



*Prinect*  
Color and Quality

**HEIDELBERG**

Guideline for Prinect Axis Control for  
printing presses with Prinect CP2000 Center



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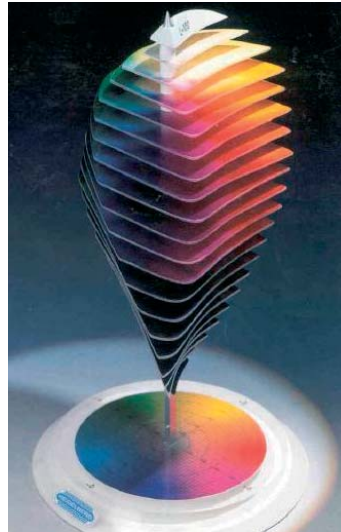
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# 1 Introduction

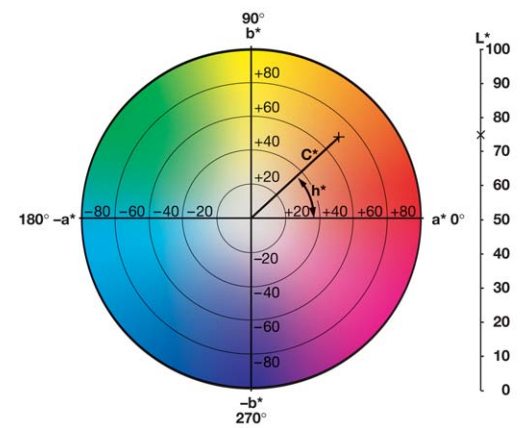
## 1.1 Definitions

<sup>1</sup>The correct notation is  $L^*a^*b^*$ .  
 $Lab$  will be used throughout this text  
 by way of simplification.

- Lab<sup>1</sup> color space, Lab values  
 To define a color precisely, its location within the Lab color space is indicated by three coordinates:  
 $L^*$ : lightness or luminance (0 = black, 100 = white)  
 $a^*$ : red-green axis  
 $b^*$ : yellow-blue axis  
 Neutral grey hues have  $a = 0$  and  $b = 0$ .

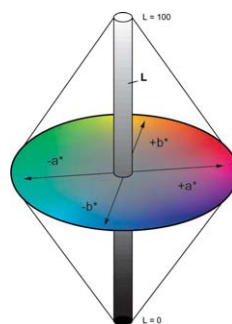


Left: Lab color space as a 3-dimensional model  
 Right: a/b color plane



<sup>2</sup>On-screen the letter d is used instead of  $\Delta$ .

- $\Delta E^2$   
 (pronounced: delta E) describes the distance between two colors within the Lab color space.  
 Distances within the Lab color system correspond to visually perceived differences between colors. In other words, a given  $\Delta E$  value will always be perceived the same regardless of the chrominance (colors) and lightness.



$\Delta E$	Perceived difference
smaller than 0.2	not visible
0.2–1.0	very small
1.0–3.0	small
3.0–6.0	moderate
larger than 6.0	large

- $\Delta E_0$   
 Describes the distance between the defined reference value and the best value achievable (best match) with the combination of ink and paper white being used.
- Density (D)  
 The density of a measurement patch is determined with the aid of an appropriate filter. There are standardized filters for the process colors

Black, Cyan, Magenta and Yellow. The densities of special colors are determined using the filter that yields the largest values.

- Z70

Indicates dot gain in the 70 % tint patch of Prinect® color control strips. Tolerance values are stored in a tolerance archive.

In order to obtain consistent results throughout a print run, the dot gain must remain constant. When making films and plates, it is also necessary to take into consideration how the halftone dot areas will thicken when transferred to the substrate during printing. Unless the plates are matched to the process, it will be impossible to get the right colors.

- S/D

Slur/doubling values as percentages

S/D values are determined from the area coverage differences in the line patches (also known as ladder targets). Tolerance values are stored in a tolerance archive.

- ΔF

Control parameters as percentages

ΔF values are determined by comparing the reference Lab values with the actually measured Lab values. They describe how far the measured color deviates from the reference value, expressed as a percentage.

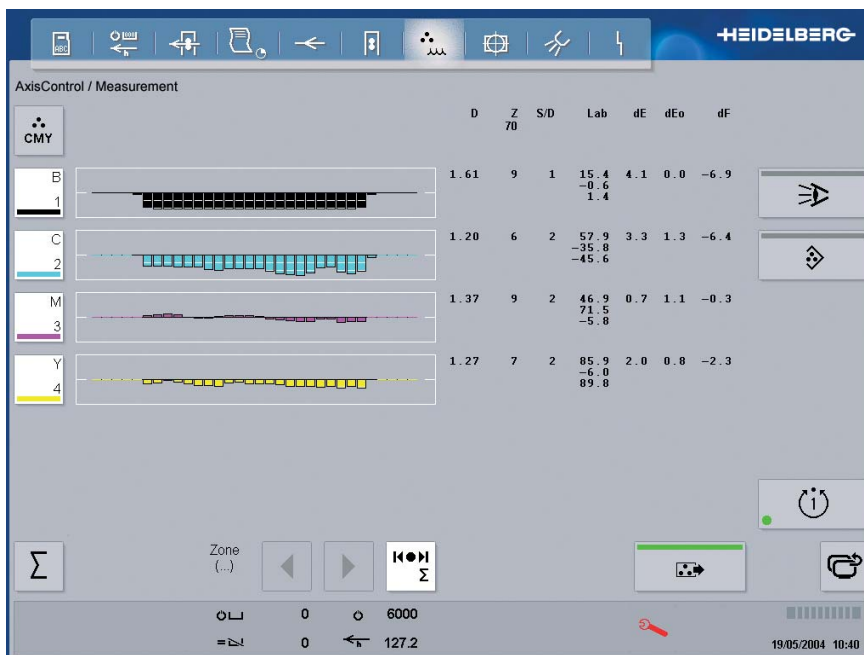
- Rules of thumb for the relationships among ΔE – ΔF – ΔD for the process colors:

1 ΔE ~ 3-5 % ΔF

1 ΔE ~ 3/100 ΔD

1/10 ΔD ~ 12 % ΔF

These conversions are only intended to provide a general orientation. These precise values will vary depending on the inks used, the color separation, and the ink film thickness.

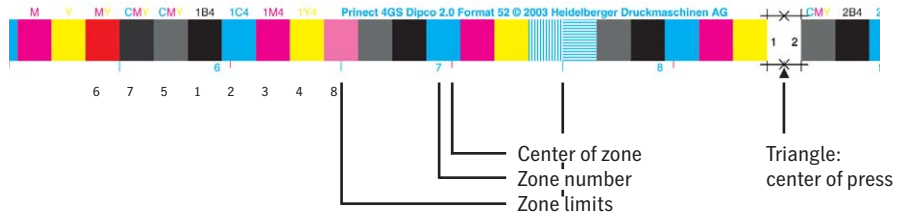


This figure shows the screen Axis Control/ Measurements. To the right of the screen you'll find numerical values for density, slurring/doubling, Lab, ΔE, ΔE<sub>0</sub>, and ΔF, in each case referring to the selected zones. On the left there is a graphical representation of the ΔF values for the individual zones and inking units. The reference value is set as the zero line. The bars indicate the magnitude of the deviations from the reference value. In this example, Cyan is under-inked across the entire width.

## 1.2 The principle of Heidelberg Color Control Strips

In the following, the color control strip “Prinect 4GS” and the functions of its individual patches are described in detail by way of example.

Section of a 4GS color control strip with explanations.



Color control strips consist of repeating sequences. The color control strip “Prinect 4GS”, for example, consists of sequences with a total length of 104 patches (corresponding to 520 mm or 16 zones).

The color control strip “Prinect 4GS” has various types of patches:

- Patches 1–4: solid patches, i.e. patches printed 100 % with one color, in this example the process colors CMYK (on the strip, B stands for Black). These patches are used to control solid colors.
- Patch 5: grey balance patch consisting of 70 % Cyan, 60 % Magenta, 60 % Yellow. Used for grey patch control of the chromatic colors CMY.
- Patches 6+7: solid overprint patches for determining ink acceptance when printing multiple colors on top of one another; widely described as ink trapping.
- Patch 8: halftone tint patch, here: Magenta. For determining dot gain values. Prinect color control strips have a 70 % tint patch, but other values are also possible.
- Patches 9+10: lines at different angles to identify slurring and doubling defects.

In Heidelberg presses, each ink zone is 32.5 mm wide, so there are exactly 13 measurement patches within two zones.

When mounting the color control strip, make sure that:

- It is correctly aligned with the ink zones of the press and
- There is a 5 mm paper white margin on the left and right end of the strip.

