shiny surface. While drying, the ink penetrates the paper (absorption) and loses its gloss. This not only changes the color tone, but also the density. It is only possible to a limited extent for the press operator to use densitometry to compare wet sheets with the reference values, which also refer to dry ink.

To get round this problem, two linear polarizing filters at right angles to one another are placed in the path of the densitometer. Polarizing filters only permit light waves oscillating in a certain direction to pass. Part of the resultant aligned beam of light is reflected by the surface of the ink, but its direction of oscillation remains unchanged. The second polarizing filter is rotated 90° in relation to the first, which means that these reflected light waves are blocked.

However, if the light is only reflected after it penetrates the film of ink, either by the ink or the paper, it loses its uniform direction of oscillation (polarization). Consequently, part of it passes through the second polarizing filter and can be measured.

Filtering out the light reflected by the glossy surface of the wet ink thus has the effect of making the densitometric measurement values for wet and dry ink roughly equivalent.



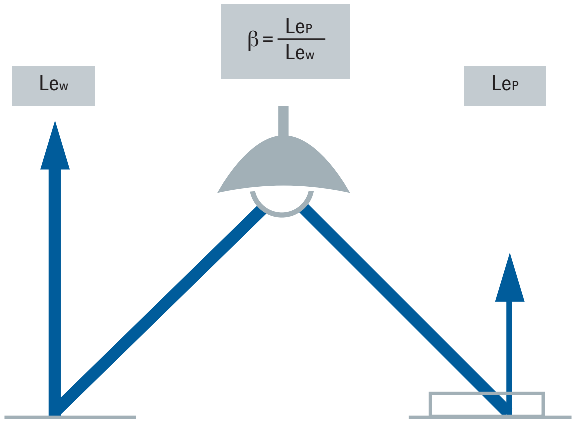
3.3 Densitometric Values

The measuring result displayed by densitometers is the ink density (D), expressed as the logarithmic ratio of light absorption by a reference white to light absorption of the ink film.

The following formula is used to calculate the density:

$$D = \lg \frac{1}{\beta}$$

The reflectance (also called the beta value) is calculated as follows:



$$\beta = \frac{Le_P}{Le_W} = \frac{50\,\%}{100\,\%} = 0.5$$

LeP is the light reflected by the measured ink and LeW the light reflected by the reference white.

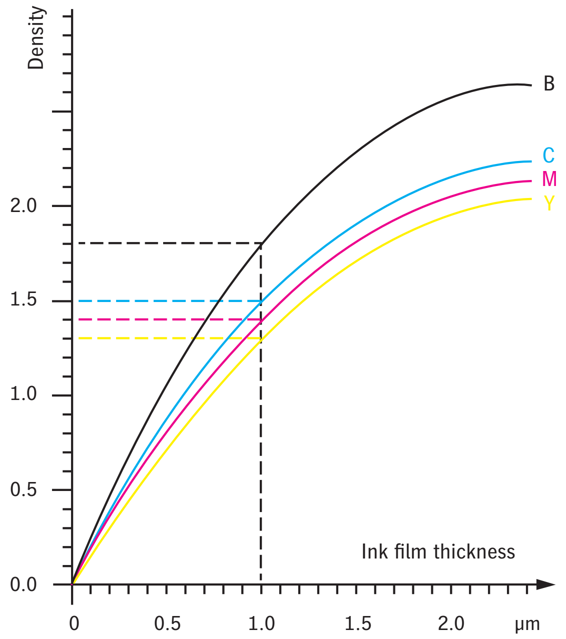
The reflectance (ß) indicates the ratio between the light reflected by a sample (the printed ink) and a standard white (reference value).

The above ß value produces the following density:

$$D = \lg \frac{1}{\beta} = \lg \frac{1}{0.5} = \lg 2 = 0.30$$

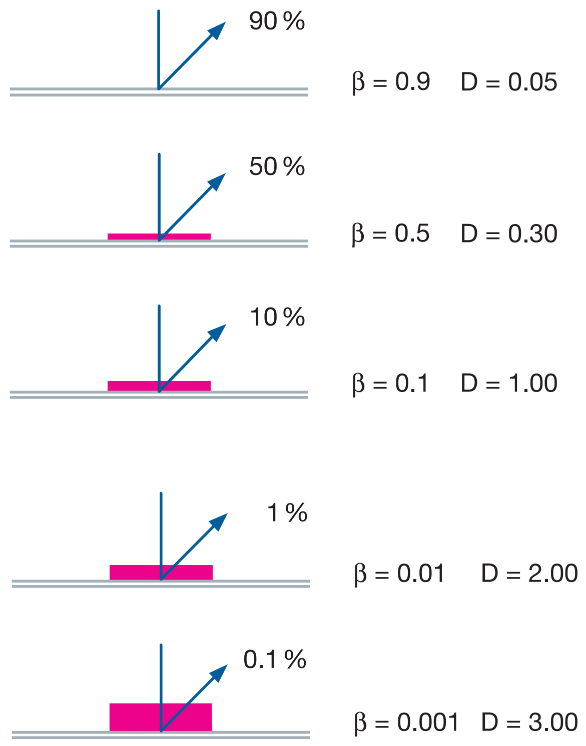
The diagram below shows how the ink film thickness and density correlate for the four process colors used in offset printing.

The dotted vertical line indicates the usual ink film thickness used in offset printing of approximately one micrometer. This diagram shows that the density curves only flatten out at much higher values. Above these thicknesses, there is hardly any further increase in density. Even if a full can of ink were to be measured, the value obtained would not be any higher. Of course, ink films this thick are of no relevance to the standard four-color process.



A close correlation exists between ink film thickness and ink density. The diagram shows that the reflection diminishes and the density increases as the film of ink gets thicker.

Please see page 31 for the calculation formulas.



3.4 Measurement

3.4.1 Calibration to Paper White

Before any measurements are performed, densitometers are calibrated to the applicable paper white (reference white) in order to eliminate the influence of paper coloring and the paper's surface when evaluating the printed ink film thickness.

The density of the paper white is measured relative to "absolute white" and this value is then set to zero (the reading is D = 0.00). One exception to this rule is North America, which has a regulation covering calibration of the densitometer to absolute white.

3.4.2 Solid Density

The values measured in a solid area indicate the solid density (DV). This is measured in a color control bar that is printed on the sheet perpendicular to the direction of travel and has a number of patches, including solid patches, for all four process colors (and spot colors if required).

The solid density can be used to monitor and ensure a uniform ink film thickness across the entire width of the sheet and throughout the run (within certain tolerances).

3.4.3 Halftone Density

Halftone density is measured in the halftone patches of the color control bar, recording a combination of halftone dots and paper white. This is also referred to as an integral measurement.

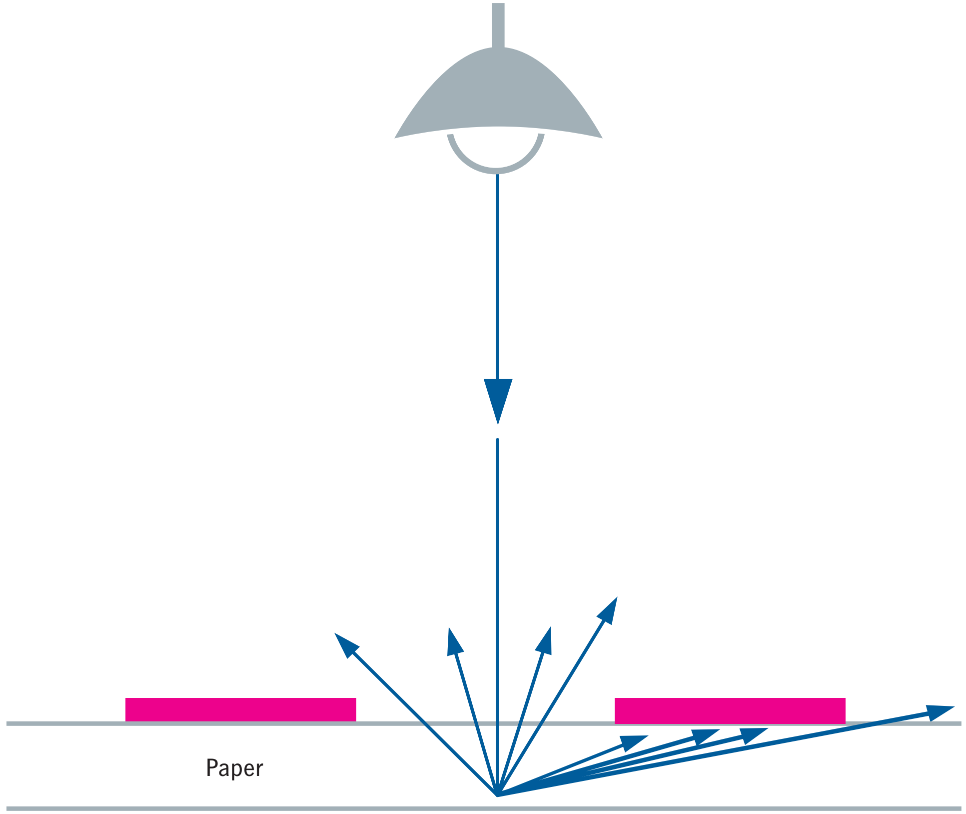
The measured value is the halftone density (DR). This value increases with the proportion of halftone dots and the ink film thickness.

3.4.4 Optically Effective Area Coverage (Tonal Value)

When using densitometry to measure halftone images, it is not the geometric area coverage (the percentage of the patch's surface covered by halftone dots) that is measured, but rather the "optically effective area coverage".

The difference between geometrical and optically effective area coverage is that, regardless of whether they are assessed by a visual check or measured with a densitometer, part of the light shining on the sheet penetrates the paper in the blank areas between the halftone dots, and part of what is reflected strikes the back of the dots and is absorbed by them.

This effect is known as "light trapping". It makes the halftone dots appear larger than they actually are. The optically effective area coverage thus consists of the geometrical area coverage plus the optical magnification effect.



3.5 Evaluation

The values measured for the solids and halftones can be used to calculate tonal value, dot gain and contrast – provided the densitometer has first been calibrated to paper white.

3.5.1 Tonal Value

The printed tonal value (FD) can be determined from the measured solid and halftone densities (DV and DR) as follows using the Murray-Davies equation:

$$F_D(\%) = \frac{1-10^{-DR}}{1-10^{-DV}} \cdot 100$$

3.5.2 Dot Gain

The dot gain (Z) is the difference between the measured printed tonal value (FD) and the known tonal value in the film (FF) or data.

$$Z(\%) = F_D - F_F$$

3.5.3 Relative Print Contrast

The relative print contrast is also calculated from the measured solid density (DV) and the halftone density (DR). The DR value is best measured in the three-quarter tones.

$$K_{rel.}(\%) = \frac{DV - DR}{DV} \cdot 100$$

3.5.4 Ink Trapping

Ink trapping is calculated from the densities measured in single-color solid and two- and three-color overprint patches, taking into account the color sequence.

The ink trapping calculated using the following formulas indicates what percentage of a color is overprinted on another. It is compared with the color applied first, the trapping of which is assumed to be 100 %.

3.5.4.1 Overprinting Two Colors

With this type of printing

D1+2	is the density of the two overprinted colors
D1	is the density of the first-down color and
D2	is the density of the second-down color.

N.B.: All density values must be measured using the color filter that is diametrically opposite the second color.

3.5.4.2 Overprinting Three Colors

With this type of printing

D1+2+3	is the density of all three overprinted colors and
D3	is the density of the last-down color.

N.B.: All density values must be measured using the color filter that is diametrically opposite the last-down color.

