Prinect

Color and Quality

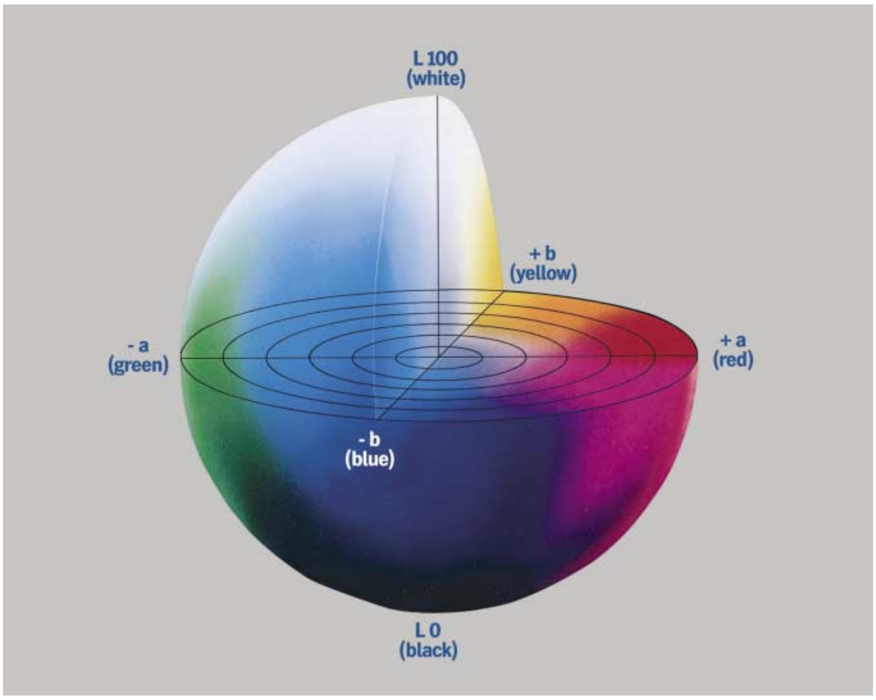
HEIDELBERG

Introduction into Colorimetry and Spectrophotometry

Contents

Colorimetry and spectrophotometry – cutting-edge tools in the print media industry

The first industrial application of spectrophotometry and colorimetry was in the paint industry. The main aim was to try and keep batches of paint as similar as possible and therefore to minimize differences when touching up paintwork. Anyone who's had damaged paintwork on their car repaired will know how well it can be done nowadays. And the printing industry is basically faced with the same challenge. Reprints should look like the initial print and always have the same color impression, no matter what printing method is used.



L*a*b*-ball

At the end of 1980s, the first spectrophotometers and indeed colorimetry made their way into the printroom. Printers now found themselves confronted with L*a*b*[1] values and ΔE[2] color deviations. This new technique presented competition to the familiar world of color densities, and printers suddenly found themselves in territory that till then had been the reserve of other industries.

When it comes to controlling colors via density, there is a close correlation between the color density and ink thickness on paper. In certain areas, these behave in an almost linear fashion. Printers only have to deal with a single figure (e.g. Cyan D_{log} 1.50) which describes the coloring. Relying on their experience and the proportional behavior of the two factors, printers then use the density measured to define the adjustment of the ink zone opening. This can be worked out using a rule-of-three calculation. However, the visual appearance of the color is not taken into account in this process.

The situation is different when it comes to measuring and controlling using colorimetric values. Coloring is shown as a three-dimensional parameter (e.g. L*a*b* values 55 / -37 / -50), which is why printers initially thought it was impossible to derive the recommended adjustments for the ink zones from these figures. Recommended adjustments using colorimetric values employs a color model which is stored in the measuring device. The new ink

[1] **L*a*b***
Tristimulus values for unambiguously determining the color location in the color space
L = lightness (0 = absolute black, 100 = absolute white); a = red-green axis; b = yellow-blue axis

[2] **ΔE (Delta E)**
Dimension for determining the difference between two color tones. ΔE 1 is the smallest perceptible unit

zone setting is calculated from a comparison between the optical spectrum of the measured color and a target value. Unlike density measurement, this method not only takes account of the absorption behavior of the paper and ink, but also other color-relevant parameters like paper white, the surface structure of the paper and the hue of the ink. If the hue in print differs from the desired color value (color sample, proof, digital value), this difference is shown as a ΔE value.