Important for the Prinect 6GS and 8GS color control strips: due to the large number of different patches and the fact that each patch is 5 mm wide, it is not possible for every type of patch to be within each ink zone. If a certain patch is not found in a zone, its value is assumed to be the average of the corresponding values from the two neighboring zones. No numerical values are displayed for deviations in these zones, because inking is controlled based on the neighboring zones. The graphical display in these zones shows the average of the neighboring zones.

The table below provides an overview of the different color control strips and their makeup.

## Solid and greyscale patches

	Patch type	every zone	Patch every other zone	3 per control strip
<b>Prinect 4GS</b>	Solid patch	K, C, M, Y		
	Greyscale patch	C, M, Y		
<b>Prinect 6GS</b>	Solid patch	K, X, Z		K, M, Y
	Greyscale patch	C, M, Y		
<b>Prinect 6GS99</b>	Solid patch	X, Z	K, C, M, Y	
	Greyscale patch	C, M, Y		
<b>Prinect 6S</b>	Solid patch	K, C, M, Y, X, Z		
	Greyscale patch			
<b>Prinect 6S+</b>	Solid patch	U, V, S1, S2, S3, S4		
	Greyscale patch			
<b>Prinect 8GS</b>	Solid patch		K, C, M, Y, X, Z, U, V	
	Greyscale patch		C, M, Y	

## Special patches

	Ink acceptance patches	Dot gain patches	Slurring/doubling patches
<b>Prinect 4GS</b>	CM, CY, MY, CMY	K, C, M, Y	K, C, M, Y
<b>Prinect 6GS</b>	CM, CY, MY, CMY	K, C, M, Y, X, Z	K, C, M, Y, X, Z
<b>Prinect 6GS99</b>	CM, CY, MY, CMY	K, C, M, Y, X, Z	K, C, M, Y
<b>Prinect 6S</b>		K, C, M, Y, X, Z	
<b>Prinect 6S+</b>		U, V, S1, S2, S3, S4	
<b>Prinect 8GS</b>	CM, CY, MY, CMY	K, C, M, Y, X, Z, U, V	K, C, M, Y

Prinect® Axis Control® also lets you define your own customized color control strip that is structured differently from the Prinect color control strips. However, be aware that the individual patches may not be smaller than 5 × 6 mm. For details on how to do this consult: “Creating and Editing Color Control Bars” in the User Manual.

### 1.3 Why is a color control strip or are several patches not detected?

- **Wrong reference value → difference between reference and actual values too large**
  - Wrong color set loaded
  - Soiled ink(s)
  - Wrong measurement conditions set
- **Swapped color separations**
  - Reference values are incorrectly assigned in Prinect Axis Control
- **No calibration or incorrectly calibrated**
- **Paper or lenses soiled**
- **Wrong color control strip positioned**
  - If the color control strip is not in the archive, it can be created and saved with the correct definition and size.
- **Sheet and color control strip upside down or rotated**
- **Color control strip printed too close to edge of sheet**
  - There must be least 5 mm of blank white paper between the color control strip and the edge of the sheet on the left and right.
- **Measuring head incorrectly positioned**
  - Use the arrow keys on the console to precisely position the green mark in the middle of the patch.
- **Lamp defective**
- **Printed inks cannot be correctly measured (e.g. metallic inks)**
- **Actual measurement value is too far off the reference value (> +20%)**



## 2 Functions and Features of Prinect Axis Control

Prinect Axis Control is a color measuring system for all print shops wishing to efficiently monitor quality right at the control console of their Speedmaster®. Because it is fully integrated into the ergonomic design of the Prinect® CP2000 Center®, it can be used on all models.

### Functionality and capabilities

- Spectrophotometric color measurement in color control strips
- Measurement of quality parameters – colorimetric and density values for solid and grey balance patches, slurring/doubling, dot gain, trapping, relative print contrast and metamerism.
- Storage of values for repeat jobs
- Job reports for quality analysis and documentation with the add-on tool “Prinect Axis Control Reporting”
- Color database (HKS, Pantone)
- Digital measurement elements (Dipco) for prepress included
- Integrated in Prinect CP2000 Center for direct process control
- Online control of inking in individual printing units
- Reliable control of special colors with high reflectance
- Objective color measurement and control

### The limitations of Prinect Axis Control

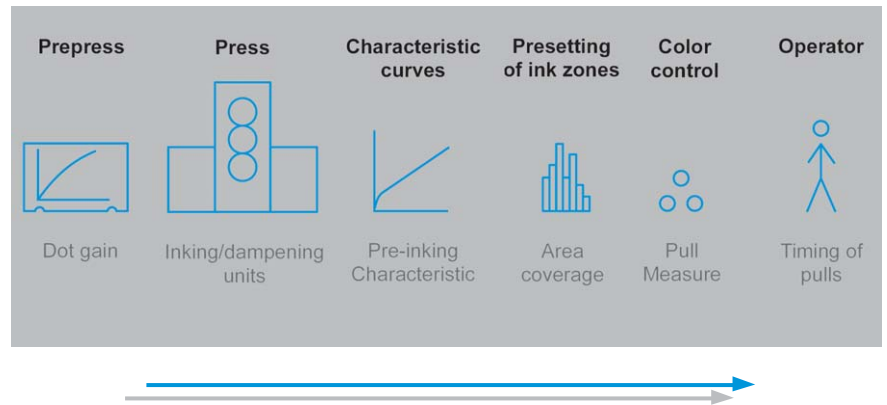
Prinect Axis Control cannot be reliably used to measure and control print results with:

- Metallic inks
- Opaque inks
- Transparent substrates (plastic sheet)
- Metallized substrates
- Color control strips with patches smaller than 5 × 6 mm



### 3 Basic rules to optimized printing

Use of the Prinect Axis Control color measurement system alone does not automatically guarantee that the results will meet expectations. The reference values can only be approximated. Color control works best with an integrated workflow that begins in prepress and extends down through the production process to the press operator. In the following, the important aspects for getting the best possible results with Prinect Axis Control are described.



## 1. Determine the dot gain in the production process

Adjust platemaking to take account of the dot gain when printing

## 2. Get the press ready<sup>3</sup>

- Put the press in a stable, reproducible state
- Determine optimum reference values (= color standards) for standard process colors

## 3. Optimize pre-inking and characteristic curves for presetting the inking<sup>4</sup>

- Pre-inking: get inking units in the right state for production
- Presetting of inking: determine how far the zones should be opened to achieve the desired color standard

## 4. Use presetting data

Preset the zones for the right area coverage values. Sources for values: Prinect® Prepress Interface or Plate Image Reader.

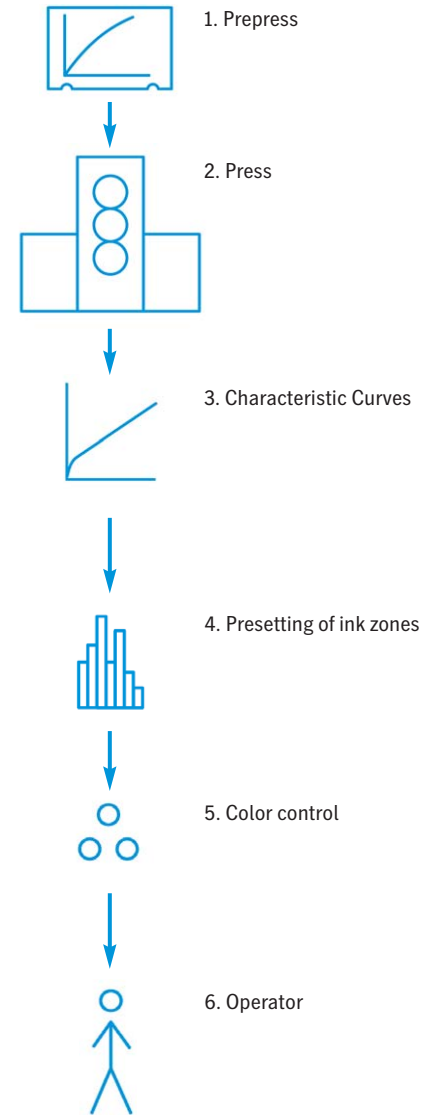
## 5. Color control only with Prinect Axis Control

Do not change zones by hand: this interferes with the control system and results in poorer quality!

## 6. Responsibilities of the press operator

- Make sure that the inking unit is in a stable state; check for the green indicator on the Prinect® CP2000 Center.
- Printing just short of where smearing begins: minimize the dampening solution feed to obtain high-contrast reproduction.

Under optimum conditions the desired colors of less than  $\Delta E 5$  compared to the reference values can be achieved after printing about 130 sheets. From here on, Prinect Axis Control can take over.