The formulas given here are also used by all Heidelberg color measuring and control systems. Other methods also exist for determining ink trapping. All of the methods are controversial and, consequently, the results produced should not be taken too seriously. They are, however, useful for comparing press runs (and in particular for comparing sheets pulled from the same run). The higher the FA value, the better the ink trapping.

$$F_{\substack{2\\1}}(\%) = \frac{D_{1+2} - D_1}{D_2} \cdot 100$$

$$F_{\substack{3\\2\\1}}(\%) = \frac{D_{1+2+3} - D_{1+2}}{D_3} \cdot 100$$

x = suitable for standard colors
• = suitable for spot colors
( ) = limited suitability

	Densitometer	Spectrophotometer
Mixing of spot colors		•
Inking setup		
By standards	x (•)	x •
Using color control strips	x (•)	x •
Using colorimetric values (L*a*b*)		x •
Using proofs		x •
Based on specimens		x •
Based on image data		x •
Assessment of color suitability		x •
Inking adjustment		x •
Pressrun control		
Based on solid patches	x (•)	x •
Based on single-color halftone patches	x (•)	x •
Based on multicolor halftone patches		x •
Based on in-image measurements		x •
Detection of ink soiling		x •
Detection of changes in substrate		x •
Measurement values		
Solid density	x (•)	x •
Tonal values/dot gain	x (•)	x •
Relative ink trapping	x (•)	x •
Absolute ink trapping		x •
Metamerism		x •
Subjective impressions		x •

3.6 Limits of Densitometry

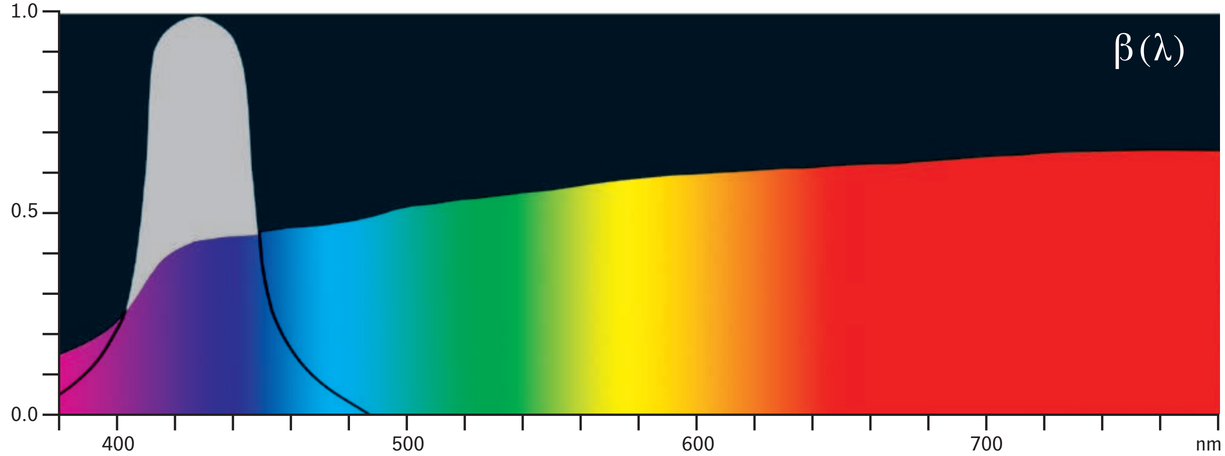
Densitometers work in a similar way to the method used to create color separations, with filters geared specifically to the four process colors. They provide a relative measure of the ink film thickness, but do not reveal anything that directly correlates with human color perception.

Consequently, they are of limited use. The table on page 33 shows their typical applications as compared to spectrophotometers.

One major constraint on densitometry is that the same ink densities do not necessarily create the same visual impression. This is always the case when the colorants being compared differ, which is why proofs, test prints on different paper and / or with different ink than will be used in the production run, or other samples cannot serve as reliable references for setting the inking.

Being restricted to the three color filters – red, green and blue – is also significant. As soon as color sets comprising more than the four process colors come into play, problems arise when measuring the additional colors. No filters that work in the absorption range of such colors are defined for them, resulting in ink density and dot gain values that provide insufficient information.

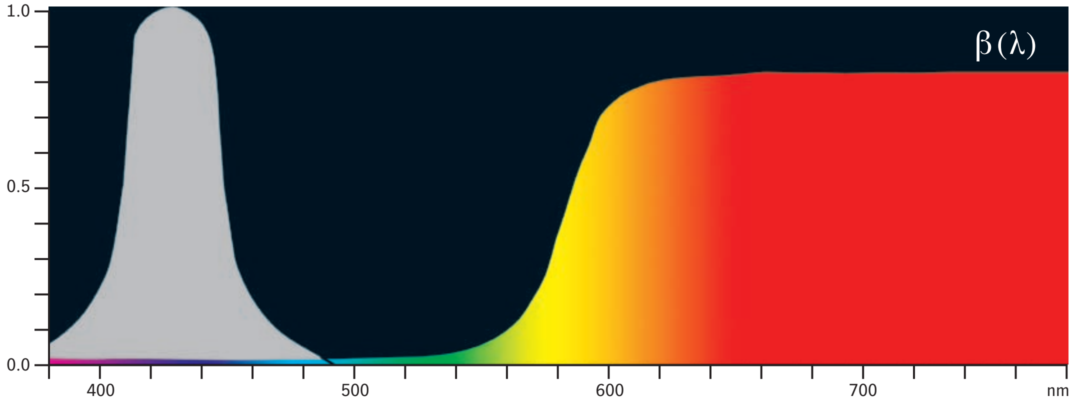
The use of densitometers also proves problematic for regulating inking based on multicolor halftone patches (e.g. gray patches). Measuring a gray patch with all three color filters produces different ink densities than when measuring each color in isolation.



Each of the three colors makes a more or less substantial contribution to all ink densities.
This is because the process colors are not genuinely pure primary colors with each representing two-thirds of the spectrum and therefore also absorb light in other wavelengths. Densitometers are useful for monitoring quality in press runs using the four-color process, but they are only of limited use in all other applications.

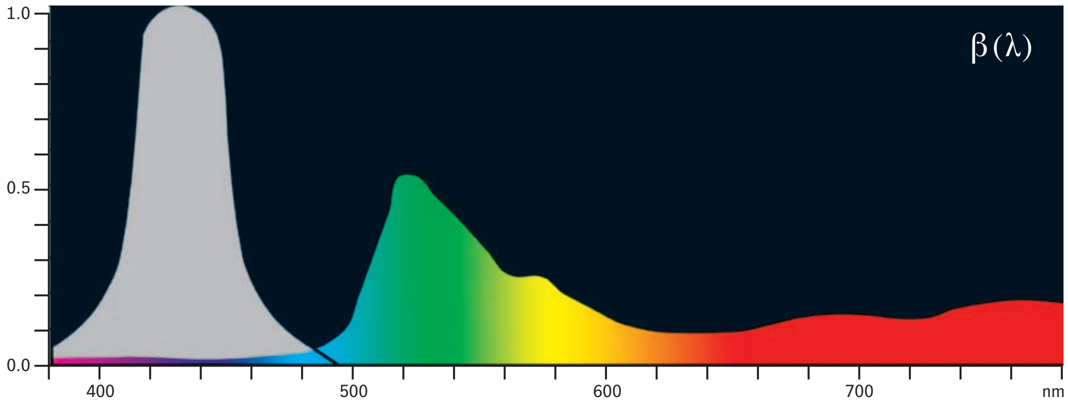
As can be seen in the diagram above it, the color tone shown here (Pantone Warm Gray 1) has relatively high remission, which falls away slightly in the blue spectrum (380 to 500 nanometers). Accordingly, the highest density value (0.27) is measured with a blue filter.

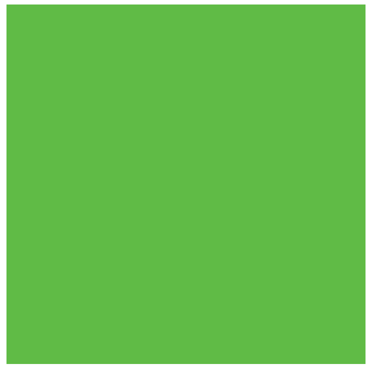
Color specimen: Pantone Warm Gray 1



Color specimen HKS 8

Density (blue filter) = 1.60
L* = 62.0
a* = 61.4
b* = 72.4





Color specimen HKS 65

Density (blue filter) = 1.60
L* = 58.7
a* = -58.8
b* = 59.7

The spot colors HKS 8 and HKS 65 in the second and third examples have radically different tones. This is also evident in their remission curves. However, both colors have the greatest absorption in the blue spectrum (380 to 500 nanometers), which means that once again the highest density value (1.60 in each case) is measured with the blue filter. This demonstrates the fact that density values measured with the same color filter in no way yield the same color tones.

Only colorimetric measurements can tell us something about a color's appearance.

4 Colorimetry

As explained in the section on color systems, three parameters are needed to describe a color unambiguously. Colorimetry tells us how to obtain these values and how they are interrelated.

4.1 Measuring Color

Spectrophotometers are used to measure colors.

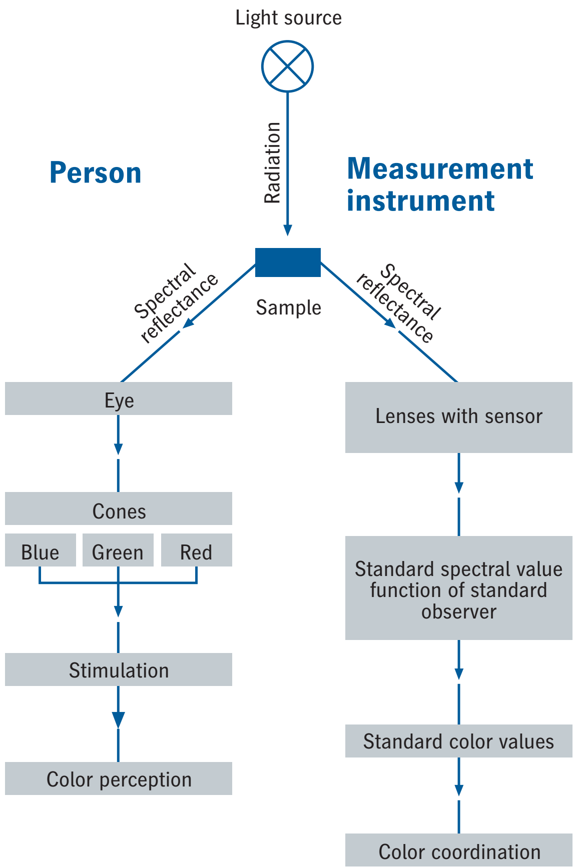
The principle of colorimetric instruments is based on how human beings see and perceive color (see figure).

A color (specimen) is illuminated by a light source. Part of the light is absorbed by the specimen while the rest is reflected. The reflected light is what our eyes register because it stimulates the cones (color receptors) sensitive to red, green and blue.

This stimulation results in electrical signals being sent via the optic nerve to the brain, which interprets them as colors.

This natural process is emulated in colorimetric instruments.

To perform a measurement, a printed sample is illuminated. The reflected light passes through one or more lenses and strikes a sensor. The sensor measures the light received for each color and relays the results to a computer where the data is weighted using algorithms that simulate the action of the three types of cones in the human eye. These algorithms have been defined by the CIE for a standard observer. They produce three standardized color values – X, Y and Z. These are then converted into coordinates for the CIE chromaticity diagram or some other color space (e.g. CIELab or CIELUV).