Historical background to colorimetry

The correlation between physics and physiology when it comes to color perception was recognized very early on. While physicist Isaac Newton had already made a key contribution to spectrophotometry and colorimetry in 1704 with his attempts to split white light into spectral colors, the effect on the human eye was actually defined 100 years later by the physician Thomas Young. Young was reportedly the first to describe how color was perceived with the three receptors in the eye for the primary colors red, green and blue. It is now known that every color impression can be fully described by three values.

Spectrophotometry as a basis for colorimetry

Spectrophotometry forms the basis for color measurement. In printing applications – no matter whether the measurement is performed in a color control strip or print image – spectrophotometers generate the optical spectrum of the measuring sample. This can be used to derive the appropriate tristimulus values or even process dimensions. The most important tristimulus value is the colorimetric $L^*a^*b^*$ value which describes a color with complete unambiguity. One benefit of the $L^*a^*b^*$ color space is that color distances that are perceived to be identical also have the same metric distance. ΔE 1 is the smallest color distance that the human eye can perceive. Process-oriented parameters such as density or dot gain can also be derived from the spectrum. Spectrophotometry lies at the very heart of color measurement, while colorimetric evaluation of the measured spectrum represents the technical embodiment of how we perceive color.

Prinect® Axis Control® is integrated in the Prinect® CP2000 Center® press control station and performs spectrophotometric measurement in the color control strip.

Forms of colorimetric control

There are essentially two forms of colorimetric control. Firstly, solid color control in a color control strip (for process and special colors) and, secondly, gray-patch control which measures halftone gray patches (CMY) and the individual solid colors and halftone patches of the chromatic colors CMY.

Heidelberg® has now added a third method of control – image measurement. Heidelberg Prinect® Image Control is the first device worldwide that is capable of measuring in the subject, i.e. over the entire print sheet, and controls the ink zones based on the image data. So it actually measures the product that will be sold to the customer.

All three forms of control are based on a colorimetric target value. The control ensures that the print results are optimally matched to the target value – color agreement between the print run and reference sheet is therefore the yardstick for success.

The colorimetric approach of the Heidelberg color measuring systems means you are using measuring technology which reproduces the way the human eye works and how it perceives color and ensures that the perceived color difference between the press sheet and OK sheet is minimized through the use of control technology.

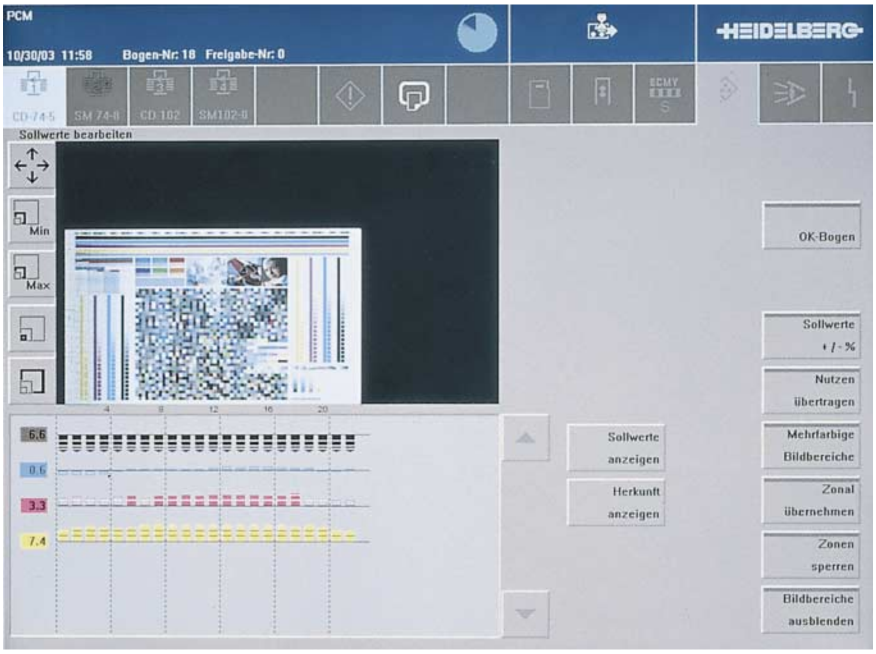
Color control in practice

A question often asked is whether the operator has to know all the ins and outs of colorimetry when using Heidelberg color measuring systems? The answer is not at all. Printers can concentrate on the print results as usual, as they receive recommendations for controlling the ink zones. That said, the measuring device has to be appropriately prepared beforehand, which involves scanning in the paper white and specifying target color values. The HKS and Pantone[3] special color scales are stored as standard. The target values for process colors are generally defined using standards or even an OK sheet. Preparing the measuring equipment takes only a few minutes and can be performed during press setup.