<sup>3</sup>All press settings should be performed again at least once a year.

<sup>4</sup>For details on how to proceed, see "Prinect Color Solutions".

When press sheets are pulled for inspection, the inking units must be in a stable state. Sheets pulled too soon may exhibit excessive or insufficient inking because they are still increasing or decreasing. That is why it is important to watch for the green indicator on the Prinect CP2000 Center display – it's better to pull a bit later than too early!

If the level of less than  $\Delta E 5$  compared to the reference value is not attained in the first sheet pulled, recheck the characteristic curve for presetting the inking.

If, while printing a typical form with normal area coverage, the inking units take considerably longer than 130 sheets to stabilize, check the pre-inking setting and adjust it if appropriate.

## 4 Basic settings of Prinect Axis Control

### Check calibration; regularly recalibrate

- Use the provided customized calibration card.
- Heidelberg® Service will perform the first calibration. It should then be repeated every three months.

### Define measurement conditions (*Job/Axis Control/New/Options*)

The defined measurement conditions are important for comparing results obtained using different devices.

### Light

- D50: daylight, slightly reddish
- D65: daylight, slightly bluish
- A: standardized light bulb light, reddish
- C: standardized daylight but without UV portions

D50 is the standard applied in the European printing industry.

### Observer

Selectable between 2° and 10° standard observer.

The default setting for offset printing is the 2° standard observer.

### Filter

Selectable between polarized and unpolarized.

Polarization filters remove surface reflections from the ink. As a result, measurements of wet and dry sheets are nearly identical. Polarization filters only affect the density values. The filters are not applied for the Lab values. Measurements with Prinect Axis Control though are always made in an unpolarized mode, because Prinect Axis Control does not have a physical polarization filter. The “polarized” density value is calculated from the unpolarized spectral measurement.

### Density filter standards

The following filters are defined for density measurement:

Selectable filter sets: DIN 16536 NB, DIN 16536, ANSI A, ANSI T

For Prinect Axis Control, the recommendation is to use either “DIN 16536” or “AnsiT” (in North America).

### Color control strips

In “*Service/Archive/Color Control Bar Archive*” you can suppress unused color control strips. The most frequently used bar can also be preselected.

- For analog mounting: use CPC color control strips
- For digital mounting: use Prinect (or Prinect FOGRA) color control strips

Note: unused color control strips should not be irretrievably deleted, but only moved to the “unused color control strips” field. They then disappear from the standard menu, but if needed can be re-enabled for use.<sup>5</sup>

<sup>5</sup> None of the color control strips supplied with the equipment can be deleted; only user-defined bars can be erased. See the User Manual for details on how to create your own color control strip.

### Defining a color set

An appropriate color set must be defined for the ink series and stock quality used. For information on the possibilities for determining reference values, please read section 6.2 “Creating color sets”.

### Tolerances

Display of deviations in the measurement overview menu

- Outlined bars for deviation within  $\Delta E$  tolerances
- Solid bars for deviation outside the tolerances

The “tolerance” setting only affects how setting parameters are displayed on-screen. It does not influence the precision of any follow-up recommendation!

## 5 Typical make-ready for a new job

### 5.1 Procedure

#### Make-ready

- Set the stock format
- Assign colors to the printing units using the color symbols.
- After about 130 sheets, pull a sheet; make sure that the green indicator is lit, indicating that the inking units have stabilized (see figure below).
- Set the measurement conditions, substrate class and tolerance (*narrow/medium/wide*).
- Measure substrate (= paper white).
- Color assignment: from a suitable color set (see 6.2 “Creating color sets”) in the color archive or from individual measurements using the function “*Sample*”.
- Select a color control strip and position it.

When there is a connection to prepress via Prinect Prepress Interface and data is supplied for positioning the color control strip on the sheets, the measuring head is automatically pre-positioned.

- Check whether the graphical and numerical values are plausible. If not, double-check the settings!
- Approve the follow-up recommendation.
- After two to three follow-ups the reference colors are achieved.

#### Production

- Regular pull, measure and follow-up sheets. Here too, make sure that the green indicator is lit!
- If necessary, manually adjust reference values: OK sheet/zonal transfer/change(%) /block zones (see 6.3: “Changing reference values”)



Adjustment being initiated

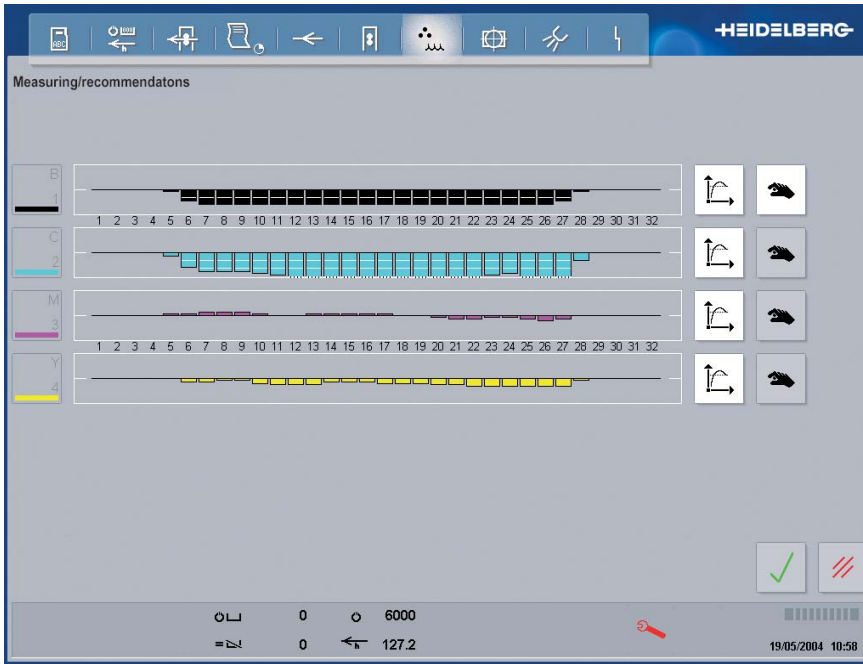


Adjustment being made

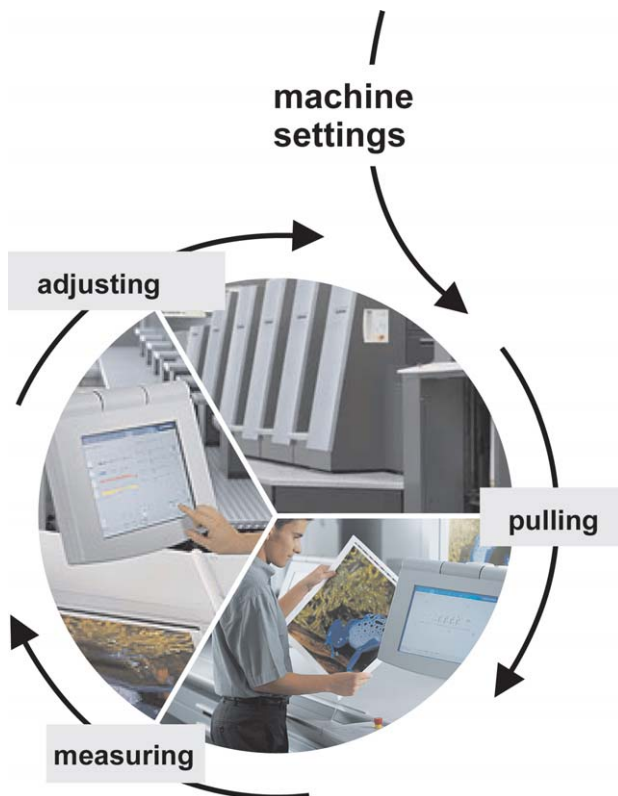


Adjustment completed –  
inking stable again

The green indicator and how to read it.