4.2 Standard Color Values

Before colors can be measured, it is necessary to determine standard color values based on measured reflectance under standardized conditions. Three factors are variable when measuring body colors and need to be set by the user – the reference white, the type of light (illuminant), and the observer.

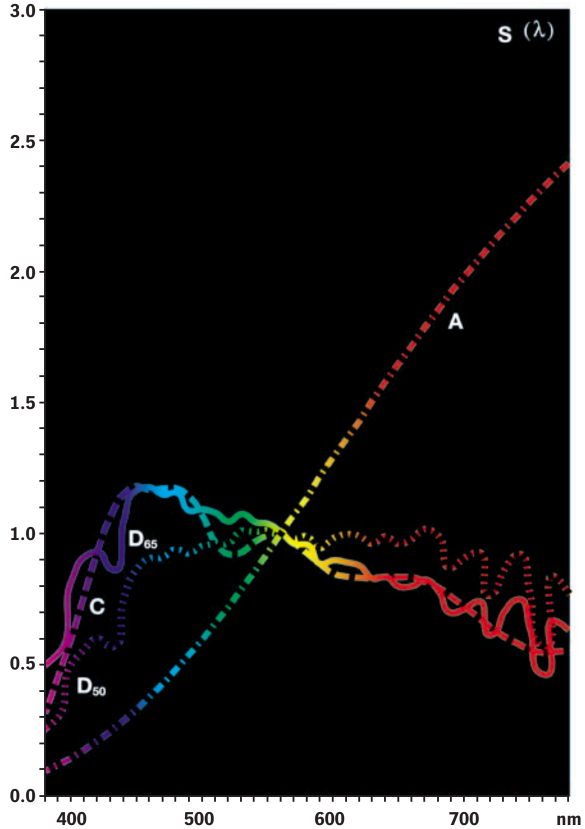
Normally, colorimetric values are based on "absolute white". They are calibrated to the measuring device's white standard (usually a ceramic surface), which in turn is calibrated to an absolute white.

4.3 Standard Illuminants

Without light there is no color. The type of light thus plays a role in how perceive a color. The color of the light itself is defined by its spectral composition.

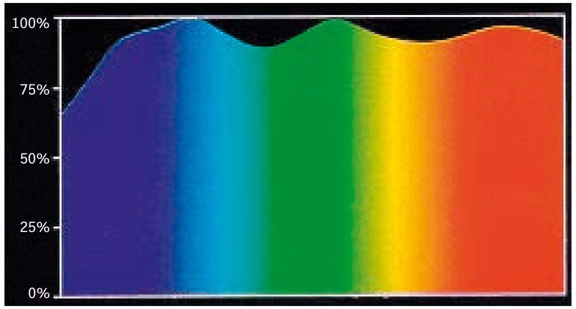
The spectral composition of natural sunlight is influenced by the weather, the season and the time of day. Photographers and film makers often have to wait for some time for the ideal light conditions.

The spectral composition of artificial light also varies. Some lamps emit reddish light while others tend more towards green or blue.



Lighting conditions affect spectral reflectance and thus color perception. Standard color values therefore have to be based on standardized light.

For standardization purposes, the spectral distribution (intensity) of various illuminants has been defined in the wavelength range 380 to 780 nanometers. The figure on the left shows the spectral distributions of the standard illuminants A, C, D 50 and D 65.



Standard illuminant 50 resembles average daylight, with the greatest radiation intensity in the blue region. The figure above shows illuminant D 50.

4.4 Standard Observer / Spectral Value Functions

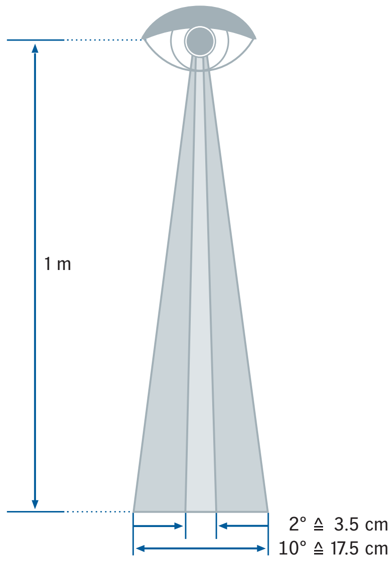
Every human retina has three types of cone with different spectral sensitivity. For people with normal color vision, the color perception resulting from the specific sensitivity of the cones is approximately the same. Colors are therefore only perceived differently from person to person in exceptional cases. For example, a color may appear bluish green to some but greenish blue to others.

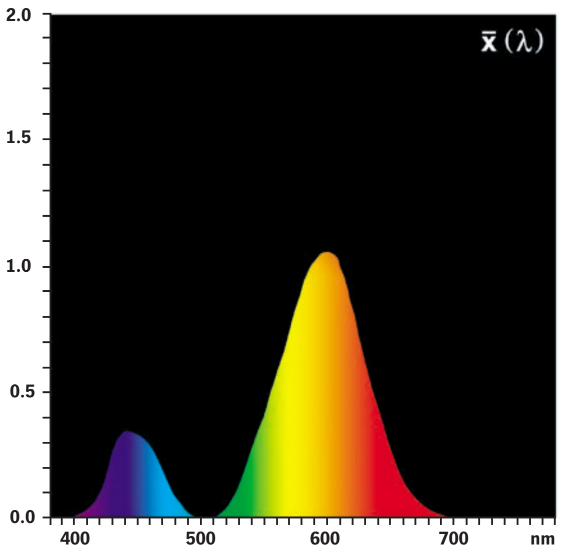
For colorimetric purposes, it is therefore essential to define a person with an average perception of colors – the "standard observer" – to balance the individual differences in color perception. In 1931, experiments were carried out for this purpose using people with normal color vision.

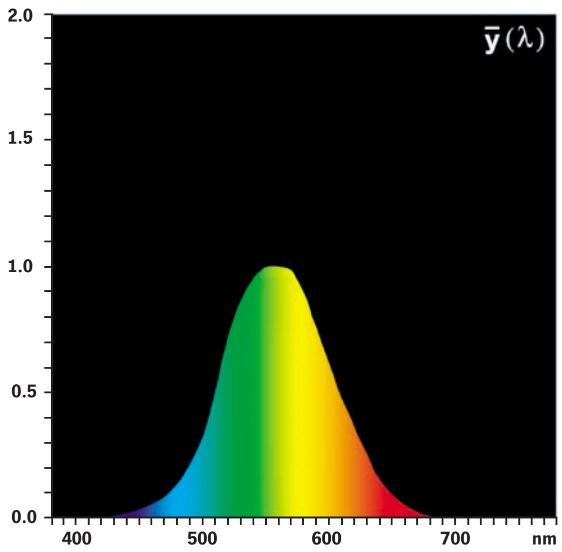
The findings were used to derive the standard spectral value functions $\bar{x}$, $\bar{y}$ and $\bar{z}$ specified by the CIE, which have been made binding by national and international standards such as DIN 5033 and ISO 12647.

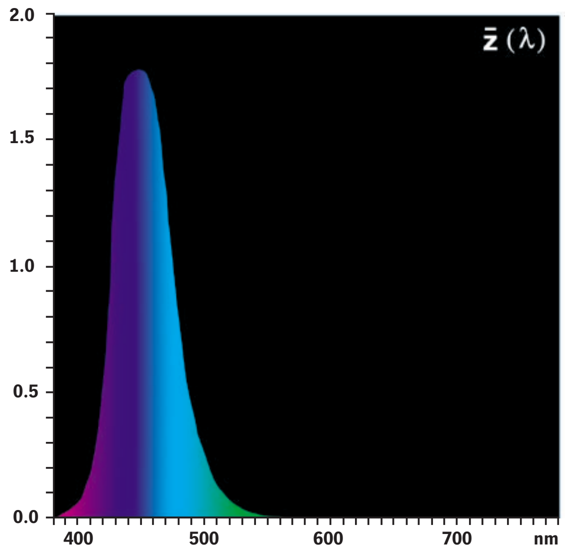
The experiments were conducted using a circular split screen 2 degrees across (see figure on the right). This corresponds to a screen 3.5 centimeters in diameter viewed from a distance of one meter.

In 1964, the tests were repeated with a screen 10 degrees across and the results were also standardized, giving rise to the "10-degree standard observer". However, this is not used in the printing industry.









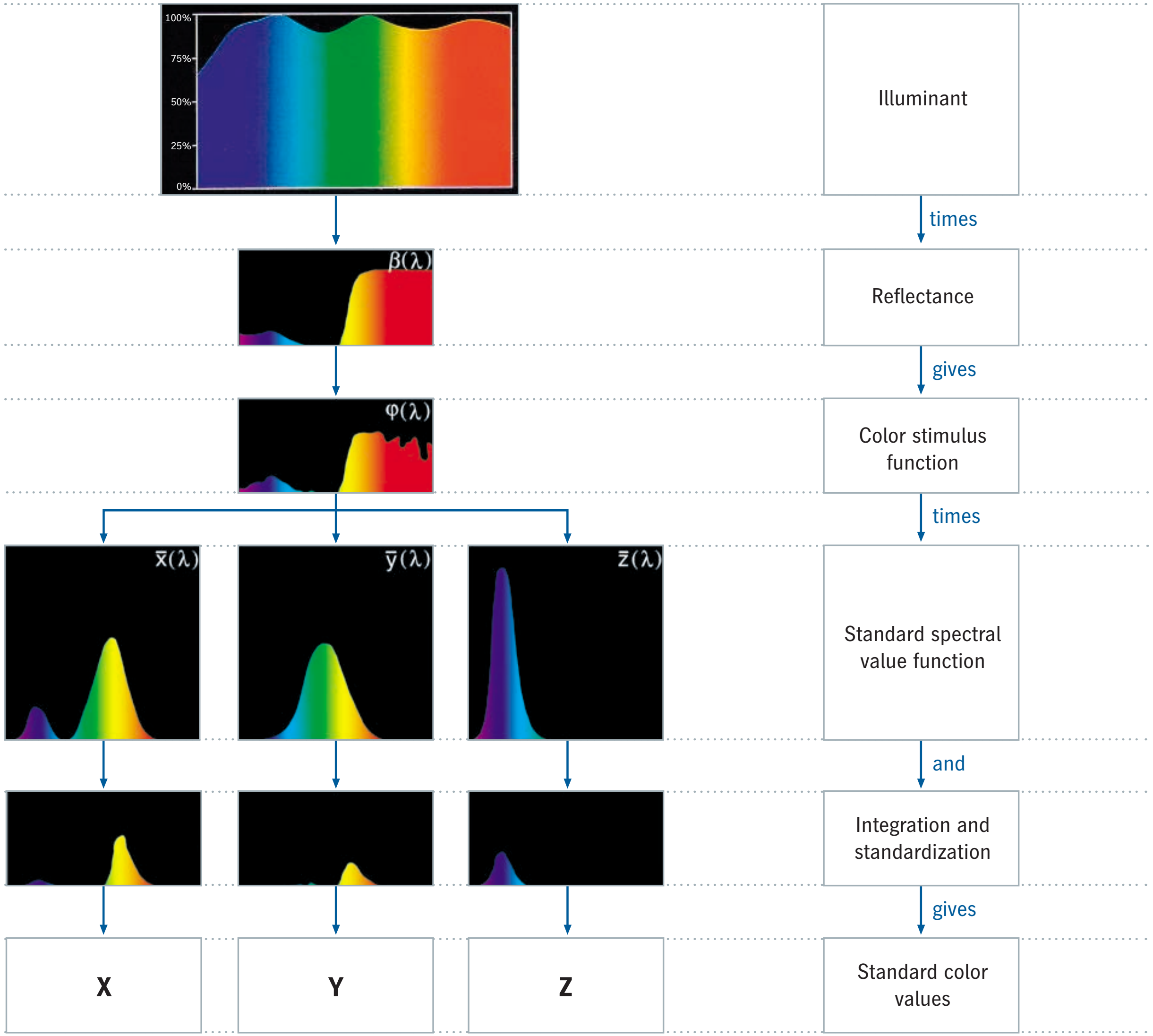
4.5 Evaluation with Spectrophotometer

The standard color values are calculated based on the spectrum of the S(λ) illuminant, the measured spectral reflectance of the color β(λ) and the standardized spectral value functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ for the standard observer.