[3] **Pantone®, HKS**
Color swatches for special colors

Prinect Image Control performs spectrophotometric measurement of the entire print image. Up to 4 Speedmaster® presses can be connected.

The latest printing result is compared with the target value in each measuring operation. The display shows the recommended settings for achieving the target value in both numerical and graphic form. Printers have plenty of time to check the control recommendation before approving it or can opt for automatic adjustment. In this case, the ink zones are adjusted immediately after measuring without any need for the printer's intervention. Printers therefore don't have to grapple with tristimulus values or even complex mathematics.



Printers can see at a glance where color has to be adjusted. The black line shows the target coloring. The bars show the percentage recommended adjustment per ink zone. Printers require no knowledge of mathematics or colorimetry.

The customer's perspective

Printers have to provide the customer with a finely tuned color print product which corresponds to the original. How they do this and the labor involved is generally of no importance to the customer. The customer's focus is on the product and whether it is acceptable to his critical eye, his "in-built sense of colorimetry". Implementing this in the printroom is the aim of objective colorimetric measuring and control technology. And Heidelberg supports this aim with its Prinect Axis Control and Prinect Image Control color measuring systems.

Application of colorimetry in the printroom

Color standards have been in use in the printing industry for a long time. And various different measuring devices are used to monitor compliance with these standards. In the main, two different types of measuring device are utilized:

- densitometers with/without connection to the press
- spectrophotometers with/without connection to the press

The downside to offline devices is that the printer has to rely on the measured values displayed to assess and adjust the ink zone opening, a process which is extremely time-intensive when there are several inking units on a press, especially if several ink zones have to be adjusted at the same time. This is a relatively reliable process when performed by experienced operators printing process colors and the corresponding density values. However, it's more difficult with special colors as the filter colors of the measuring devices are generally only designed for the process colors cyan, magenta and yellow and the density values displayed do not enable reliable control recommendations to be obtained. And it's practically impossible with colorimetric values, since three-dimensional L*a*b* values are difficult to correlate with the thickness of the ink layer.

For reasons of accuracy, reliability and speed, a measuring device which provides recommended adjustments for all the ink zones on the press online is altogether more preferable than an offline device.

For printers looking not only to measure and control the printing process in terms of density and tonal values but who also set great store by visual agreement between the print and the original (proof, previous print run) or who have to achieve CIE L*a*b*[4] data, an online spectrophotometer offers extensive opportunities, especially given the increasing standardization within the printing industry.

[4] **CIE-L*a*b***
Color space determined by the Commission International d'Eclairage based on human perception of color.

Requirements for measurement and control at the press

Before looking at how the measuring devices work, the key requirements for reliable measurement and control should first be outlined. The most prominent of these are ink presetting and pre-inking.

Ink presetting is basically defined by the ink coverage values on the printing form, i.e. by the subject to be printed, and the material parameters, i.e. the characteristics stored in the press control station. Ideally, CIP4-PPF data from the prepress stage, which is transferred to the press either online or with a memory card, is utilized to determine the ink coverage values.

The objective of ink presetting is to ensure that the color is as close as possible to the desired specified value when printing begins. This is achieved by setting the ink zone openings and the color strip widths in every zone according to the expected ink consumption per inking unit. Ink presetting uses the characteristics to translate the ink coverage values into ink zone openings. This ensures that the ink fountain roller delivers the exact amount of ink that will be taken up by the paper.

A frequently underestimated factor is what's known as pre-inking, whereby, even before the first sheet is printed, the amount of ink that will be required later by the stable inking unit during the production run, is delivered into the inking unit. The ideal situation is that the first sheet pulled corresponds as best as possible to the specified color desired. This requirement is based on the experience that, the larger the deviations from the specified value are, the more the number of control operations inevitably increases. In essence, this means that if the values are set correctly in advance, they will not have to be re-adjusted later on.

