# New Developments – Color Measurement and Regulation in offset printing

Densitometry has proven to be the ideal measuring technique for regulating color in printing. After all, there's a direct relationship between the amount of ink applied and the corresponding density values measured on the printed sheet. MAN Roland was a pioneer in densitometric applications and even though the company's measuring devices, control methods and regulating algorithms have been permanently improved over the past 25 years, the principle itself has not changed. And it's still the most effective way to achieve exact and reproducible results in four-color printing.

For some years now, the printing industry has been using colorimetry for assessing printed results, especially in connection with standardization and color management covering all process stages in the digital production chain. This is because, with special colors in particular, exact assessment of the color effect achieved in the end can only be provided by colorimetrical analysis. This is especially important for packaging printing.

The developments in measurement and regulation techniques for evaluating color in offset printing are explained here by Joachim Müller and Alexander Klüh from the electronics development operations at MAN Roland Druckmaschinen AG in Offenbach/Main, Germany.

**1** Press control console with ColorPilot for simultaneous density and color measurement on a ROLAND 500.

For more than two decades now, printers have been using measurement and regulation techniques to produce printed sheets that are a faithful reproduction of the original right throughout the run. Densitometry – measurement of the ink density – plays an important part in this. The density of the ink film on the substrate is optically measured and then the system establishes whether more or less ink is needed in the zones measured. Finally, complex regulating algorithms result in the ink metering elements allocated to these zones opening or closing. In these areas, more or less ink is fed to the sheet which influences the color of the print.

MAN Roland was a pioneer in this field and introduced the first generation of the Roland CCI inking regulation system as early as 1977. "CCI" stands for "Computer Controlled Inking", and this was the first time that modern electronic computer technology was linked with the sheetfed offset printing process.

Since then improvements regarding speed, measuring accuracy and reliability have been made every four or five years. The breakthrough for Roland CCI came with the advent of the new generation of digitally controlled printing presses with a high degree of automation – this was when the integration of computer technology in printing press manufacture really started to advance. Roland CCI sales have risen sharply since 1988. The proportion of presses that are not only equipped with inking control but automatic inking regulation as well is growing all the time. In the United States for instance, 80% of all ROLAND 700 presses sold there are equipped with Roland CCI.

### Roland CCI continues to set new standards

With press speeds continually increasing, it was essential that the printer be able to intervene quickly and effectively to avoid printing waste sheets. After all, when a press is running at 15,000 sheets per hour, 4.2 sheets pass through the press per second (Fig. **2**).

The trend to more and more printing units per press made it necessary to have more control patches in the control strips. As the third generation of Roland CCI was introduced at the end of the eighties, these changed requirements were taken into account:

- ❒ Measuring times were drastically reduced: A control strip 1,020 mm long could now be measured in around 14 seconds.
- ❒ CCI was now able to measure control strips with patches only 3 mm wide.

This enabled the control strips to have more measuring patches and thus provide more information about the printed sheet (340 measuring patches for a medium-format sheet). And control strips were now available for up to eight individual colors.

With the introduction of the ROLAND 700 in 1990, the time needed for the system to adjust the ink slides was reduced dramatically. Whereas this had previously taken around six seconds with a six-color press, this was cut to well below one second.

And with the fourth generation Roland CCI that came onto the market in 1998, MAN Roland set new standards once again. The new measuring head was able to measure a print control strip only 4 mm high (Fig. **3**).

This meant

- ❒ 33% less space needed for control bars compared to the preceding version and
- ❒ provided great potential for saving materials costs.

But the most important step forward was made in 2002 with the introduction of ColorPilot which logically unites the proven method of density regulation with colorimetric measurement in one system (Fig. **1**).