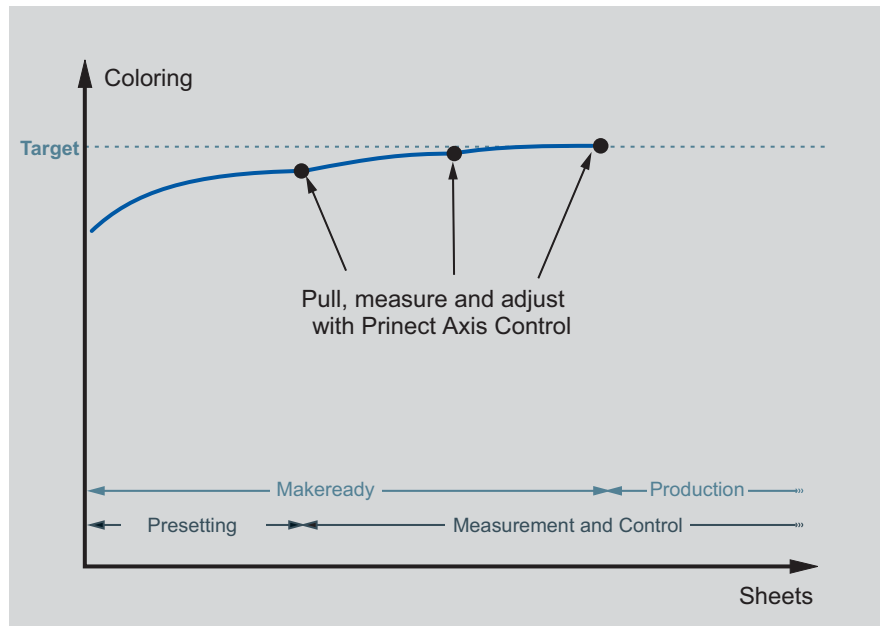
This figure shows the screen “Measurement/adjustment recommendation”.  
 Shown here: Dio (from dF, zonal profile and control algorithm)  
 In measurement: dF, i.e. colors relative to reference values.  
 Here the function “Color Booster” can be individual enabled and disabled for each inking unit.



Schematic of the cycle “pull-measure-follow-up”.

## 5.2 Changes during a job

If everything is done correctly as described in “basic rules for optimized printing”, the colors will approach the reference values during printing roughly as shown here:



Optimum make-ready with presettings.

The first step toward reaching the reference values is made with pre-inking, the characteristic curve for presetting the inking, and ink presetting data. The inking units are filled with ink beforehand and allowed to stabilize for production.

**IMPORTANT:** Don't pull sheets prematurely.  
Make sure the green indicator on the Prinect CP2000 Center is lit!

With optimized presettings, the colors should be approx.  $\Delta E$  5 compared to the reference levels.

It takes about three follow-ups to achieve a deviation smaller than  $\Delta E = 2$ , which should then remain stable for individual zones over the print run as a whole. It should be taken into account, however, that the printing conditions can change with longer runs.

Zones that are outside the printed image or contain a certain color only in the color control strip should be blocked, as they are not relevant to the results of printing.

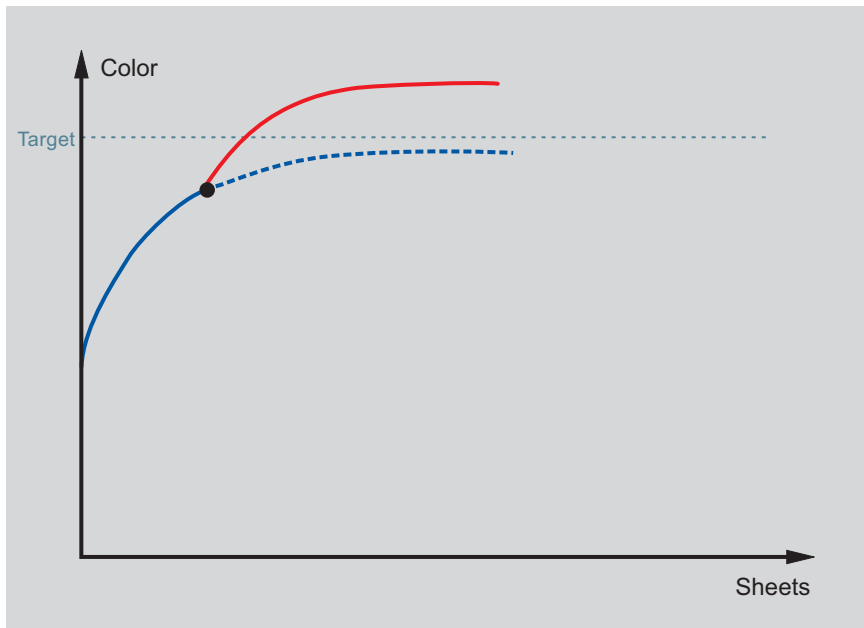


If the first inspection sheet pulled exhibits color deviations larger than  $\Delta E 10$  (despite using data from Prinect Prepress Interface or Plate Image Reader and pre-inking), recheck the press settings. If there is a clear tendency for over- or under-inking to occur, the characteristic curve for presetting the inking and the pre-inking settings should be adjusted.

Particularly over-inking of the first sheet pulled is a critical sign. It may be helpful to wash the press and restart the job with different presettings. Because the inking units act as reservoir, especially when running low coverage they can be slow to adjust and quite a few waste sheets may have to be printed before the lower inking level is reached.

If it is impossible to consistently reproduce the reference density, this may be because the inking unit has not stabilized. Possible causes:

- Zones have previously been manually adjusted
- The rotational speed of the ink fountain roller or the use of oscillators has been changed
- The press speed has been changed but the characteristic curve for speed compensation is not appropriately defined
- The feed rate or composition of the dampening solution has changed
- **Premature pull (see figure)**



Inspection sheet pulled before the inking unit has stabilized. The result: inking is overcompensated.

## 6 Reference values

### 6.1 Color sets

The reference values for color control are stored in color sets. Each color set should at least contain values for:

- The paper white
- The process colors
- The grey balance patch

It can also contain Lab values for non-process colors.

It is absolutely essential to measure the actual stock used for each job. This value can then be used to adjust the stored color values.

Prinect Axis Control comes with standard color sets designated “Heidelberg”. These only represent average values for various ink series. It is therefore important for you to define your own color sets for the inks and paper classes used.

### 6.2 Creating color sets

- In Service/Archive/Color Archive you can copy an existing color set and assign a meaningful name (e.g., name of the ink series used) to the copy.
- Select the stock quality (glossy/matt coated/uncoated).
- Use a sample (preferably a freshly printed sheet with the reference colors) to measure and save first the paper whiteness value, then the solid patches, and if relevant the grey balance patches as well.

It is absolutely essential to measure the paper white first!

### 6.3 Ways of entering reference values

#### 1. Reference values from DIN ISO 12647

Lab reference values cannot be numerically keyed into Prinect Axis Control. Reference values should be captured from a series of color reproductions. To comply with the stipulations of DIN ISO while printing, the color closest to the value specified by the standard should be incorporated into a color set. If necessary, it can then be adjusted by an appropriate percentage.

Note: the permissible tolerance of  $\Delta E = 5$  is reduced by the color deviation  $\Delta E_0$  between the set reference value and the values stipulated by DIN ISO.

#### 2. Color samples from color books

Color sample collections are available for non-process ink series. It is possible to read in a sample and add the measured value to a color set.

Color samples can only be used if the substrate on which the book is printed are the paper used for the pressrun are of the same type (glossy/matt coated/uncoated) and if the book stock's whiteness is also measured before. It is advisable to print a specimen of a non-process color, visually assess it, and then insert it into the color set. This lets you take account of batch-to-batch fluctuations and printable ink film thicknesses.

### 3. Measuring an OK sheet

For recurring jobs, it is possible to scan in color patches from the OK sheet of the original job and store the results in a color set.

Please note that, for process-related reasons, measurements are always made in unpolarized mode and are therefore different depending on whether the sheet is moist or dry. Consequently, controlling the colors of freshly printed sheets based on values read in from a dry OK sheet may yield results that deviate slightly from it.

### 6.4 Reference values from a print series

Reference values should always be determined from a series of prints. The aim is to determine the value that yields the highest density in the solid patch without dot gain causing the 70 % tint patch to fill in. This permits high-contrast printing.

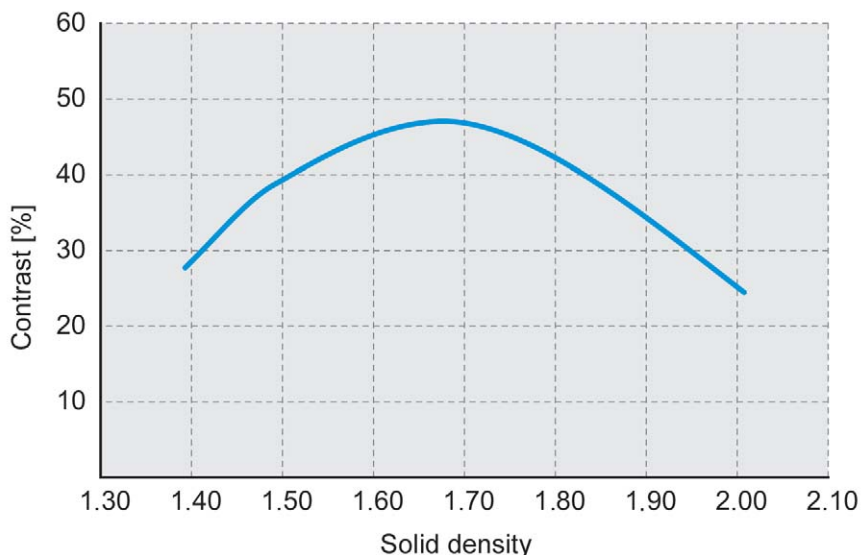
Procedure:

- Print sheets with inking levels ranging from too low to too high.
- Apply the Murray-Davies formula to calculate the maximum print contrast from 100 % and 70 % patches on different sheets:

$$K = \frac{D_V - D_{70}}{D_V} \times 100;$$

where K = relative print contrast as a percentage value  
 $D_V$  = density of solid patch  
 $D_{70}$  = density of 70 % tint patch

That color level is best at which the relative print contrast is the highest. The reference value for the color separation can be taken from this sheet for the color set.