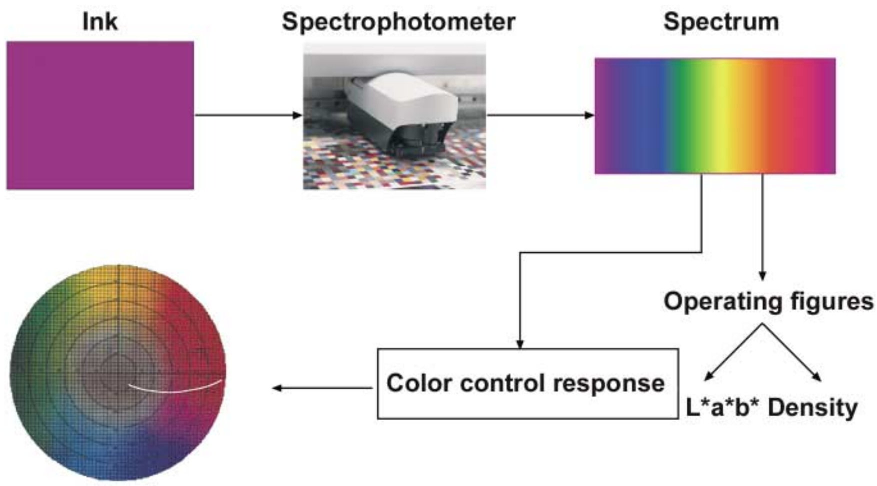
At the start of printing, the process steps described above define the preset color and thus the starting point for color measurement and control.

How the Heidelberg color measurement and control systems work

In principle, Heidelberg utilizes spectrophotometers for all its latest color measuring systems, regardless of whether color density or L*a*b* values are to be measured. The spectra generated are transferred during the measuring operation to the device's internal computer, where the appropriate software calculates the desired values from the spectra. The spectral color values form the basis of the colorimetric control, i.e. the recommended adjustments for the ink zone openings are calculated directly, without involving densities.

In order to perform a control operation, the spectral values have to be stored in the measuring device as specified/target values. This requirement has been met for Pantone and HKS colors in all Heidelberg devices. No spectral values are stored for process (4C), high-pigment and other colors. The reason for this is the wide variety of different types of ink that are used in practice as well as the frequent considerable differences in process colors. Thus, the spectral value for these colors has to be calibrated by the printer using a print sample (full tone). This then provides the new target color location.

In practice, this procedure can be carried out in a few minutes and offers the advantage that the target values generated can actually be achieved with the ink used in the printshop. Furthermore, quality monitoring of deviations in hue is also supported – as can occur for example with different batches of ink.



The colorimetric control process. Both the operating figures and color control response are derived directly from the spectrum of the measured ink.

Practical example of ascertaining the target value

Imagine a printshop is looking to print in compliance with Printing Media Standard 2004. This standard specifies the dot gain and also gives the specified colorimetric values as CIE L*a*b* values which form the basis for the specified color in print. Due to extremely different influencing factors, the CIE L*a*b* values can never be fully achieved, which is why tolerances are defined for the individual process colors and, in particular, for the production run. It is important for the printer to know how close he can get to the specified value with the printing ink he is using.

There are two practical methods for determining the target value (= production run standard):

1. The creation of a series of colors ranging from under- to over-coloring and subsequent measurement of the print sheets. The print sheet that exhibits the lowest ΔE deviation to the specified value and lies within the permissible tolerance is a suitable standard for the measuring system.
2. Have the ink supplier produce lab proofs on production run paper. Load these proof strips into the measuring system as the standard.

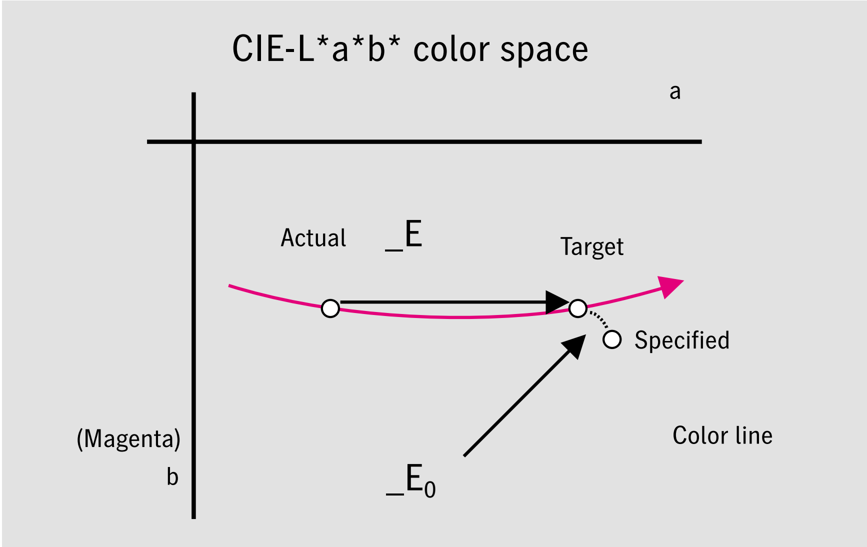
Measuring and control in print

Print run measurement can begin after the target values have been defined. The first pull also provides the first actual values, which, as explained at the beginning, should not be too far removed from the target value. The role of the control process is now to adjust the ink zone openings, i.e. the thicknesses of the ink layer, so that the target color is achieved in as few control operations as possible.