The lambda in brackets (λ) indicates that the calculation depends on the wavelength λ of the light. The first step is to multiply the radiation function of the standard illuminant S(λ) for each wavelength λ (i.e. for each spectral color of an illuminant) by the reflectance values β(λ) measured for the color. This produces a new curve – the color stimulus function ψ(λ).

The second step is to multiply the values of the color stimulus function by those of the standard spectral value functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$. This produces three new curves.

Finally, integral calculus is applied to determine the areas below these curves, which are then multiplied by a standardization factor to obtain the standard color values X, Y and Z, which precisely describe the measured color.



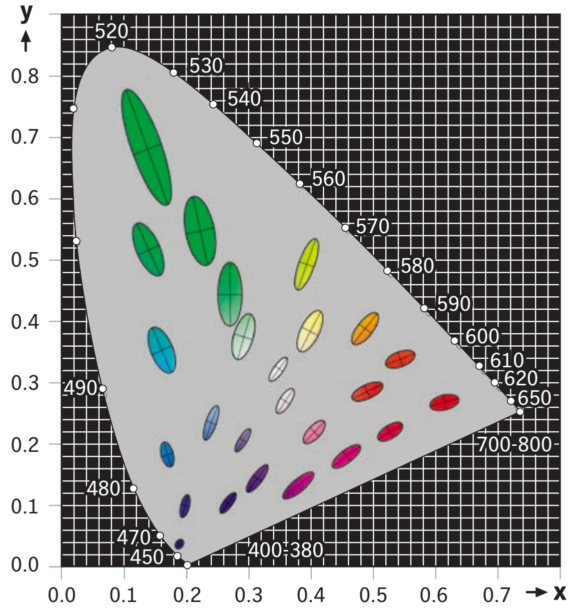
4.6 Equispaced Differences in Color Tone

The CIE color space has already been explained in section 1.4 on color systems. However, this color space has one major drawback – equal distances in the chromaticity diagram are not perceived as being equal for different color tones.

The American D.L. MacAdam explored this phenomenon in a large number of experiments. The figure shows what are known as the MacAdam ellipses, enlarged by a factor of ten. Because the CIE chromaticity diagram is actually three-dimensional, in reality they are ellipsoids. The size of the ellipsoids represents a measure of the perceptibility threshold of color deviations (seen from the center point of the relevant ellipsoid and for the relevant color tone).

As a result, this system cannot be used for evaluating color distances. Using it would mean accepting different tolerances for every color tone. In order to reliably and usefully calculate color distances, a color space is needed in which the distance between two colors actually corresponds to the perceived distance between them. Two such systems are CIELab and CIELUV, which are mathematically derived from the CIE chromaticity diagram.

This transformation mapped the MacAdam ellipsoids of different sizes onto spheres almost exactly the same size. As a result, the numerical distances between colors match the perceived distance between them to all intents and purposes.



4.7. The Lab Color Model

The problem of our perception of color being depicted with insufficient realism was solved by the CIE in 1976 with the development of the Lab color model. This is a three-dimensional color space in which color differences perceived to be equally large also have measurably equal distances between them. This means that each color can be precisely designated using its specific a and b values and its brightness L. The really significant thing about this color space, however, as with the standard color system, is its device independence and its resultant objectivity.

The CIELab color space normally takes the form of a sphere with 3 axes. These axes are defined as follows:

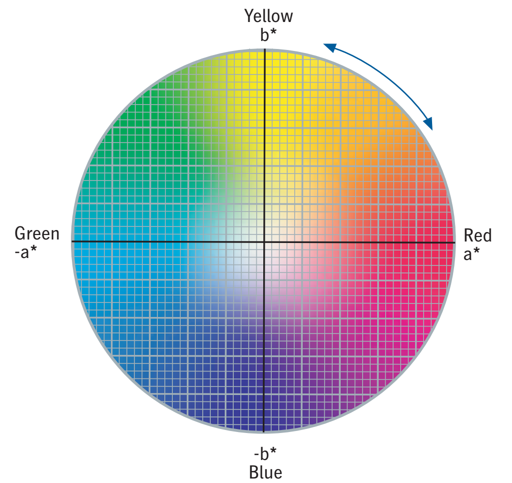
L = brightness axis
a = red-green axis
b = blue-yellow axis

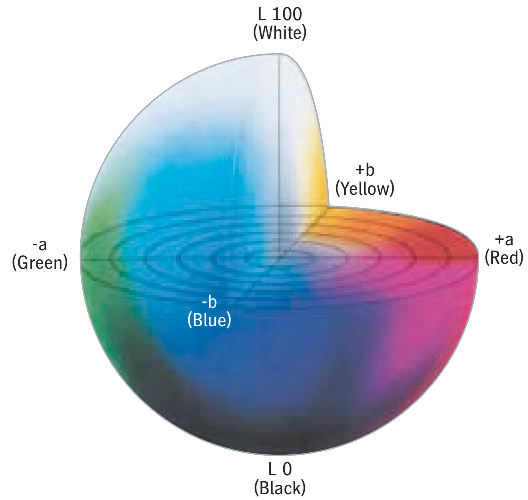
L always lies between 0 and 100, with 0 representing absolute black and 100 absolute white.

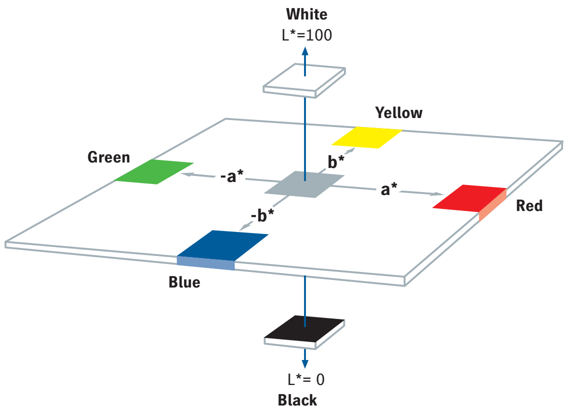
The a + b values are at 0 in the center of the axis, that is to say in the area with a completely neutral color. The further away from 0 the a and b values are, the more chromatic/saturated the color.

In order to ensure unambiguous color perception, at least to the extent possible with different people, a standard observer and the standard illuminant D 50 (5000 Kelvin) were defined. The standard observer views a color sample at an angle of either 10° or 2°. Only the 2° observer is defined for the printing industry. The L*a*b* designation indicates the color values' reference to the standard observer.

The colorimetric description of inks with CIEL*a*b* values has now become standard. The color loci for the process colors cyan, magenta, yellow and black are specified in the ISO 2846 standard. However, this standard only defines the actual ink under specific printing conditions. It is mainly used by ink manufacturers. The color space to be achieved in sheetfed offset printing, on the other hand, is defined by the ISO 12647-2 standard, based on standard inks as defined in ISO 2846-1.







Example	Specified target color	Actual measured color
L*	70.0	75.3
a*	55.0	51.2
b*	54.0	48.4

L* = 75.3 means that the color in question is light and its position of a* = 51.2 and b* = 48.4 situates it between yellow and red. The color in this particular example is thus a light yellowish red or orange.

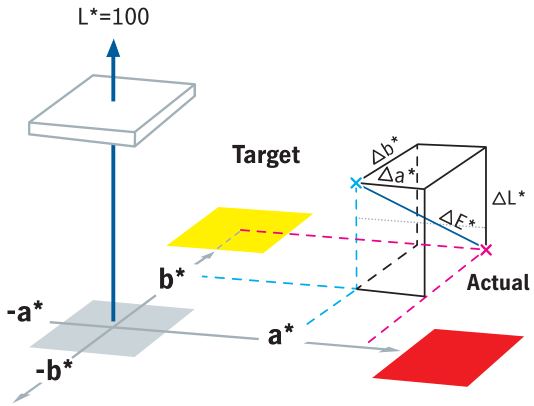
The actual measured color deviates from the specified reference color.

4.7.1 The CIELab Color Distance

The difference between two colors is expressed in ΔE in the L*a*b* color space. ΔE* 1 is the smallest color difference that the human eye can perceive. The following formula is used to calculate the color distance ΔE*:

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

ΔL*, Δa* and Δb* are the differences between the reference and actual values. They correspond to the distances of the color loci projected onto the 3 axes.



The following example relates to the calculation of the color distance between reference and actual values

Color deviations can be classified as follows in terms of their visibility:

$\Delta L^* = 75.3 - 70.0 = 5.3$

$\Delta a^* = 51.2 - 55.0 = -3.8$

$\Delta b^* = 48.4 - 54.0 = -5.6$

$\Delta E^*_{ab} = \sqrt{5.3^2 + (-3.8)^2 + (-5.6)^2} = 8.6$

Color deviations can be classified as follows in terms of their visibility:

ΔE between 0 and 1	Deviation that is not normally visible
ΔE between 1 and 2	Very small deviation, only visible to a trained eye
ΔE between 2 and 3.5	Moderate deviation, also visible to an untrained eye
ΔE between 3.5 and 5	Obvious deviation
ΔE over 5	Significant deviation

Colorimetric values of sheetfed offset inks to ISO2846-1

Color	CIELab values			Tolerances			
	L*	a*	b*	△ E*ab	△a*	△b*	L*
Yellow	91.0	−5.1	95.0	4.0	-	-	-
Magenta	50.0	76.0	−3.0	4.0	-	-	-
Cyan	57.0	−39.2	−46.0	4.0	-	-	-
Black	18.0	0.8	0.0	-	1.5	3.0	≤18.0

Colorimetric solid (full-tone) values in sheetfed offset printing to ISO12647-2:2004 Amd1:2007 for the production run, measured on a black backing

Paper grade	1+2	3	4	5
	L*/a*/b*	L*/a*/b*	L*/a*/b*	L*/a*/b*
Black	16 / 0 / 0	20 / 0 / 0	31 / 1 / 1	31 / 1 / 2
Cyan	54 / −36 / −49	55 / −36 / −44	58 / −25 / −43	59 / −27 / −36
Magenta	46 / 72 / −5	46 / 70 / −3	54 / 58 / −2	52 / 57 / 2
Yellow	87 / −6 / 90	84 / −5 / 88	86 / −4 / 75	86 / −3 / 77
Red (information)	46 / 67 / 47	45 / 62 / 39	52 / 53 / 25	51 / 55 / 34
Green (information)	49 / −66 / 24	47 / −60 / 25	53 / −42 / 13	49 / −44 / 16
Blue (information)	24 / 16 / −45	24 / 18 / −41	37 / 8 / −30	33 / 12 / −29