Idealized representation of a print series. In this example, the greatest print contrast is achieved at a color level of approx.  $D=1.7$ .

**Very important:**

In color sets, a distinction is made between the paper classes of “glossy coated”, “matt coated” and “uncoated”. The most important differences between these types have to do with surface gloss (calculation of polarized and unpolarized density) and ink absorption/acceptance when overprinting different colors. In order to properly use a color set, these basic material properties must be identical in the source and the paper actually being used for the print run. Each color set is therefore limited in its application to the same stock type for which it was defined. The differences between “glossy coated” and “matt coated” are minimal, however.

The value for the paper white must always be included in the color set!

Printing inks are translucent, and the substrate consequently always affects the color. Normally, color sets are measured from the printed sheet and defined accordingly. The paper white will be compensated by calculation so that the color set can also be used with other papers.

## 6.5 Changing reference values

Reference values contained in a color set can be changed if necessary. There are various ways to do this:

### 1. Changing reference values during job preparation

Right when creating a job, the reference density value can be manually changed to the desired value in steps of 0.01. The corresponding Lab values are automatically adjusted accordingly.

### 2. From an OK sheet

If a sheet has been defined as OK based entirely on a visual assessment (which often happens when getting a customer’s approval), it can be defined as the new standard. After approval of an OK sheet, inking is then no longer controlled based on the values stored in the color set but instead using the OK sheet as the reference.

### 3. Zonal transfer

Zones on the press sheet in which the colors have been defined as OK can be transferred to other zones. Especially when printing multiple “ups” or image copies, this function is very useful. Please note, however, that an average value derived from the selected source zones is transferred and not the actual zone profile.

When working with a perfecter press, in double-sided mode you can use the function “transfer to other side”.

#### 4. Changing by a percentage value

For measurement and color control, the color level can be adjusted by a percentage. As soon as you confirm the changes, they are displayed as the new deviation to the reference.

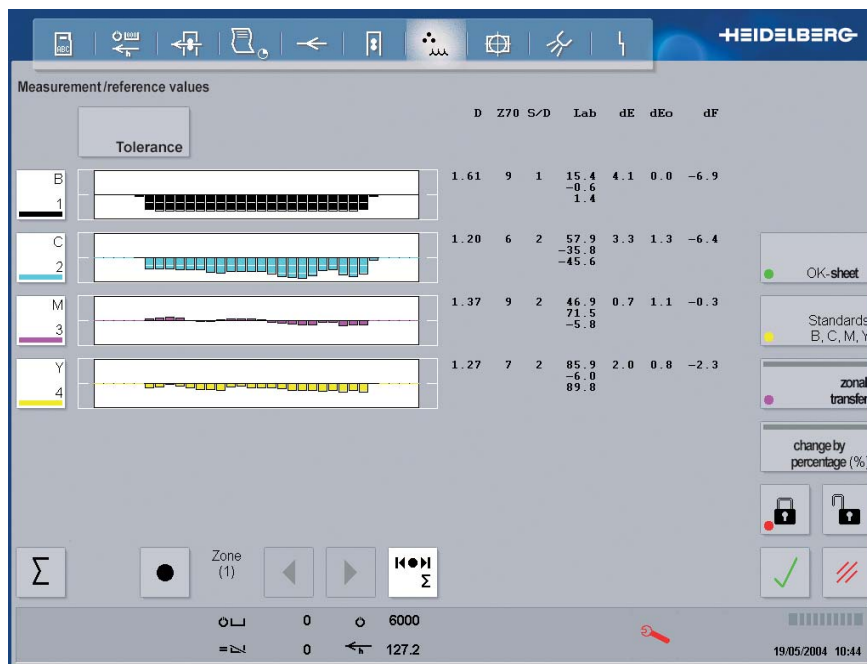
Density and Lab values never change independently of one another. Both are based on the spectral distribution of the light reflected by a patch and captured by the measuring head. The Lab and density values are calculated from this spectrum.

If the thickness of the printed ink film changes, its reflectance also changes. The resulting different spectrum causes the Lab and density values calculated from it to change as well.

The possibilities for changing reference values should only be utilized when absolutely necessary, however. Instead of making manual changes, it is better to define the color set so that the desired print results are achieved entirely by making measurements and to follow-up the calculated recommendations. It is also important to ensure a standardized printing process with consistent reference values. This nearly eliminates the need for manual changes.

If Prinect Axis Control indicates substantial color deviations although a sheet looks fine, this can have the following causes:

- Wrong color set selected, so that the wrong reference values are being applied
- Paper white not measured in an unprinted area of the sheet
- Incorrect measurement conditions or the wrong paper class defined



The view “Measurement/reference values” with the buttons “OK sheet”, “zonal transfer” and “change by percentage”.

## 7 Control methods

Prinect Axis Control offers a choice between solid control and grey balance control for the chromatic colors CMY.

### **Solid control**

Here control is based on the solid patches for each color separation. Black and all non-process colors are always controlled using the solid patches.

### **Grey balance control**

The grey balance patches are used to control the balance among the process colors C, M and Y. These color separations are overprinted with area coverage values of C = 70%, M = 60% and Y = 60%.

Some color control strips, including the Prinect 6GS, are specifically designed for grey balance control and only have solid patches for CMY in a small number of zones.

Advantages of grey balance control:

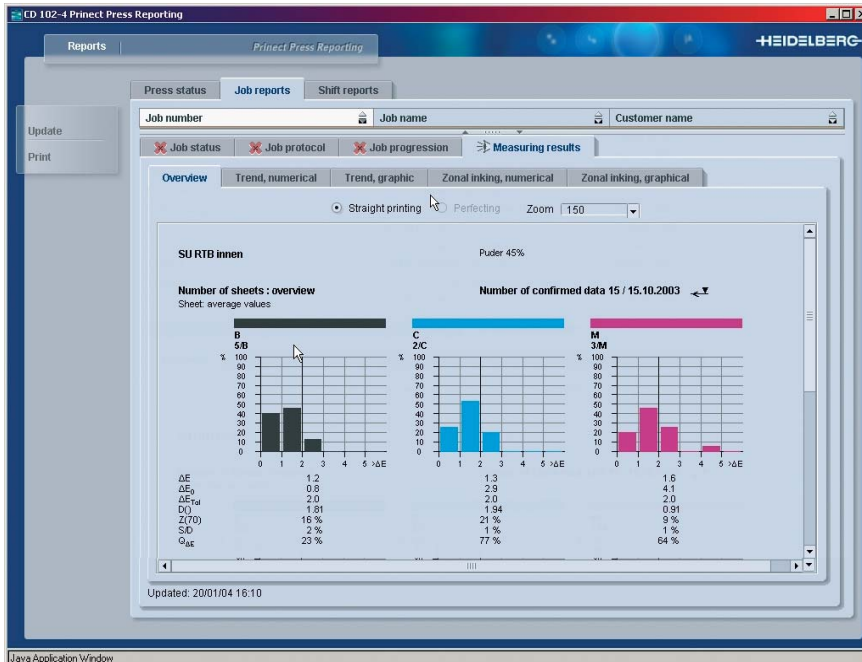
- Minimal color fluctuations and changes are registered during the production run.
- The color balance is critical for the visual appearance of a printed image.

The grey balance reveals even the tiniest changes in printing conditions, inking or register.