The most important features are:

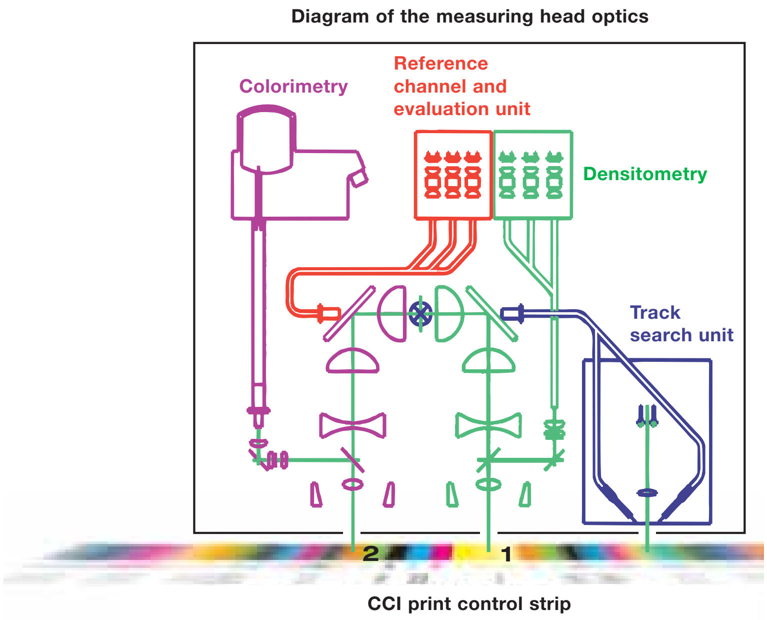
- ❒ Measurement and regulation according to ink density using the same method and in the same precision.
- ❒ Spectral measurement of the **L**, **a**, **b** color spaces by the same measuring head but with a separate measurement system (Fig. **4**).
- ❒ Functions are provided that enable the colorimetrically measured values to be linked with density regulation.

### The advantages of regulating by density

For many years, densitometry has proven to be the ideal technique for controlling inking in the printing process. After all, there is a direct relationship between the measured

**2** The ROLAND 300 has a max. printing speed of 16,000 sheets/h.

**3** CCI print control strip (original size) for color measurement and regulation.




**4** Simultaneous density and color measurement from very small measuring patches makes ColorPilot an ideal tool for standardized printing:
**1** = measuring the ink density,
**2** = spectral measurement of the L, a, b color spaces.

densities and the ink film thickness on the sheet: within the normal ink film thickness range for process colors (ca. 1 µm) there is virtually a linear association between density and ink film thickness (Fig. **5**). Therefore the densities are extremely suitable for measuring and regulating the ink film thicknesses on the sheet.

Using polarization filters with density measurement eliminates scattered gloss effects caused by the ink drying, and so any measured differences between wet and dry inks can be ignored.

Automatic regulation of the ink slide settings makes life easier for the printer who only has to regularly pull a sheet and measure it to confirm that the system is regulating correctly. Apart from that, the regulating algorithm can be left to take care of ink metering during the production run. And print quality over the run is statistically evaluated and logged to provide quality verification for the customer.
The main advantage: Regulation based on the relevant variable, ink film thickness, makes the printing process stable. Once the desired result is achieved, density regulation makes it easy to keep this constant.

### Colorimetry supplements densitometric measurement and regulation

Density as a measured value does not represent the optical appearance of the color on the printed sheet. It cannot be used to make judgments on the appearance of the color on the sheet. Nor do density values help to recognize whether the pigmentation of an ink is wrong, in other words, whether the color tone of an ink is incorrect. In such cases, altering the ink slide settings does not help. Only colorimetry can help here.

### Densitometry ideal for commercial printers

For commercial printers who rarely print anything other than halftone pictures in four-color process, density is the ideal regulating basis. This applies above all when the production processes in prepress and printing are standardized to a large extent.