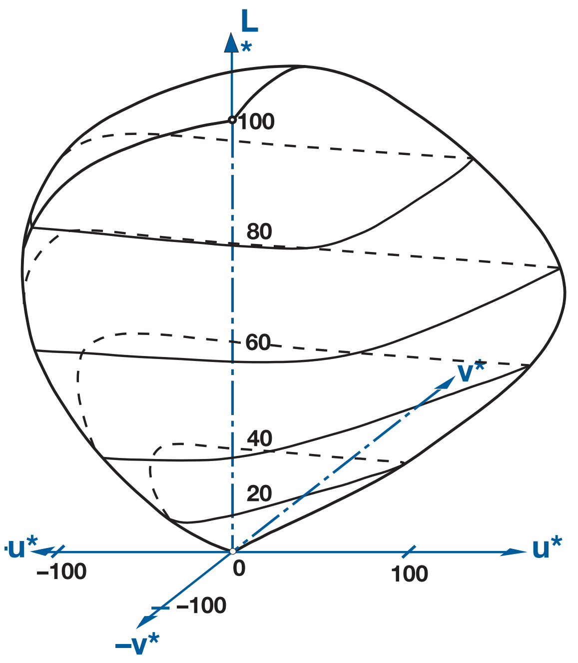
4.7.2 CIELUV

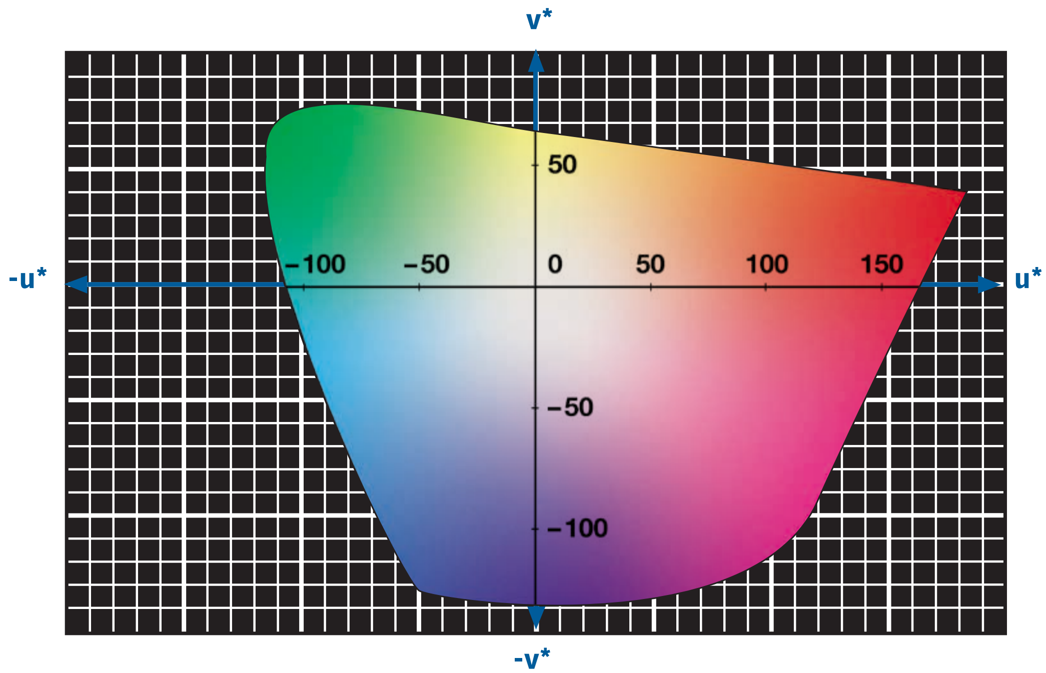
The CIELUV color space is also derived from the CIE chromaticity diagram. Its three coordinate axes are designated L*, u* and v*.

Because the CIELUV and CIELab color spaces result from different transformations, they differ in shape. Both are used for body colors.

The figure shows a cross-section of the CIELUV color space for body colors with a luminance value of L* = 50. The green colors are located further inward than in the CIELab color space, and the blue range is larger.

The CIELUV color space is often used to assess the light colors of television screens and computer monitors. Its advantage is that it is derived by a linear transformation, which means that the color relationships are the same as in the CIE color space (this is not the case with CIELab).





4.7.3 CIELCH

CIELCH refers to the use of the cylindrical coordinates C (chroma, as a distance from the center) and h (hue, as an angle) instead of Cartesian coordinates a*, b* and/or u*, v* in the CIELab or CIELUV color space. In other words, it is not a color space in its own right.

The calculations involved correspond to those in CIELUV.

Actual color: L* = 75.3

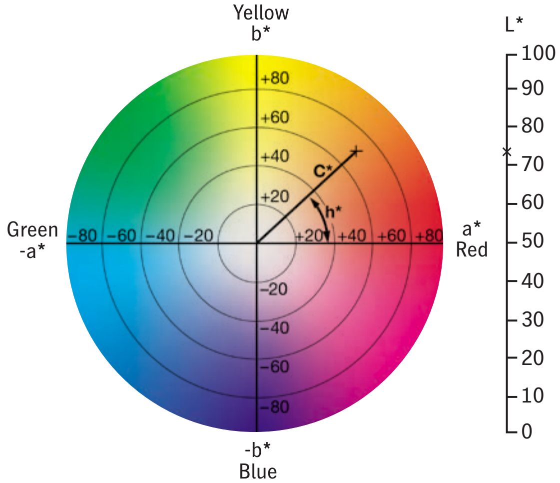
C* = 70.5

h* = 43.4°

The lightness L* remains unchanged.

The chroma C^*_{ab} is calculated with $C^*_{ab} = \sqrt{a^{*2} + b^{*2}}$.

The hue angle h^*_{ab} is calculated from $h^*_{ab} = \arctan\left(\frac{b^*}{a^*}\right)$.



4.7.4 CMC

CMC, a system for evaluating color distances based on the CIELab color space, was developed in Britain in 1988 by the Colour Measurement Committee of the Society of Dyers and Colourists (CMC). Unlike CIELab or CIELUV, it describes how well differences in color are accepted by an observer, not how they are perceived.

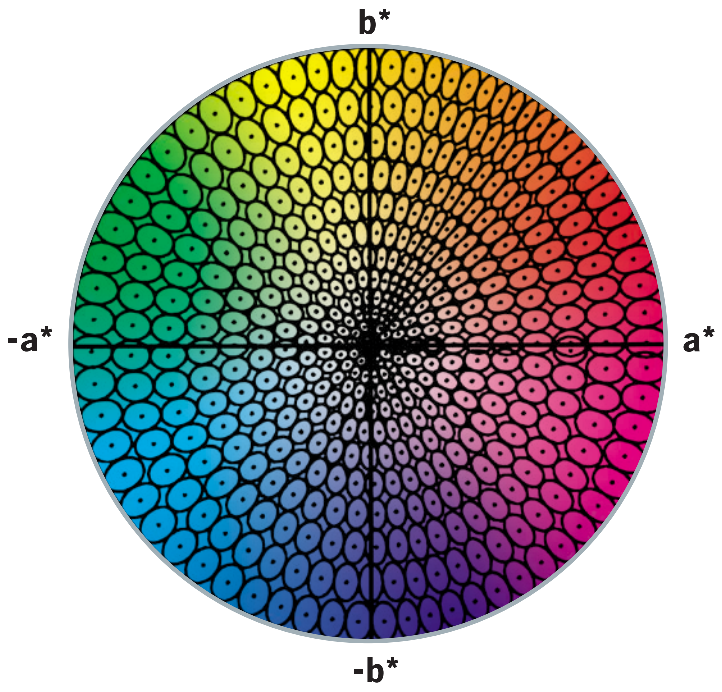
It addresses the fact that, generally speaking, color fluctuations near the lightness axis are perceived as much more irritating than deviations in more saturated colors. Similarly, fluctuations in chroma (saturation) are accepted more readily than fluctuations in the hue angle.

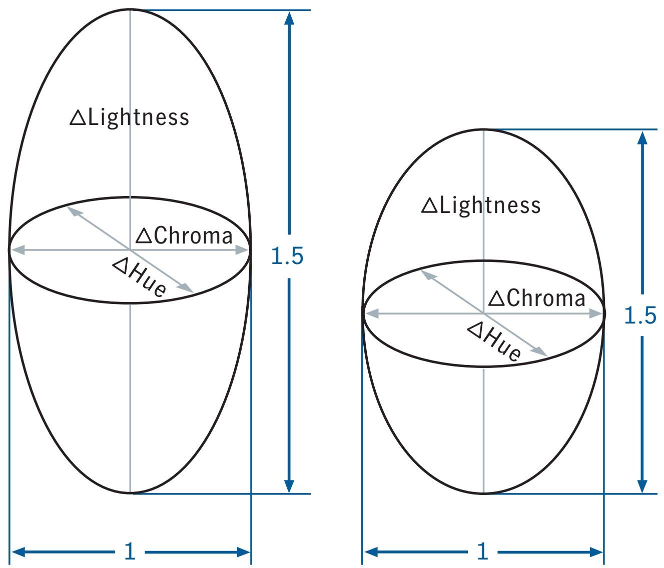
The figure on page 46 illustrates application of the CMC principle to assess color distances in the CIELab color space. Each ellipse shows colors with acceptable deviations around the target locus based on the CMC formula.

As can clearly be seen, the ellipses (representing tolerances in the CMC color space) are smaller in the achromatic area than in regions of greater saturation. They are also shaped to reflect the fact that the permissible deviations in hue angle are smaller than those in the chroma value. They allow for flexible adjustments for assessing lightness and color tone deviations. These adjustments are made using two weighting factors, l and c (where l is the weighting factor for lightness, and the weighting factor c for the color tone is normally 1).

The textile industry often uses weighting factors with a ratio of l : c = 2 : 1. This means that lightness deviations are twice as likely to be accepted as color tone deviations.

This relationship can be adjusted to suit each application. As a result, however, the color distance values are only informative and comparable in conjunction with the same weighting factors.





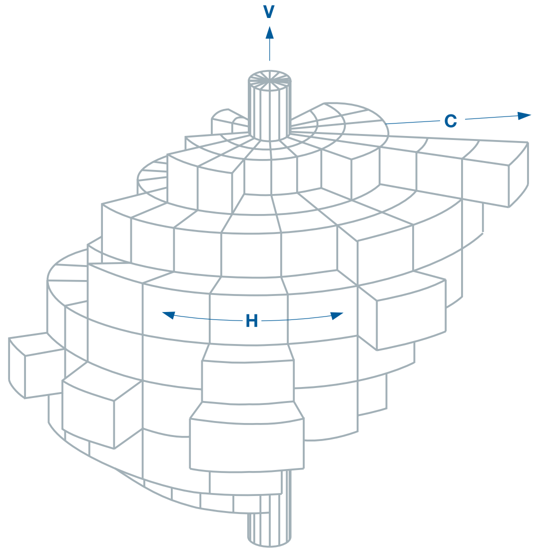
4.8 Munsell

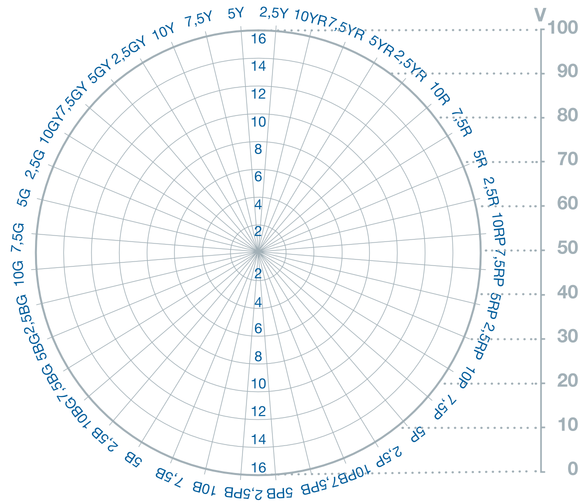
In 1905, Alfred Munsell developed a system for quantitatively and objectively representing color distances as they are perceived. He used the terms hue, chroma (saturation) and value (lightness) to describe the attributes of color. Five basic hues make up the notation system – red, yellow, green, blue and purple. It was published in 1915 as the “Munsell Book of Color” for 40 color tones with the C illuminant, including both glossy and matt samples.