# 8 Reporting and protocol functions

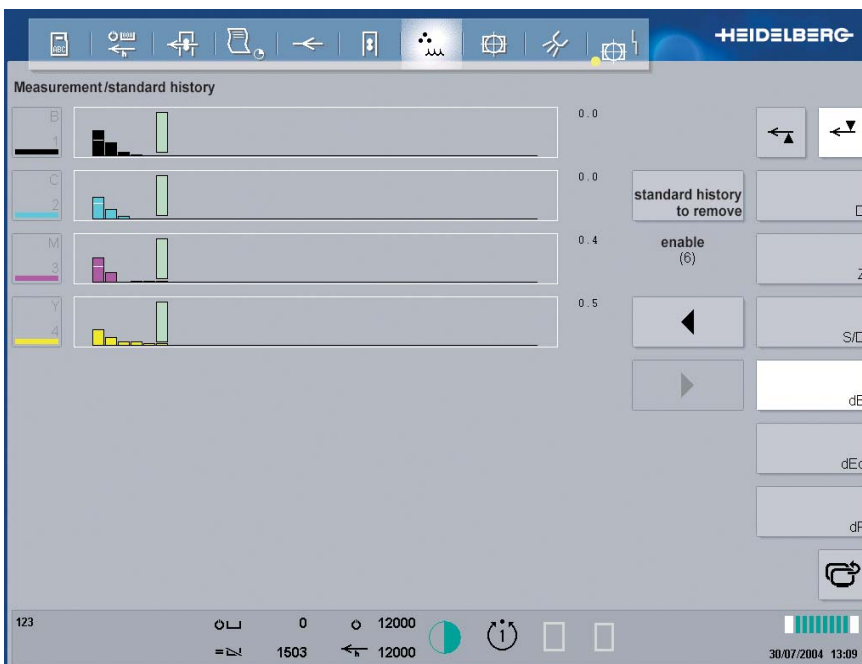
## Prinect Axis Control Reporting

This software module permits detailed documentation of all follow-ups and their specific data so they can be called up on a networked PC. The reporting module must be additionally licensed and enabled.



## Control history

Every time you follow-up the average values for density, dot gain, slurring/doubling,  $\Delta E$ ,  $\Delta E_0$  and  $\Delta F$  are saved in the control history and are displayed there.



# 9 Quality: the reason for color measurement and color control

## 9.1 The goals of color measurement and color control

- To achieve specified reference values
- To faithfully reproduce originals
- To deliver demonstrably consistent print quality
  - Colors are always controlled on the basis of changes in ink film thickness. Two ways of accomplishing this are widely spread in the printing industry: densitometry and colorimetry.
  - Densitometry is optimized for chromatic colors in offset printing. Colorimetry, by contrast, can be universally used for all processes, because it simulates the perceptions of the human eye (see section 10.1: “Human color perception”).

## 9.2 Spectral measurement and colorimetry

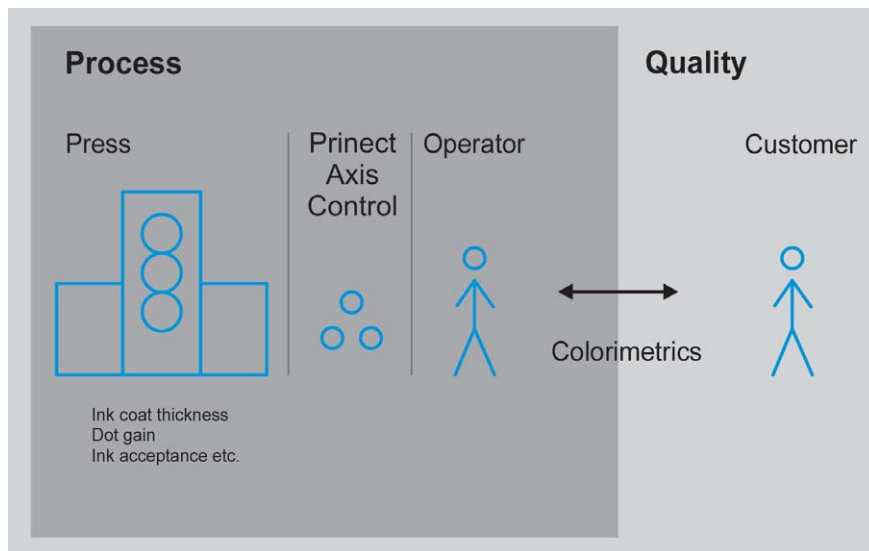
Spectral measurement is the basis for calculating color measurement figures, whether these are density or colorimetric values. Prinect Axis Control also displays density values, as well as parameters derived from them: dot gain and slurring/doubling. Colorimetric values are used to control color by minimizing the colorimetric discrepancy  $\Delta E$  between the actual print results and the reference value. The goal is to achieve the best possible color match between both. Colorimetric color control makes use of a color model that combines the color appearance of the printed ink with its thickness on the sheet. This process is computerized and automatic. The press operator is thus free to concentrate completely on the results of control: the recommendations made by Prinect Axis Control for adjusting the inking. The advantages of this control strategy:

- Only colorimetric control ensures compliance with DIN ISO standards.
- The color balance can be controlled using the sensitive grey balance patches.
- Control of special, non-process colors is significantly better than density-based control.
- Spectral measurement can compensate for ink soiling, batch-to-batch fluctuations in the ink, and changes in the substrate being printed on by appropriately controlling to the  $\Delta E_0$  value.
- Spectral measurement is the only way to generate ICC profiles. This enables prepress to make plates that are tailored to the inks and stock used.
- A  $\Delta E$  value can be intuitively understood as a measure of color deviation without possessing any specialist knowledge, because it corresponds to normal human color perception. Density variations can influence the appearance very differently depending on the color separation.



If you only had to deal with the production process itself, it would definitely be possible to successfully apply different color control strategies, at least for the process colors.

But when dealing with customers and struggling to ensure standardized printing conditions, it is necessary to make objective statements about quality. Lab color values and the deviation  $\Delta E$  are the best way to make generally valid quality assessments. Controlling the production run on the basis of colorimetric values makes it possible to directly implement and monitor the customer's quality stipulations right at the press.

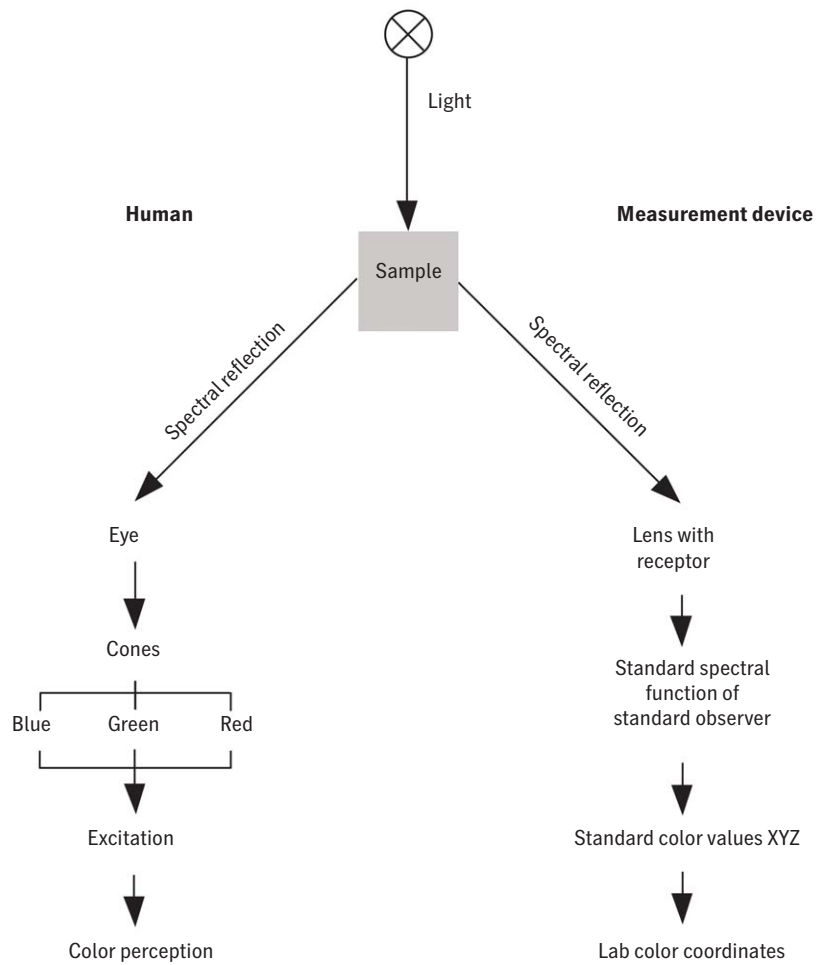


# 10 Color theory

## 10.1 Human color perception

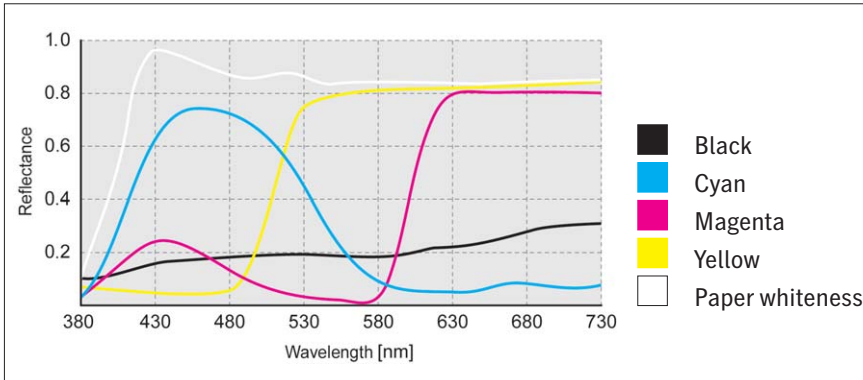
The human eye perceives colors with three different types of receptors, so-called cones, each of which responds to light of different wavelength ranges. When light enters the eye, the corresponding cones are stimulated and relay nerve pulses to the brain. It is there that actual color perception results.