### Packaging printers use special colors

The situation is however different with packaging printers who mostly print solids in special colors. There one can encounter the following appearances that decrease quality:

### Metamerism

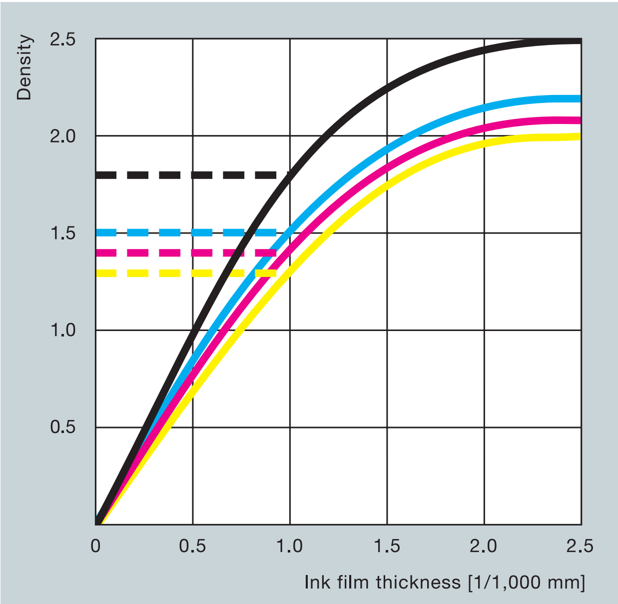
Inks with the same density values do not give the same color impression on the paper, and colors that appear to be optically the same have different densities in printing. This effect is called metamerism.

### The visual impression depends on the substrate and other process influencing variables

Depending on the nature of the substrate used (thickness, absorption capacity, color), the same inks with the same density produce a different visual impression on the sheet. The color of the substrate is the major cause of different color impressions.

### The visual impression is what counts

A color that the run density log confirms has been printed within an acceptable density tolerance range




**5** The relationship between ink film thickness and density.

can under certain circumstances show pronounced visual fluctuations. And the reverse can also happen: density fluctuations during the run can hardly be visually perceived. And process disturbances during the run may make it necessary to change the nominal densities to match a newly-defined OK sheet. This can be the case for example when the ink/water balance changes or when ambient temperature influences the printed result.

Therefore accurate conclusions about the color impression on the paper based on ink density are limited to certain combinations of paper and ink. But there is no connection that can be generally applied.

## Colorimetry reproduces the visual impression

In order to make an objective assessment of the visual impression on the sheet, one needs a measurement and evaluation system that reproduces what the human eye sees. And this is what colorimetry provides.

## What is colorimetry?

In the search for a clear specification of color impressions, the international printing community settled on the so-called CIE system in 1931. As a further development, the CIELab color difference system was introduced in 1976. This system defines color impression as a location in a three-dimensional color space in which the three axes stand vertical to one another and are designated **L**, **a**, **b** (Fig. **6**).

**L** is the brightness axis.
**a** represents the green/red axis,
**b** represents the yellow/blue axis.
Colors with the values **a** = 0 and **b** = 0 are achromatic or neutral gray.
Paper white: L = 93, a = 0, b = –3,
Black: L = 18, a = 0, b = –1.
The further the colors are away from the L-axis, the purer they become.
An example (Lab values according to DIN ISO 12647-2):
Cyan: L = 54, a = –37, b = –50,
Magenta: L = 47, a = +75, b = –6,
Yellow: L = 88, a = –6, b = +95.

The color difference or the color deviation of two colors with the coordinates **Lab** 1 and **Lab** 2 is the distance between the two points in the color space and is called Delta E ($\Delta E$).

As opposed to other systems, the **Lab** system has the outstanding quality that the same $\Delta E$ color differences in the **Lab** color space are also perceived by the human eye as being the same. And so in practice permissible color variation, in other words the tolerance range for a color, is given as the physical unit $\Delta E$.

## Colorimetry especially effective for packaging printers

The demands placed on color fidelity have increased in all areas of printing but especially so in the packaging printing sector where in some cases the benchmark for color impression of the printed products is set extremely high. Packaging printers almost always need to produce solids from special inks to print colors that are designed to achieve identification with the manufacturer or the product itself.