Each of the five basic hues is subdivided into as many as 100 even-numbered color tones, each of which has a grid comprising 16 chroma and 10 lightness levels. The figure shows a cross-section of the Munsell color tree with 40 color tones. Not all of the slots in each grid are occupied, resulting in an irregular color space.

Munsell coordinates cannot be mathematically converted into CIE coordinates.

Other color systems include the DIN color atlas (DIN 6164), the Natural Color System (NCS), the OSA system (from the Optical Society of America), and the RAL design system (RAL-DS).





5 Use of Colorimetry

5.1 Spectrophotometry

Spectrophotometry measures the visible spectrum, for example from 380 to 730 nanometers. The light reflected by an ink is split into its spectral constituents using a diffraction grid or other technologies, and these are captured by a large number of sensors.

The measured reflectance values are used to calculate the standard color values X, Y and Z. This is done on a computer using the standard spectral value functions x, y and z. Because these functions do not need to be modeled with filters, the absolute precision of spectrophotometers is very high.

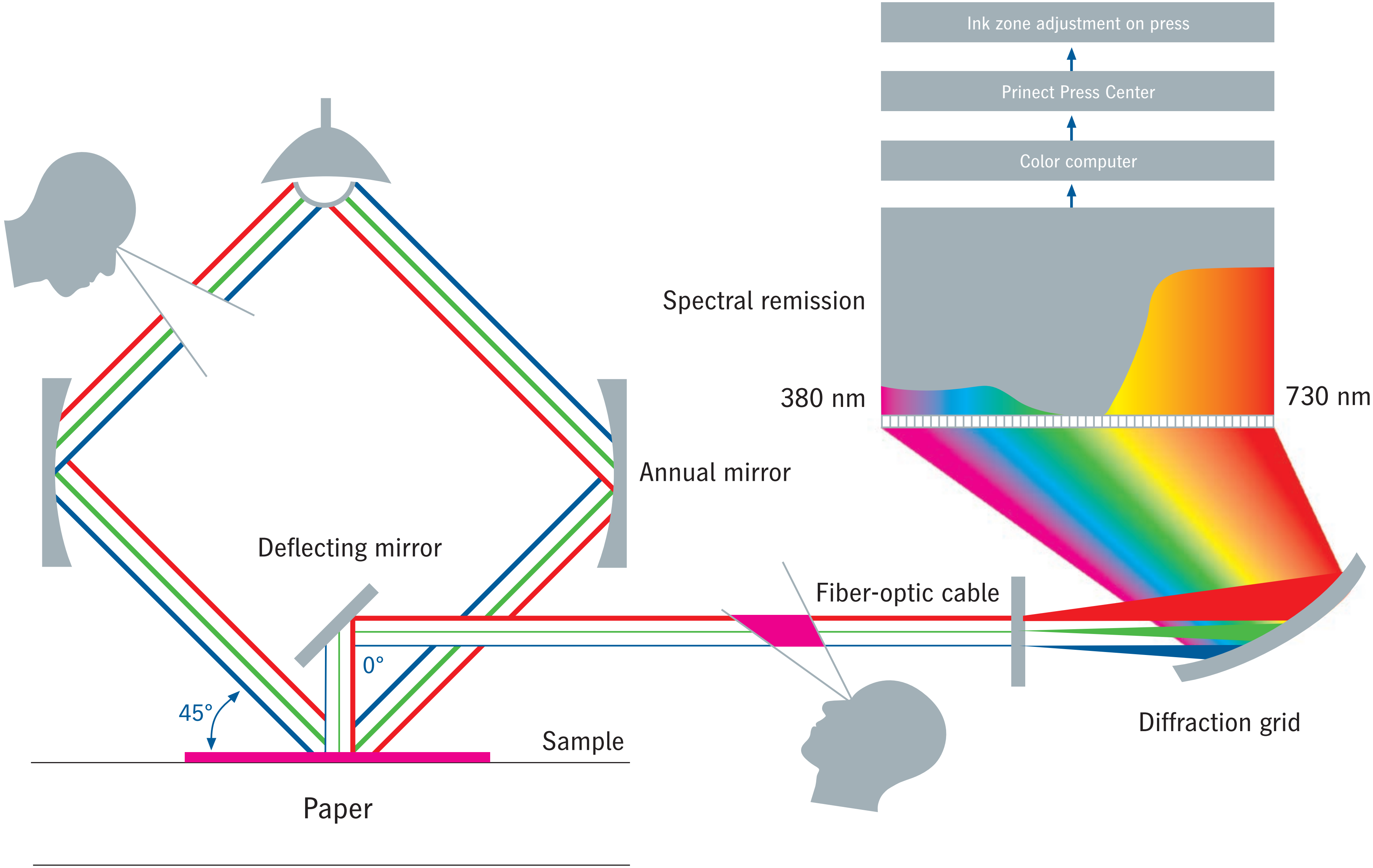
A major advantage of spectrophotometry – besides its high absolute precision – is the fact that spectrophotometers can output the standard color values for all standardized illuminants and observers, provided the corresponding values have been stored. They can also calculate densities for any filter standards.

Ink manufacturers are required to comply with precise specifications when making their products. This is very important for standardized colors (ISO 2846-1), but also for all HKS and special colors. They achieve this by measuring a specimen with a spectrophotometer and then using an appropriate formulation program to calculate the proportion for mixing the ink.

The operating principle of a spectrophotometer is shown in the diagram on the right.

First, the light source is directed onto the printed specimen at an angle of 45°. The light reflected at an angle of 0° is relayed from the measuring head to the spectrophotometer via a deflecting mirror and a fiber-optic cable. There, it is split into its spectral colors by a diffraction grid (in a similar way to a prism).

Photodiodes then measure the radiation distribution across the entire visible spectrum (between 380 and 730 nanometers) and pass the results to a computer where the measured values are subjected to a colorimetric evaluation and output as Lab values.
Once the measured values have been compared with previously entered target values, the system calculates relative recommended adjustments for the various colors and relays these to the Prinect Press Center® press control system where the data is converted into absolute values for controlling the individual ink zone motors and sent to these motors.



Ink zone adjustment on press
Prinect Press Center
Color computer
Spectral remission
380 nm
730 nm
Annual mirror
Deflecting mirror
Fiber-optic cable
0°
45°
Sample
Paper
Diffraction grid

5.2 Color Control Bars

Heidelberg also offers a library of digital print control elements (Dipco) for all Prinect products used to monitor and control inking and color. This comprehensive package includes all digital elements needed to check and control the results obtained at each stage of the print process, from prepress to printing. The color control bar to be used essentially depends on the coloring of the relevant job. All the relevant bars are stored in the Prinect color measuring systems. They are selected either manually by the printer or automatically by Prinect Image Control in the Prinect color workflow. Prinect Inpress Control uses synchronization marks to identify the type and position of the bar on the sheet fully automatically. With Prinect® Axis Control®, it is sufficient simply to indicate the bar's approximate position on the sheet. The results from measuring every element of the color control bar are compared with the stored reference values. Based on this comparison, the Prinect color measurement systems then calculate recommended adjustments for the individual ink zones in each of the printing units.

How to position the color control bars

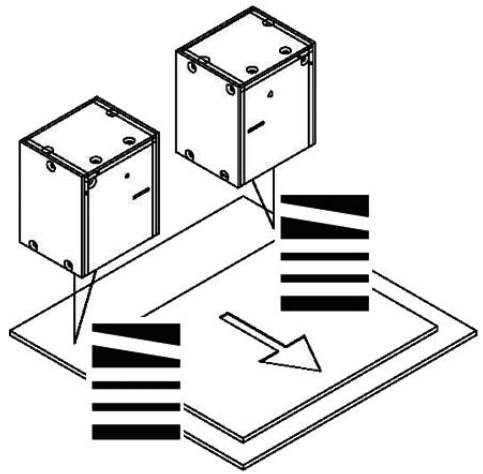
- Do not place diagonally on the sheet, but parallel to a sheet edge.
- Position the bar so that it is pointing towards the center of the sheet.
- Position all parts of the bar together in one row, without separating them.
- Select the correct bar for the print job (process colors only, process and spot colors, or spot colors only).
- Select the correct bar for subsequent measurement and control with color measurement systems.
  - full-tone / gray-patch control
  - full-tone control only
- Select the correct bar for the halftone patches to be evaluated.
- Always use bars with 40 % and 80 % patches for standard-compliant measurement and better adaptation of the characteristic curve.
- Do not reduce or increase the height or width of color control bars.
- Position bars so that they will not be where the grippers grab the sheet.
- Bars can be placed at the leading or trailing edge or in the middle of the sheet (perfecting printing).

When working with Prinect color measurement systems, do not position the bars directly adjoining the print image (position about 1 mm away or 0.5 mm for Prinect Inpress Control).

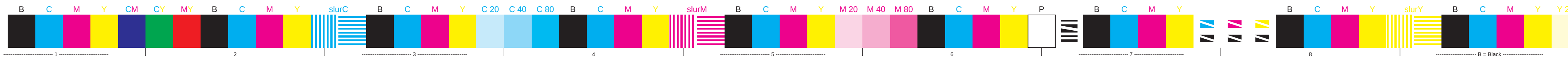
When working with Prinect® Axis Control®, leave 5 mm of paper white to the left and right of the bar. The first and last patches must be whole and must be solid patches.

With Prinect Inpress Control, it must be ensured that the synchronization marks are located in the printable area!

The individual patches in the bars are to be either 4 mm or 6 mm high and 3.25 mm or 5 mm wide. The ink zones are 32.5 mm wide on all Speedmaster® presses, which means there is room for either 13 or 20 patches across two ink zones.



With Prinect Inpress Control, special sensors in the measuring head identify the color control bar fully automatically



5.3 Color Control with Heidelberg

5.3.1 Color Measurement and Control Systems from Heidelberg

In principle, Heidelberg only offers systems based on spectral measurement and colorimetric control. Differences in coloring are relayed online to the press control console where they are converted into ink zone adjustments. The operator decides whether the necessary ink zone adjustments on the press are to be performed automatically on completion of the measuring process or the go-ahead is to be given manually by pressing a button.

All instruments can measure and display solids, half-tones, slurring or doubling in the color control bar. All color control bars required are included in the scope of supply (DIPCO).

Prinect Axis Control • Measuring instrument integrated into the press control console with motorized measuring head movement in X and Y directions. Sheet absolutely flat, even with high grammages, thanks to vacuum suction. Operated from the touch-screen monitor of the Prinect Press Center.

Prinect Axis Control

Prinect Image Control • Standalone measuring instrument for connection to a maximum of 4 Heidelberg presses. Sheet absolutely flat, even with high grammages, thanks to vacuum suction. Operated from the instrument's own touchscreen monitor. Gray patch control, measurement and control of the entire print image, color management, process control, Mini Spot workflow, repeats taken over in the print sheet or from a separate original, integrated color database with Pantone and HKS L*a*b* values.

Prinect Image Control

Prinect Inpress Control • Measuring instrument integrated in the press. Automatic identification of color control bar. Measurement at all speeds. Additional adjustment console with hand-held spectrometer for measuring paper white and color specimens.

Prinect Inpress Control

5.3.2 Colorimetric Control Methods

Heidelberg color measurement and control systems offer a choice of 3 different control modes:

- Colorimetric based on full-tone (solid) patches
- Colorimetric based on gray patches *
- Colorimetric based on in-image measurements **

Originally, only two colorimetric control modes were available – full-tone control using a color control bar (for process and spot colors), and gray-patch control using an autotypical gray patch (CMY) and additional solid and halftone patches for the chromatic colors.