Spectral measurement devices simulate this process by spectrally measuring the light striking them and using the results to calculate the standard color values XYZ. These can in turn be used to directly calculate Lab color coordinates, among others.



## 10.2 Spectral distribution of the visible light

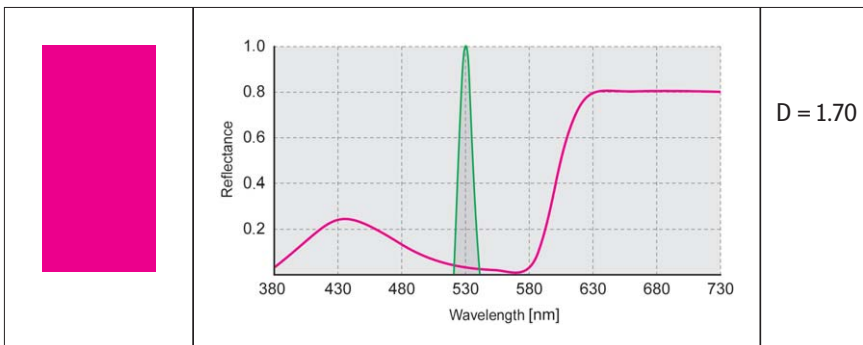
Prinect Axis Control measures the spectral distribution of the light with a resolution of 10 nm. These values – called reflectance values – are the basis for all subsequent density and Lab value calculations. Measurement is performed by bending the light through a lattice. Wave lengths between 380 and 730 nm are captured.



Example reflectance curves of CMYK and paper whiteness.

### From spectrum to density value

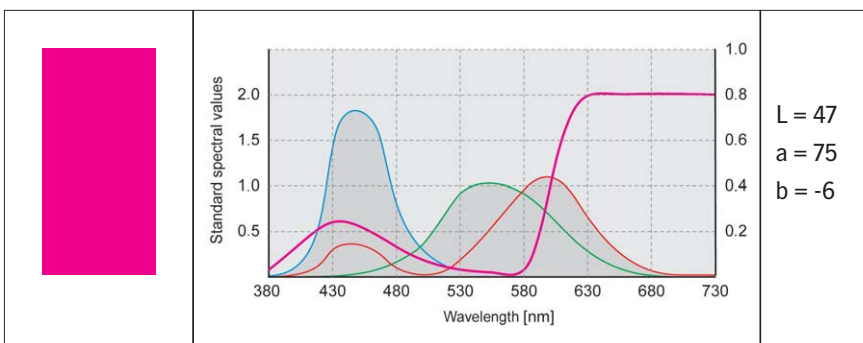
Density values are defined by the reflectance of the light captured in the wavelength range of the filter used. The rest of the spectrum is ignored. There are standard filters for the process colors Cyan, Magenta, Yellow and Black.



Reflectance curve of a solid Magenta patch, obtained with the corresponding standard narrowband filter.

### From spectrum to Lab value

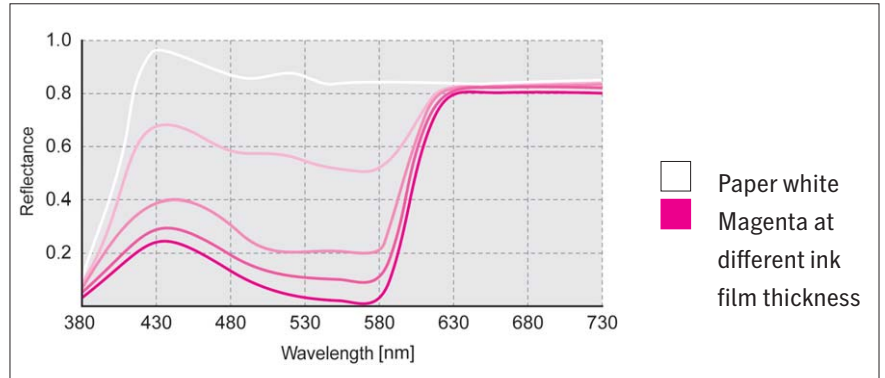
The Lab values are calculated using the standard spectral value functions defined by CIE. There are three such functions, corresponding to the three types of color receptors in the human eye. As can be seen in the figure, the entire visible spectrum is captured.



Spectral pattern of a solid Magenta patch, with standard spectral value functions.

### 10.3 Two control strategies: Density and Lab

Both D and Lab change depending on the ink film thickness. Because the ink film thickness is the only controllable parameter in printing, it is obvious that both values will always change at the same time. For example, when ink zones are opened further this increases the ink film thickness. This affects the remitted spectrum and thus both, the density and the Lab value.



#### Density:

Within the range that is relevant for offset printing (ink film thicknesses of around 1  $\mu\text{m}$ ) the density of the standard processes colors changes almost linearly in relation to the ink film thickness. Changes in the film thickness can thus be directly expressed as differences in density.

For example, increasing the ink film thickness by 10% normally also increases the density by approximately 10%.

However, even if the reference density is precisely achieved this does not mean that the color will have the desired appearance. This is only the case in absolutely stable, standardized processes, which hardly ever occur in actual practice.

#### Lab:

In the Lab color space there is also a virtually linear relationship between color coordinates and ink film thickness. However, the three-dimensional nature of this color space makes it considerably more difficult to depict changes in ink film thickness. The  $\Delta E$  value is therefore used as an easily visualized way of representing changes in the color coordinates and thus also the ink film thickness.

The goal of colorimetric control is to approach the reference value as closely as possible. The remaining color deviation, which cannot be eliminated with the printing process as it stands, is indicated by  $\Delta E_0$ .

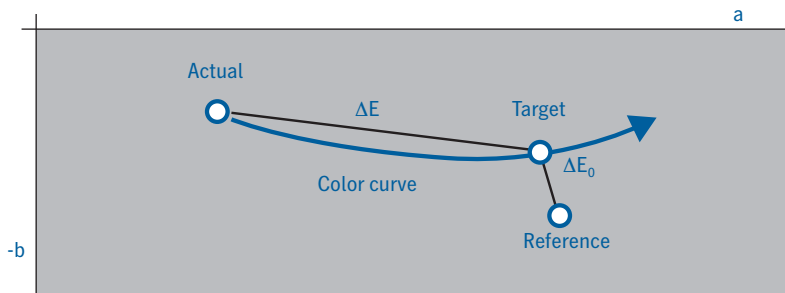
### 10.4 What does “ $\Delta E_0$ ” mean?

For every combination of ink and paper, the curve of printable colors can be determined within the Lab color space by measuring prints with different ink film thicknesses and patches with different halftone values.

Colors that are not located on this curve cannot be achieved with that particular combination of ink and paper. The distance from the best achievable point on the curve is defined as  $\Delta E_0$ .

$\Delta E$  describes the discrepancy between the measured color value and the achievable color value, the best match.

- When the best possible result has been achieved with the ink used,  $\Delta E$  is equal to zero.
- When the achievable color falls short of the desired color, the distance between them is indicated by the value  $\Delta E_0$ . This color deviation cannot be reduced by control. The only way to reduce  $\Delta E_0$  is to change the printing process, for example by using a different ink.
- Consequently,  $\Delta E$  and  $\Delta E_0$  are not interdependent values.



Starting at the actual color, the color curve passes through the colors that are achievable by varying the ink film thickness.

Possible reasons for a large  $\Delta E_0$  value:

- Soiled ink
- Wrong reference value assigned
- Incorrect settings for measurement conditions and paper class
- Paper white incorrectly measured
- Paper white has changed during the run
- Different ink used
- Ink batch is non-standard

### 10.5 Lab values of actual printing inks

The following values are provided only by way of example; the Lab values will be different depending on the ink series, the ink film thickness and the paper. The “process standard for offset printing” according to DIN ISO 12647<sup>6</sup> can provide an orientation:

<sup>6</sup> Measurement as per DIN ISO 13655: light type D50, 2° observer, geometry 0/45 or 45/0, measured on a black base.