And these high demands on color impression and keeping it identical throughout the run precludes superimposed printing from process colors. Special inks are used instead, which the printing plants mix themselves or take from the well-known color assortments such as those provided by Pantone or HKS.

### Guidelines used to convey the required color impression of a print product

In ideal cases the customer provides color samples and often samples for the maximum permissible upper and lower color tolerances. Another possibility is to use an OK sheet approved by the customer as a model for color compliance.

Ink density is not a suitable variable for judging deviations in color between the sample and the production run. There are several reasons for this:

- ❒ The printing inks used for the sample and the production run are formulated from different pigments.
- ❒ The substrate used for the sample and the production run are different.
- ❒ The printing ink used for the production run has been contaminated by another ink.

In these cases the color impression can be different despite the fact that ink density was kept within the tolerances.

### Colorimetry in ColorPilot

The “ColorPilot” system introduced in spring 2002 for MAN Roland sheetfed presses links densitometry and colorimetry (Fig. **7**). In addition to the proven densitometric measurement and regulation, ColorPilot simultaneously measures the **Lab** color location from each solid patch in the print control strip. No extra time is needed for this.

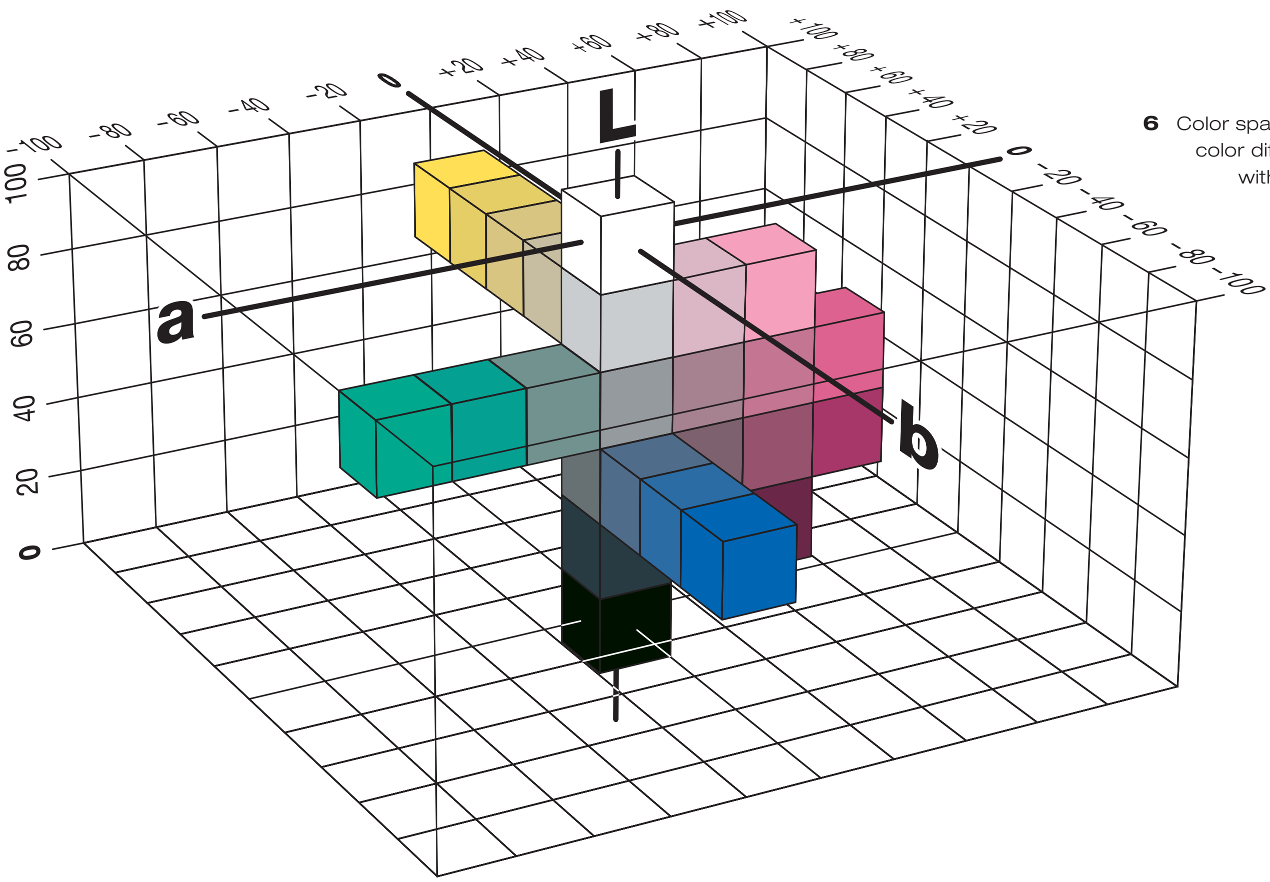
A nominal color location “Labnom” can be entered for each printing unit and each ink slide zone. This can be either