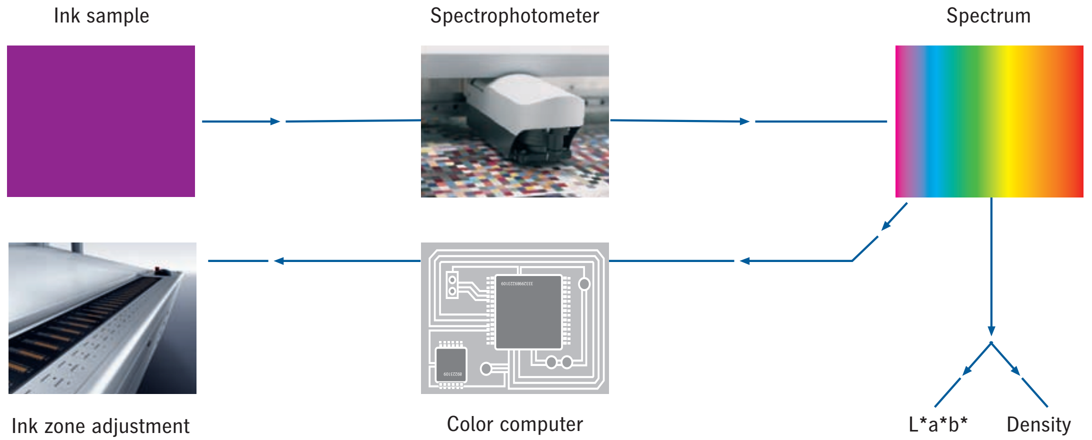
Heidelberg has added a third mode that is based on measurement of the print image itself. Heidelberg Prinect Image Control is the world's first system that is able to measure the entire printed image and control the ink zones on the basis of the data obtained. It is ideal for making sure that the sold product measures up.

All three control modes use colorimetric reference values. In other words, the objective is a perfect color match between the press and reference sheets. The colorimetric approach underlying color measurement systems from Heidelberg means that a technology is used that emulates the color perceptions of the human eye to minimize the detectible color discrepancies between the OK sheet and the press sheets.

* Not with Prinect Inpress Control
** Only with Prinect Image Control

5.3.3 Prerequisites for Measurement and Control on Printing Presses

Before looking at how different measurement systems work, it is important to describe the most important prerequisites that must be met to ensure reliable measurement and control. The focus is on presetting the ink keys and priming the ink train. How the inking is preset depends mainly on the job's area coverage values and the material parameters (characteristic curves stored in the press control system). Ideally, area coverage values are ascertained using CIP4-PPF data from prepress that is transferred to the press either online or using a storage medium. The point of presetting the ink zones is to get the colors as close as possible to the target values right from the start. The ink keys and ink stripe widths are set appropriately in every zone of each inking unit in line with the anticipated ink consumption. In order to determine the appropriate settings, the characteristic curves are applied to convert the area coverage values into presetting values. A frequently underestimated factor is priming of the ink train. Before the first sheet is printed, the amount of ink is introduced into the ink train that will later be applied during the production run under stable conditions. If inking is set well to begin with, there's no need to adjust it subsequently. When starting to print, the steps described here determine the point at which color measurement and control can begin.



5.3.4 How the Heidelberg Color Measurement and Control Systems Work

Heidelberg uses spectrophotometers for all its color measurement systems, regardless of whether they output ink density or L*a*b* values. The spectra measured are relayed to an integrated computer and used to calculate the required values. These color values are the basis for colorimetric control. In other words, the recommended adjustments for the ink zones are calculated directly using a color model that models the change in coloring when the ink film thickness changes.

For control purposes, it is vital for the spectral values to be stored in the measuring instrument as reference values. The reference values for Pantone and HKS spot colors are stored in Prinect color measuring instruments at the factory.

No spectral values are stored for process (4C), highly pigmented and other colors. There are two reasons for this – the large number of ink makes and types used in practice, and the fact that the colors of process inks often vary considerably. This makes it necessary for the press operator to determine the spectral values of these inks by measuring a (full-tone) print specimen to ascertain a new target color locus. This only takes a few minutes and has the advantage of generating reference values that can realistically be achieved with the ink used in the printshop. Quality control by monitoring color deviations is also feasible, for instance between different batches of ink.

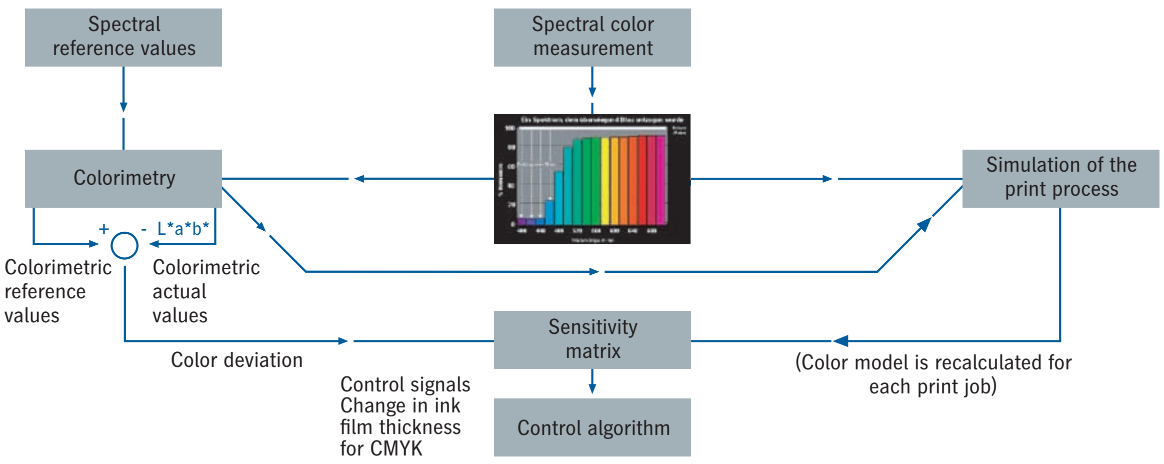
5.3.5 Determining Reference Values – a Practical Example

Let's say you wish to print according to the ISO 12647-2 standard. This standard defines dot gain as well as colorimetric reference values expressed as CIE L*a*b* coordinates. Due to the influence of various factors, the CIE L*a*b* values can never be perfectly matched, which is why tolerances are also given for the individual process colors under production conditions. It is important for the press operator to know how closely he can approximate the reference values with the inks he is using.

There are two practical approaches for determining the achievable target value (= press run standard):

1. Make a series of prints ranging from underinked to overinked and measure them. The sheet in which the color is closest to the target value within the permissible tolerances is suitable for use as the standard for the measurement system.
2. Have the ink manufacturer prepare a laboratory test print on the same paper that will be used for the job. Scan it to serve as the standard for the measurement system.

Conversion of color deviations into recommended adjustments for ink zones and in-print control



5.3.6 Inline Measurement and Control

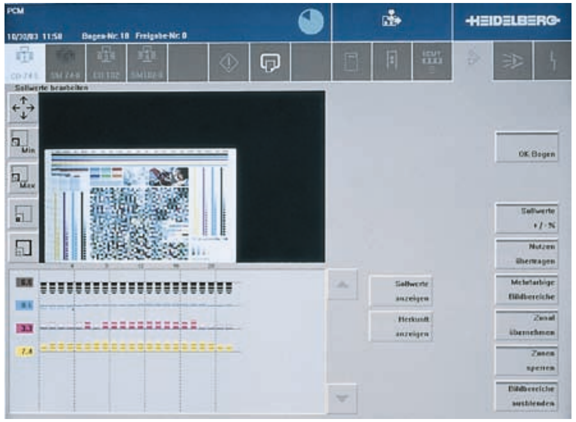
After the target values have been determined, measurement of the press run can begin. The first sheet pulled provides the first actual measured values, which should not be too far from the target values. The objective now is to adjust the ink zones and thus the ink film thicknesses to achieve the target values as quickly as possible.

This approach may seem simple at first, but it is based on a complex color model that describes how changes in the ink film thickness affect the color of the ink used. Colorimetry by itself can only tell us where the color achieved so far is located within the color space (the actual measured value) and where we need to get it to (the target or reference value). What it doesn't tell us is how to accomplish this. But this is not the job of colorimetry. That is what the color model is for. It can be used to work out how the color changes if, for example, the ink film thickness is increased by 5 percent. If the film thickness on the paper is changed, its visual appearance naturally also changes. Imagine a series of prints ranging from very light inking to full saturation within the CIE L*a*b* color space. They lie along a line that varies not only in terms of lightness, but also in its position on the a and b planes. This is called a color line. When using full-tone control, the achievable color tones are fixed by the ink's pigmentation and the paper used. The color model can be used to calculate which film thickness comes closest to producing the target value, and where the target value is located within the color space.

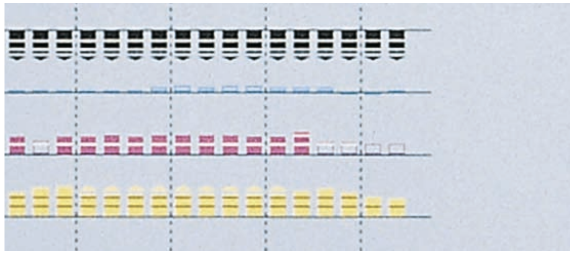
5.3.7 How Colorimetry Helps

In practice, this means that the operator sees at a glance whether or not he can achieve the required color results. If all parameters of the print process are optimally coordinated, he can expect to achieve them. If the printing conditions change, for instance due to blackening of the chromatic colors in the press run, the colors can deviate significantly from the targets. Colorimetry can then be a major help by revealing whether the required color results can still be achieved within the specified tolerances under these conditions, or whether it is necessary to take steps such as washing the inking rollers. When using a different type of ink, the color measurement system also shows, right from the very first pull, whether or not the achievable color is within the tolerances. This can be the case when working with a different make or type of ink and a previously stored reference value. Different batches of the same type of ink may also enable you to achieve the CIE L*a*b* value, but with different densities. If you only printed based on the reference densities, the visual appearance of the prints could subsequently be different. This is one reason why the ISO standard does not provide any reference densities.

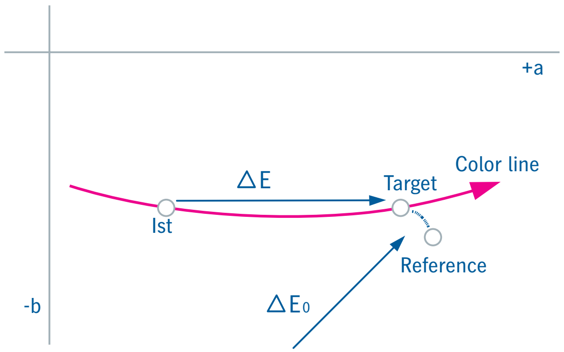
Measurement using Prinect Image Control



The operator sees at a glance where the inking needs to be corrected.



The black line shows the reference colors. The bars show the underinking and overinking for each ink zone.



Example of a color line in the CIELab color space

5.3.8 Summary

The biggest advantage of colorimetric control is that it lets you consistently get the results of printing as close as possible to the actual appearance of the original. There are always two values visible – ΔE is the coloring difference between the measured value and the best possible match with the actual ink and paper. ΔE0 is the difference between the best match and the reference values stored in the system which cannot be adjusted. Colorimetric evaluation corresponds to the color perceptions of the human eye, with the additional advantage of being free of subjective influences and variable environmental influences and therefore being able to deliver objective readings. The measurement data can be stored and documented and used for quality certificates. Measurement results can also be automatically evaluated with the Quality Monitor software from Heidelberg.