Paper type	Coated (Paper classes 1 and 2)			Uncoated (Paper class 4)		
	L	a	b	L	a	b
Black:	16	0	0	31	1	1
Cyan:	54	-36	-49	58	-25	-43
Magenta:	46	72	-5	54	58	-2
Yellow:	88	-6	90	86	-4	75
Red (M+Y):	47	66	50	52	55	30
Green (C+Y):	49	-66	33	52	-46	16
Blue (C+M):	20	25	-48	36	12	-32

# 11 Types of measurement devices

## Measurement parameters for the printing industry:

- Measurement geometry: 45°/0° or 0°/45° (angle at which light strikes first the sample and then the measuring head)
- (Light type) Illuminant: D50 (modeled after natural daylight, slightly reddish)
- Observer: 2° standard observer

## 11.1 Spectral color measurement

Spectral measurement is performed by bending the light through a lattice. Prinect Axis Control captures light in the wavelength range from 380 to 730 nm with a resolution of 10 nm.

Procedure:

- Calibration to absolute white and adjustment according to the standard paper white
- Measurement of the sample
- Calculation of the spectral reflectance values  
The values obtained are placed in relation to the corresponding values of the paper white for each wavelength range (within the limits of the achievable resolution of 380nm – 730nm). This yields a spectral distribution that is independent of the actual light source used!
- Calculation of the Lab value  
A series of calculations is performed on the obtained spectrum to determine the Lab value.
- Calculation of the density  
Density filters stored in the device are applied to the spectrum to obtain the density values.

## 11.2 Density measurement

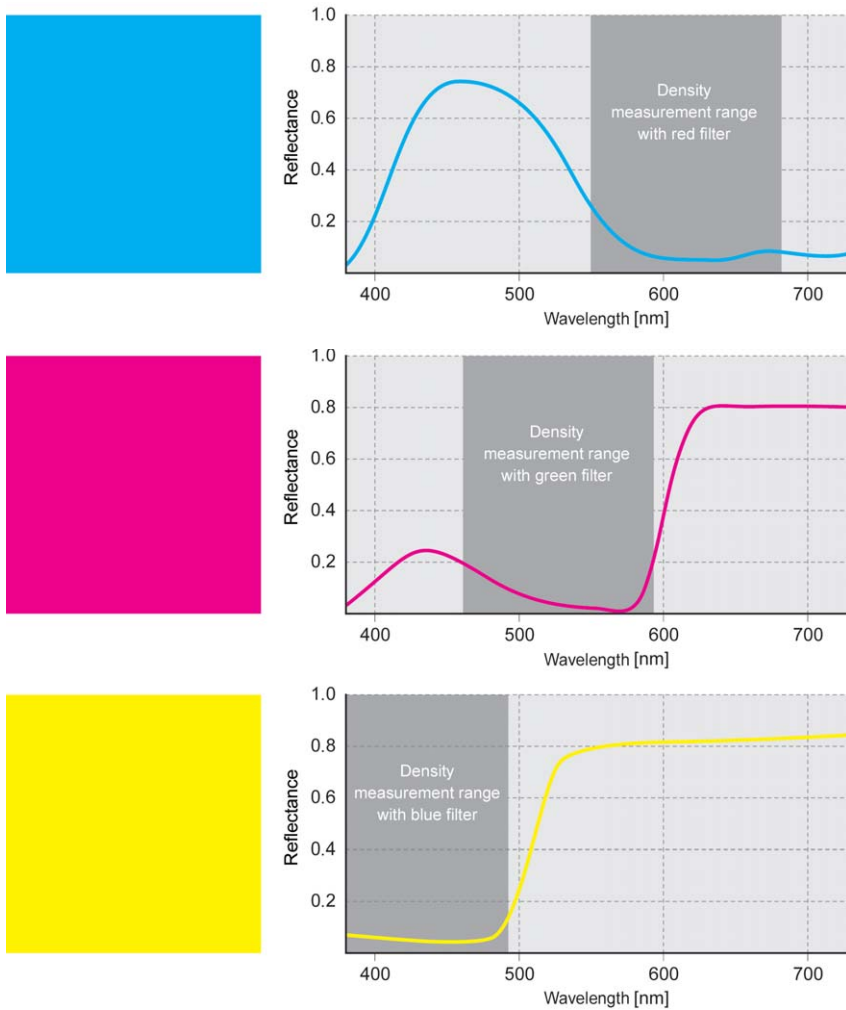
Densitometry is “color blind”. It uses various standardized filters to derive reflection values. The density is calculated by applying the formula  $D = -\log \beta$  (degree of reflectance  $\beta$  – the ratio of reflected light to incident light).

Procedure:

- Calibration to paper white
- Setting to polarized or unpolarized mode
  - Polarized: surface reflections are filtered out
    - Same values are obtained for wet and dry sheets
  - Unpolarized: surface reflections are also measured
    - Lower density value than in polarized mode
    - Different measurement results for wet and dry sheets
- Measurement of the sample

**Density measurement of the process colors CMYK:** using appropriate standardized filters

- There are standardized narrow band filters, broad band filters, etc. Different filter types yield different results!
- The filters allow light to pass in the wave length range in which the color separation being measured emits very little light, in other words in the absorption range. It is here that the ink film thickness affects reflectance most strongly.
  - Cyan: “red filter”
  - Magenta: “green filter”
  - Yellow: “blue filter”



**Density measurement of non-process colors**

That filter is used that yields the highest density value.

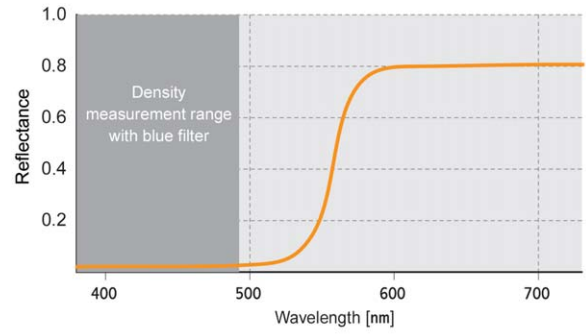
This causes the following problems:

- “Bright” colors have high reflectance; the density value obtained is therefore corresponding low and cannot be used very well for color control purposes, because changes in the ink film thickness result in only negligible changes in density.
- Two completely different colors can yield exactly the same density value, despite being obviously different in appearance (see figure below).

D = 1.60  
L = 60.2  
a = 56.8  
b = 62.9



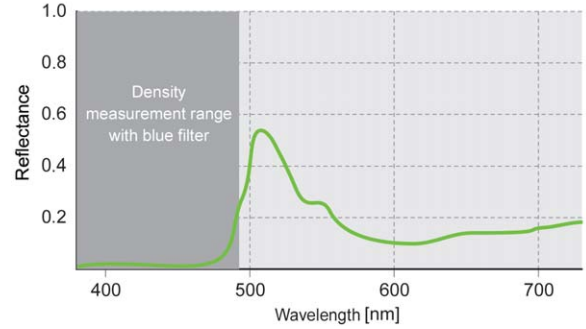
Color sample HKS 8



D = 1.60  
L = 59.4  
a = -56.7  
b = 49.3



Color sample HKS 65



Two completely different colors;  
the deviation between them is  $\Delta E=114.3$ . The same density value  
is obtained for both, however.

### 11.3 Comparability of results obtained with different measurement systems

#### Requirement: identical measurement conditions

- Illuminant
- Standard observer
- Measurement geometry
- Calibration to paper white/absolute white
- Same background/base (preferably black base) behind sheet during measurement
- Same time elapsed between pulling and measuring a sheet (especially when comparing Lab values, since these cannot be measured with polarizing filters)
- With densitometers: setting to polarized/unpolarized

#### Measurement parameters for the printing industry:

- Measurement geometry:  $45^\circ/0^\circ$  (or  $0^\circ/45^\circ$ ) (angle of light striking measuring head)
- Light type: D50 (modeled after natural daylight)
- Observer:  $2^\circ$  standard observer



**Requirement: correct functioning**

- Clean lenses
- Regular calibration. An appropriate calibration card is included.
- When calibrating to the absolute white: regularly clean the tile used

**For density comparisons with Prinect Axis Control please note:**

the polarized density values are calculated, not measured – Prinect Axis Control is not equipped with a physical polarization filter! Because measurements are always made without a polarization filter, how wet or dry a sheet is invariably affects the results of measurement – both when the system is set to “unpolarized” and when “polarized” values are calculated. As a sheet dries the colorimetric values obtained can slightly change. The amount of time that elapses between pulling and measuring a sheet it must therefore be kept consistent to ensure comparable results.













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