This seemingly simple mechanism is based on a complex color model which describes the inking pattern of the ink used when modifying the layer thickness. Colorimetry alone only shows where you are currently situated in the color space (actual value) and where you want to go (specified/target value), it does not explain how to get there. That is also not the purpose of colorimetry, but rather the role of the color model that the control procedure is based on. It can calculate how the color will change if, for example, the thickness of the ink layer is increased by 5 %.

If you change the layer thickness on paper by applying either more or less ink, it is well known that the optical impression also changes to a certain extent. If you introduce a color series of relatively little ink up to complete saturation in the CIE L*a*b* color space, a line appears. This line not only varies in terms of brightness, but its position on the a and b axes also changes. This line is called the color line.

When controlling in full tone, the achievable color locations are defined through the specified pigmentation/color intensity and the variable thickness of the ink layer applied. In this example, the color model can calculate the layer thickness at which the optimum approximation to the specified value is achieved and where this target location is located in the color space.



The results of colorimetric control show two aspects: Firstly, the color distance ΔE still to be adjusted up to the target color location representing the best possible approximation of the specified value and, secondly, the non-adjustable color distance ΔE0 which remains as a color difference between the specified and actual value.

How colorimetry supports

In practice, this means that the printer can see at a glance whether he can achieve the desired color result or not. If all parameters in the printing process are optimally coordinated, it can be assumed that the desired result will be achieved. However, if the print conditions change, for example through graying of the chromatic colors in the production run, this can lead to significant deviations in hue. In this respect, colorimetry helps by indicating whether, even under these conditions, the desired color result can still be achieved within the tolerances or whether intervention such as washing the inking rollers is required. When using a different type of ink whose specified value is not stored, the color measuring system shows as early as the first pull if the color will definitely lie within the tolerance. This can occur, for example, if the printer works with another type of ink (from a different manufacturer) while using a specified value that has already been stored. In this respect, a key feature of the measuring system then comes into play, namely the function that determines and displays the smallest adjustable color distance (ΔE0).

It is also possible that ink of the same type but from different batches can achieve the same CIE L*a*b* value, but at varying densities. So if the printer were to rely solely on specified densities, the optical impression could end up being different. That is why the new ISO standard does away with indicating specified densities.

Summary

The major advantage of colorimetric control is the ability it offers to keep the print result as close as possible to the desired optical color impression of the original and alerting the printer as soon as possible if deviations become too large. Colorimetric evaluation offers the same perception as the human eye, with the benefit of being free from subjective and varying external influences, instead providing objective results. The measuring data can be stored and logged and can also be used as a certificate of quality. Additionally, the measuring results can be automatically evaluated with the Heidelberg Quality Monitor software, a component integrated in the Prinect products Profile Toolbox and Calibration Toolbox.

Image measurement – possibilities of spectral measurement and colorimetric control

Where standard measuring and control equipment is connected to a press, measurement is usually performed using the color bar on the print sheet. Measuring patches for solid tones and screens provide information about the target coloring achieved and the dot gain in print. The equipment uses the difference between the target color value and the actual value of the pulled sheet to calculate the recommended adjustment for the relevant ink zone. The color bar is usually placed at the front or rear edge of the sheet depending on the amount of space available. The coloring of the measuring patches should reflect the level of coloring in the motif but this cannot always be done satisfactorily due to various technical reasons.

Particularly in the case of high-quality print products with high area coverage and special colors, measurement in the image has significant advantages over the conventional measurement method. Especially in packaging and label printing, even coloring across all repeats is crucial and is well served by this method.

If the above-mentioned measuring equipment involves “integral image point measurement”, Prinect Image Control from Heidelberg scans the entire print image. A measuring bar moves over the print sheet and scans up to 160,000 image points.