5.4 Standardization of Printing

The standards of the graphic arts industry described below play key roles when it comes to standardization.

5.4.1 ISO-Compliant Inks

The Euroscale, originally defined by DIN 16539 in 1975, has been improved. In 1996, ISO 2846 succeeded in establishing a common process standard that incorporated the ideas of the U.S. SWOP and the Japanese TOYO standards. Part 1 of this standard defines tolerances for colorimetric properties and transparencies for process inks for four-color sheetfed and web offset printing that may not be exceeded when making test prints on APCO paper with a defined reference ink film thickness. However, the color values given in this standard are binding only for ink manufacturers, not for printers.

5.4.2 ISO 12647-2 and ProzessStandard Offsetdruck (German Offset Printing Process Standard)

In 1981, the German Printing and Media Industries Federation (bvdm) issued its first publication on standardizing sheetfed offset printing. The practical experience gained and the relevant scientific research findings made subsequently were incorporated into the international standard ISO 12647-2 “Process control for the production of half-tone color separations, proof and production prints”. ISO 12647-2 is regularly revised to incorporate new findings and process technologies. The following details relate to the version in force when this brochure went to press – ISO 12647-2:2004 Amd 1:2007. In 2003, the German Printing and Media Industries Federation (bvdm) joined forces with Fogra to produce the ProzessStandard Offsetdruck (German Offset Printing Process Standard or PSO), the first procedure for complying with and checking standards to ISO 12647-2. The 2nd edition was released in 2008 and can be ordered in printed form from the bvdm. In addition to the values from the ISO standard, the PSO contains further recommendations and monitoring tools. The best known of these are the Fogra media wedge for proof quality control and the Fogra color control bars. However, the PSO itself is not a standard.

The Prozess Standard Offsetdruck (German Offset Printing Process Standard) of the German Printing and Media Industries Federation (bvdm), Prepress Parameters for Sheetfed Offset Printing

Screen ruling	60 lpc		
Screen angle	Nominal angular difference between C, M, K = 60° (chain dots), = 30° (circular or square dots) Y = 15° from another color, dominant color at 45° or 135°		
Halftone dot shape	Color control strip: circular dot, image: chain dot with 1st dot touch ≥ 40 %, 2nd dot touch ≤ 60 %		
Total area coverage	≤ 340 %		
Gray balance	Cyan	Magenta	Yellow
Quarter tones	25 %	18 %	18 %
Midtones	50 %	40 %	40 %
Three-quarter tones	75 %	64 %	64 %

Reference dot gain values for the five paper types

Halftone patches (%)	**Dot gain (%) with tolerances for paper types 1-5**		
	PT 1+2	PT 3	PT 4+5
40	09 – **13** – 17	12 – **16** – 20	15 – **19** – 23
50	10 – **14** – 18	13 – **17** – 21	16 – **20** – 24
70	10 – **13** – 16	12 – **15** – 18	13 – **16** – 19
75	09 – **12** – 15	10 – **13** – 16	11 – **14** – 17
80	08 – **11** – 14	08 – **11** – 14	09 – **12** – 15

Media Standard Print 2007, CIELab color values for full-tone corner colors for sheetfed, web and continuous offset printing on 5 paper types

Paper type	1 / 2	3	4	5	
	L* / a* / b*	L* / a* / b*	L* / a* / b*	L* / a* / b*	
Measurement on black backing					
Black	16 / 0 / 0	20 / 0 / 0	31 / 1 / 1	31 / 1 / 2	
Cyan	54 / –36 / –49	55 / –36 / –44	58 / –25 / –43	59 /–27 / –36	
Magenta	46 / 72 / –5	46 / 70 / –3	54 / 58 / –2	52 / 57 / 2	
Yellow	87 / –6 / 90	84 / –5 / 88	86 / –4 / 75	86 / –3 / 77	
Red	46 / 67 / 47	45 / 65 / 46	52 / 55 / 30	51 / 55 / 34	
Green	49 / –66 / 24	48 / –64 / 31	52 / –46 / 16	49 / –44 / 16	
Blue	24 / 16 / –45	21 / 22 / –46	36 / 12 / –32	33 / 12 / –29	
Measurement on substrate backing					
Black	16 / 0 / 0	20 / 0 / 0	31 / 1 / 1	31 / 1 / 3	
Cyan	55 / –37 / –50	58 / –38 / –44	60 / –26 / –44	60 /–28 / –36	
Magenta	48 / 74 / –3	49 / 75/ 0	56 / 61 / –1	54 / 60 / 4	
Yellow	91 / –5 / 93	89 / –4 / 94	89 / –4 / 78	89 / –3 / 81	
Red	47 / 68 / 48	49 / 70 / 51	54 / 58 / 32	53 / 58 / 37	
Green	50/ –65 / 27	51 / –67 / 33	53 / –47 / 17	50 / –46 / 17	
Blue	24 / 22 / –46	22 / 23 / –47	37 / 13 / –33	34 / 12 / –29	
Paper types	1	2	3	4	5
	115 gsm	115 gsm	65 gsm	115 gsm	115 gsm
	Glossy coated art reproduction	Matt coated art reproduction	LWC Web offset	Uncoated white offset	Uncoated yellow offset

The color values for green and blue for paper types 1/2 are the result of numerous test prints in Europe and the U.S. and have been incorporated into the characterization data (Fogra 39). They differ from the non-standard values of ISO 12647-2:2004 | Amd1: 2007 within the tolerance range.

Media Standard Print Specifications and tolerances for digital proofing

	ΔE
Mean ΔE for all L * a * b *color distances of color patches	4
Maximum ΔE for all L * a * b * color distances of color patches	10
Tolerance for primary colors	5
Maximum deviation of substrate	3

5.4.3 The Media Standard Print (MedienStandard Druck)

The Media Standard Print (MedienStandard Druck) first appeared in 2004 on the initiative of the German Printing and Media Industries Federation (bvdm). In addition to technical guidelines for digital data for printing, based on ISO 12647, it defines specifications and tolerances for digital contract proofs. This establishes a set of rules for agencies, prepress studios and printing companies, providing a basis for improving communication and optimizing workflows. The fifth, revised edition of the Media Standard Print was issued in 2007. It primarily establishes the following rules:

- A proof must simulate one of the five reference print conditions defined by the ProzessStandard Offsetdruck (German Offset Printing Process Standard).
- A proof must include a line of text indicating the file name, the output date, and the color management settings used.
- A UGRA / FOGRA media wedge must be included.
- The conditions for measurement and evaluation must be defined.

5.5. Benefits of Colorimetry for Offset Printing

To sum up, here is an overview of the main advantages that colorimetry offers for offset printing:

- The measurement values match the visual perception of the colors very closely.
- Colorimetry is a process-independent color evaluation method that can be used throughout the print process from prepress and all kind of proofs to final quality control of finished products.
- Colorimetric reference values can also be expressed as figures. A link to prepress is possible.
- Colorimetric reference values can be taken from specimens.
- Colorimetry is the only way to ensure objective evaluation.
- Colorimetry enables image-relevant color control (for instance using gray patches) without calibration of individual colors or stored conversion tables.
- All colors, including very light spot colors, can be controlled correctly and reliably with colorimetry.
- Dot gain is precisely captured by spectral measurement, including for spot colors.
- Control of the production run is more reliable because changes in the substrate, ink soiling and metamerism can be captured and taken into account.
- Halftone printing with more than four colors can also be controlled correctly.
- Print quality can be described and documented more effectively. There is a measure of color deviation that is independent of color tone – ΔE.
- Colorimetry enables the printing industry to get in sync with all other industries in which color plays an important role.
- Densitometry, for example to determine dot gain, is an integral part of spectral color measurement.
- Image fragments can also be compared with originals.

Glossary

Actual value
The value actually measured for a specimen.
> Reference value

Area coverage
The ratio of the area covered (with image elements) to the total area. The area coverage is generally specified as a percentage. A distinction is made in print between the effective area coverage calculated from optical measurements and the geometric area coverage calculated from area measurements.

Characteristic curve
The graphical representation of the relationship between the tonal values of prepress products, generally halftone data (tonal values), and the associated tonal values in print. > Dot gain

Color distance ΔE
ΔE describes the color distance between two colors and can be calculated as the distance of the L*a*b* values between two colors.

Color management
Method / system for coordinating the individual units and presses involved in the workflow from color image processing to finished print result. Color management is used to ensure correct color reproduction from input to output, for example on printing presses.

Densitometer
A density measuring device. Reflective densitometers are used for printing purposes. To determine the density, the result of a white measurement is set in relation to the measurement of the required color area. > Density

Density
The degree to which an ink layer is impermeable to light. On a theoretical level, this is the relationship between a measurement on unprinted paper and a measurement on printed paper.

Dot gain
Optical and mechanical process conditions result in halftone dots printed on paper being larger than the value defined in the data. The difference between the effective optical area coverage and the area coverage of the data is measured. > Area coverage

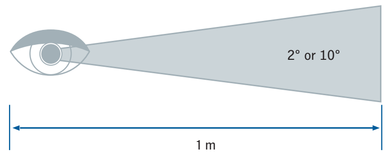
Ink fading
Term for the decline in the thickness of the ink film in the circumferential direction in offset printing.

Ink film thickness / ink level
The physical thickness of the ink applied. The ink thickness essentially determines the density value of a color area.

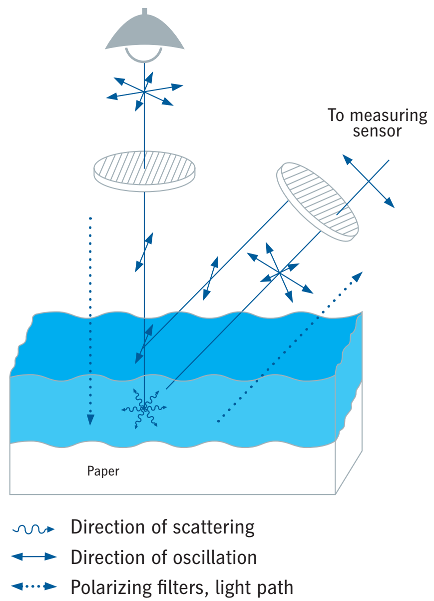
Metameric colors
Colors with different spectra that look the same under a given illuminant and different under other illuminants. This is also known as metamerism.

Mini Spots
Small print control elements that can be located anywhere on standard production jobs thanks to the limited amount of space they take up. The measurement values are then evaluated using the Quality Monitor and process or profile adjustments are made using the Calibration Tool or the Profile Tool from the Prinect Color Toolbox if necessary.

Nanometer (nm)
Unit of length, 1 nm = 0.000001 mm. For example, a fine hair has a diameter of 0.020 mm and one thousandth of this would be 0.000020 mm, i.e. 20 nm.



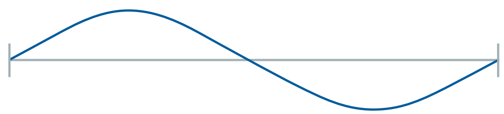
Polarizing filter
The polarizing filter can be connected upstream of the density measurement. Polarizing filters filter out the glare components of the light. This makes the measurement virtually independent of the specimen's drying status. One disadvantage, however, is that using the polarizing filter increases the density value of the specimen.



Reference value
Guideline value for a measuring specimen. The aim of every control operation is to ensure the smallest possible difference between the reference value and the actual value. > Actual value

Standard observer
A series of tests has been used to determine how the color perception of the average standard observer is linked to a specific color area. The 2° test setup reflects a typical situation for reading books and magazines. The 10° test setup simulates viewing of a billboard.

Wavelength
The physical length of a wave period.



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