- ❒ a numerical input of the **L**, **a**, **b** values of the nominal inking,
- ❒ taken from values measured on the sheet,
- ❒ obtained by measuring a solid-printed inking sample,
- ❒ obtained by measuring any print control strip that has identically wide measuring patches,
- ❒ taken from values from a nominal value standard for a series of standard inks.

### Logging color deviations

Three methods of evaluating color difference are used in the printing industry:

ΔE according to CIE Lab,
ΔE according to CNC,
ΔE according to CIE 94.




**6** Color space of the CIE Lab color difference system with the coordinates L, a, b standing vertically to one another.

All of these calculation methods are included in ColorPilot, the user simply has to decide which method to use prior to starting the measurements. The color measurement results are displayed as a graphic and numerical color deviation log (DE log). The display can be selected so that the tolerance range (permissible color deviation) and any colors out of tolerance are immediately recognized (Fig **8**).

A so-called Zoom display can be selected for every printing unit which portrays the individual Δ**L**, Δ**a**, Δ**b** components for every inking zone.

The color variation between the nominal and actual values is displayed numerically, graphically, and in a square control patch true-to-color. (Fig. **9**).

## Color deviation statistics

With the “Statistics Log” function, ColorPilot produces statistics and a histogram of the ΔE color deviations from all measurements logged during the production run.

With the “Statistics” function, the smallest, largest and median deviation from all measurements taken at each ink slide zone where a measurement patch is provided are calculated and graphically and numerically displayed.

With the “Histogram” function, the smallest, largest and median deviation over all ink slide zones on every sheet measured are calculated and graphically and numerically displayed (Fig. **10**).
The graphic and numerical logs can be printed out as a report.

## ColorPilot for packaging printers

These days the assessment of color deviation is the metrological basis for ISO 9000 quality management.

Reaching an agreement on color tolerances based on ΔE provides a printing company with a number of advantages. Color deviations are permissible within the agreed tolerance range, and this includes over-inking or under-inking, as well as other causes such as ink contamination or tone deviations in the ink and/or the substrate.
Another advantage for the printing company is the objectivity of the measurement method. Color measurement does away with the wide latitude of subjective judgments, as well as the variables that come from the type of lighting in the inspection area, or the viewing angle.

This is why color measurement is an important aid for judging the quality of inking in packaging printing.

There are two ColorPilot functions which are especially important for packaging printing:

- ❒ The Zoom log of color deviation (Fig. **9**)
  This enables the association between brightness **L** and the color values **a**, **b** to be analyzed when it is necessary to change the composition of the printing ink.
- ❒ The nominal value prediction
  Through an analysis of all color and density information, two numerical values are calculated for each printing ink:
  1. Minimum ΔE:
  This is the smallest color difference achievable with the combination of ink and substrate being used.

**7** PressPilot with ColorPilot for the ROLAND 300, 700 and 900.

2. Optimal nominal density: This is the ink density that the regulator (or the printer) needs to set in order to achieve the smallest possible color difference.

One of the special advantages of the nominal value prediction is that the printer is immediately informed whether a particular printing ink can be used or has to be modified.