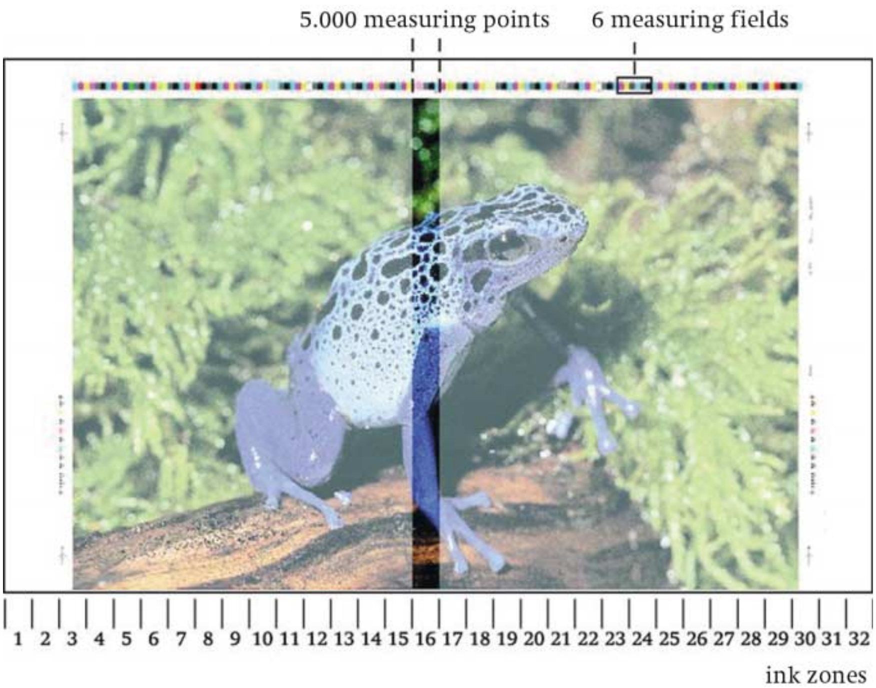
The advantage of this measuring method lies partly in the fact that no measuring points have to be defined – indeed the entire print image including color bars and other control elements can be scanned at the same time. It is irrelevant whether an image area consists of single color or multiple colors, is solid or is screened. Moreover, both complete print sheets and individual repeats can be calibrated as a reference. The latter are primarily used in packaging printing which requires precision printing based on sample templates. It is also of great use to printers of high-quality commercial print products such as furniture catalogs, fashion magazines, cosmetics adverts, etc.

There are many different approaches to performing measurement in the motif. One uses the “point-by-point” measurement method in which measuring points in the print image on the print sheet are defined by the operator and are then measured automatically during the subsequent measurement process. These systems also make it possible to measure and adjust individual measuring elements which, for example, are positioned in the bleed or on an adhesive flap. In both cases, the recommended adjustments for the ink zone setting are derived from the resultant measurement values. This type of measuring equipment is generally fitted with spectral measuring heads.

Color measurement and control with Prinect Image Control

The basic idea behind Heidelberg's image control technology is to imitate the way in which the printer visually judges the print sheet. This is made possible by the fact that the process yields objective measurement values which correspond to the human perception of color. To do this, the entire print image is measured precisely and in compliance with standards using a spectrophotometer. The accuracy of commercially available digital cameras or scanners, which calculate colorimetric values from RGB data[5], is generally not sufficient for this purpose.

[5] **RGB values**
color values based on the primary colors red, green, blue



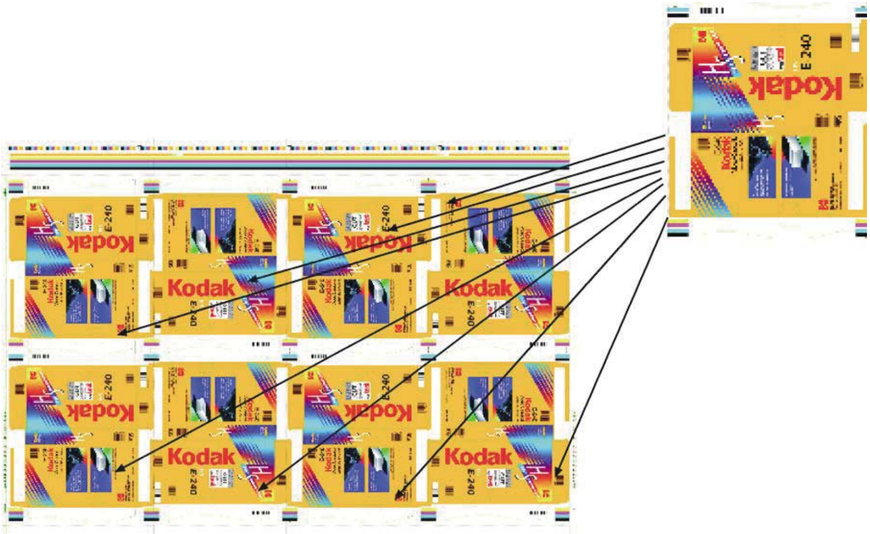
Prinect Image Control provides up to 5000 measuring points for each ink zone during image measurement. In contrast, only 6 measuring fields are evaluated during color bar control.

When visually judging a print sheet, color changes in homogeneous areas of the image are much more evident than those in inhomogeneous areas. A similar situation applies with secondary and tertiary colors in comparison with highly saturated primary color tones. Prinect Image Control takes this into account during color control in the same manner. Image edges and areas with minor color components are automatically excluded, while all the other image areas are used for evaluation. The control result for a 40” print sheet can be based on up to 5000 measurement values per ink zone. This high accuracy leads to very precise control results, in contrast to measurements in the color bar where only 6.5 measuring fields are recorded for each ink zone. Users say that the results of the image control are of excellent quality and are very stable throughout the print run.

In addition to image motifs from process colors, special colors on the print sheet can also be controlled. Colorimetry is particularly useful for label and packaging printing since it automatically delivers the best possible approximation of the specifications irrespective of where and how often the relevant color tones are found on the sheet.

Prinect Image Control in action

As mentioned above, the strength of Prinect Image Control lies in the fact that it is able to measure the print sheet in horizontal and vertical directions. This advantage is particularly useful when, for example, two consecutive copies require different changes in coloring. In such cases, the ink zone opening is calculated by the software to achieve the optimum compromise for coloring the two copies. Moreover, the system can be easily adapted to specific requirements. This means it is possible to control coloring using individual copies and/or to exclude chosen image areas from the control process.



The values of an individual copy can be transferred as a reference to the entire print sheet. A copy from a fresh print sheet or a sample copy can be used for this purpose.

In packaging and label printing, there is another key function known as "copy transfer". This makes it possible to use a copy supplied as a sample from the last printing process as a reference or to specify a copy on the fresh print sheet as a reference whose coloring parameter is then transferred to the other copies. The ink zones are then controlled in accordance with the measured deviations.

Graduated entry

To use the wide range of functions and special applications, the user must have the necessary expertise. This knowledge can be gained by attending Heidelberg training courses. The ease with which the user can work his way into image measurement will be determined by his experience. Prinect Image Control is therefore structured so that it is possible to start with the familiar color bar control. If the user is already familiar with the unit and the colorimetric system, he can begin with image control or with a combination of image and color bar control.

Spectrophotometric measurement and color management in the pressroom

For quality-oriented printshops that want to produce high-quality print products cost-effectively, a functioning color management system is essential. The different reference variables used in the past such as photographers' RGB values and printers' density values have now been replaced by colorimetric $L^*a^*b^*$ values that ensure harmonious communication between customer, prepress and press. Color management has been used successfully in the prepress for years. Color values that could be determined exactly and the available hardware and software were key to this success.

However, extending color management to the printroom took a bit longer. The reasons for this included an unmanageable assortment of different papers and inks, imprecise inking guidelines, external influences on the print result and, last but not least, a lack of measuring technology. In addition to this, printers were used to performing color adjustments on the press. As a result, a standardization process was required in order to integrate the press in the color management system. This process was speeded up by the discontinuation of lithographic films and therefore of the analog proof. Computer to Plate requires a digital proof and that means being able to display the print results reliably on another medium.

Color management enables coordinated communication between all participants in the manufacturing process

ICC profiles[6] for the print process form the basis for this. They describe the color space that can be reproduced using a particular combination of ink and paper. They therefore provide the basis for a simulation of the offset print on a proofing device or softproof, and are an indispensable component for good color separations in the prepress. The printer can refer to standard profiles or generate the profiles himself. The latter method has the advantage that the profile is precisely coordinated with the printshop's consumables. The operator is not necessarily constrained by a standard provided he stays within its tolerance. With this method, however, internal proof results are assured of much greater color fidelity. If he deviates from the standard because certain print jobs require it, ICC profiles must always be customized. This would be the case, for example, if a larger color space was required during the print stage when using highly pigmented inks and/or FM screens[7]. Whether you use your own or standard profiles, continuous checking that the print results are within the tolerances is absolutely essential. There is no need to keep generating new profiles. The measured results can be used for comparison with the stored standard. If the inking result lies outside the tolerance, in many cases you can get back to the standard again by correcting the printing characteristics. However, if the ink or the paper is changed, it is advisable to adapt the existing profiles.

[6] **ICC profiles**
Description of a color space as per the International Color Consortium

[7] **FM screen**
= frequency modulated screen
Dot size remains constant and frequency (number) of dots varies. The opposite of an autotypical screen.

Measuring technology

The colorimetric values required for generating ICC profiles are supplied by spectrophotometers. They record the spectra of measurement masters and use these to calculate the colorimetric values. In the graphic arts industry, CIE L*a*b* has become the standard color space because of the way it simulates the human perception of color. Users can choose from different types of spectrophotometers depending on the type of work they do.

Hand-held measuring instruments are the gateway into spectrophotometry. Measurement of individual color patches can be started at the touch of a button and the result shown on a display. The operator can choose whether he wants the display to show colorimetric values or densities and dot gains. Modern instruments have an interface that allows measured values to be transferred online to a PC or Mac. Profiling software evaluates the data, displays color space and printing characteristics and evens out outliers in the measurement if necessary. Guidelines in the software facilitate the setting procedure for different profiles. In PrintOpen from Heidelberg, for instance, you can select which print processes and papers the profile is to be used for and the corresponding presetting will be performed automatically. You can also influence the color separation by changing the gradation and the reproduction characteristic. Because these instruments measure each measuring field individually, recording a whole ECI_2002 test form takes considerable time.

With fully or semi-automatic measuring instruments, the measuring patches can be scanned in strips or blocks, which saves a great deal of time. If they are linked via an interface to profiling software, they can also be controlled from there.

As well as the ECI_2002 chart for profile creation, the Heidelberg Color Calibration Test Form also contains elements for determining the printing characteristics, ink trapping, ink fading, zonal ink distribution and images for optical judgement.

A further option is a spectrophotometer, used for color control on the press. These devices are usually highly automated and have the added advantage that the measured values the printer uses to adjust the ink zones are the same as those used in the prepress for profile generation. Here too, there must be an interface for transferring the colorimetric values to the profiling software. These features are offered by, for example, Prinect Image Control from Heidelberg. This device supports the printer during makeready and production monitoring and can also be used for measuring pre-defined measuring elements. It scans the whole print image in just 25 seconds. The "Color Interface" option offers precise measurement and ICC-compliant preparation of measured values from the ECI_2002 chart. As well as test forms for all (Heidelberg) press formats, it also contains the Prinect Profile Toolbox with the PrintOpen profiling program. This can be installed on the network on any Windows-computer linked to the measuring system.

Integration in the color workflow

In this version, Prinect Image Control becomes a key component of Prinect Color Solutions. The aim of this is to establish an integrated closed-loop system for permanent data exchange from prepress to pressroom and back based on Heidelberg Prinect products. Presetting data is supplied to the pressroom and the latest values from print production are sent back to prepress. Here, the measured tonal and color values ensure optimum adaptation of printing characteristics and ICC profiles to changed print conditions. To prevent the test form having to be reprinted every time there is a change of ink or paper, Heidelberg has developed tiny control elements known as Mini Spots™ whose color patches have sufficient information to perform reliable changes to profiles and printing characteristics.

Provided there is enough space (fold, adhesive flap), the Mini Spots™ can be printed as part of a normal production job. Here too, the advantages of colorimetrics come into play. For each measuring process, $L^*a^*b^*$ values, density and dot gain are calculated and transferred to the Quality Monitor, a software which is part of the Prinect Toolboxes. If the evaluation shows that an ICC profile or the printing characteristics needs to be changed , this correction is performed by the integrated Prinect Profile Toolbox and Prinect Calibration Toolbox programs. The new calibrations are then available to the RIP for proof and plate output and will be optimized again for the next print job.

Heidelberg Mini Spot™ PCS 60 for modification of ICC profiles

Conclusion

By integrating color management in the manufacturing process, a printshop creates the best conditions for communicating with its customers. Quality in the color process is no longer reliant on complicated “lithography on the press”, but is rather the result of coordinated processes between the customer, prepress and press. Corresponding technical equipment such as the spectrophotometer and profiling software are essential for this. Heidelberg has been committed to spectral measurement and colorimetric evaluation for many years. Thanks to this foresighted development, printshops with the right equipment can easily implement the current colorimetric target values of ISO 12647-2[8] and the Offset Printing Process Standard – a prerequisite for reproducible quality. Further development of Prinect Color Solutions is underway with the aim of making the color process even more efficient and reliable in future.

[8] **ISO 12647-2**
International standard for process control in offset printing.

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