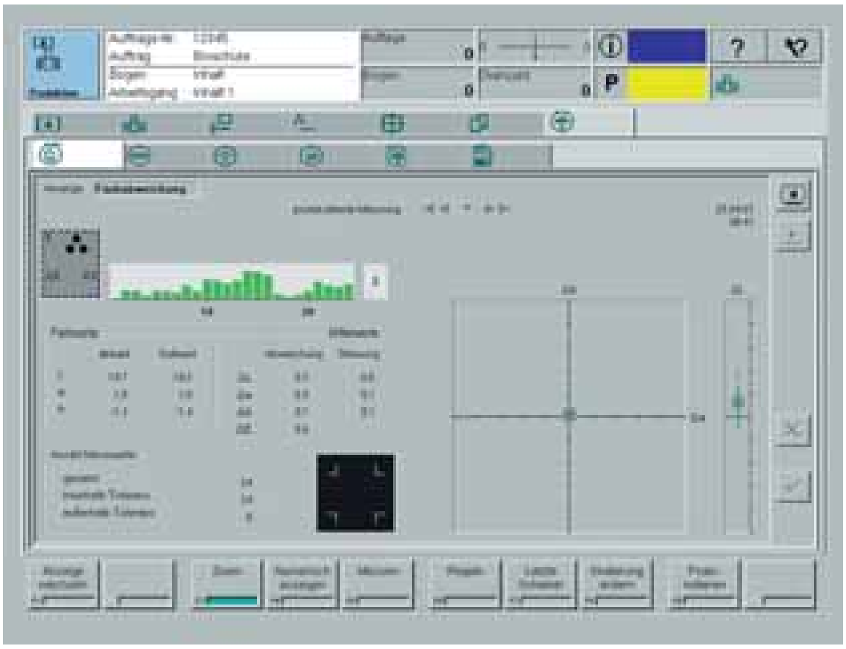
### Uniform quality through standardized printing

If one wishes to achieve cost-effective production of high-quality color printing, there is no alternative to Color Management. Right throughout the entire workflow – from generating picture data up till when the job is finished – Color Management means consistent adherence to standardized work stages. More information about this is contained in the MAN Roland brochure “Color Management in Offset Printing. Application Guidelines”, please see page 81 of this magazine to find out where this is available from.

Color Management means standardized printing. Standardization involves determining suitable characteristic values of the printing process for all types of substrates. The most important of these values are the inking of the four process colors black, cyan, magenta and yellow and the transfer of their halftone dots to the printed sheet.

Up till the early 1990s, there were only a few concepts for standardized offset printing anywhere in the world and these were all very different. Printers and their customers generally reached some form of vague agreement and these all looked very different as well.

**8** Screen shot of the log showing the ΔE color deviations of all colors.



**9** Screen shot of the log showing the color deviation of an individual color with individual components (ΔL, Δa, Δb).

**10** Screen shot showing statistical evaluation.

Author

**Dipl.-Ing. (TH) Alexander Klüh**

was born in Schlüchtern, Germany in 1971 and studied electrical engineering at the Darmstadt Technical University, specializing in the field of control systems. Mr. Klüh has worked at MAN Roland in the R & D operations since 1997 and has been involved with the development of control console software since 1998. From 2000 he has been responsible for color measurement methods and inking regulation.


This changed in 1996 with the publication of the international standard ISO 12647-2 “Process Control for Screened Color Separations, Press Proofs, Off-press Proofs and Production Runs”.

Printing industry associations in 16 countries used this as the basis to develop an overall concept for standardization in offset printing and this concept was adopted as a DIN standard in 1998.

The most important points are:

❒ Prescribed **Lab** nominal values and tolerances for color with five types of paper.

❒ Prescribed **Lab** nominal values and ΔE tolerances for full-tone inking of the process colors with five types of paper.

❒ Prescribed **Lab** nominal values for inking of the secondary colors red, green, blue, so that when two are superimposed they result in a primary color, with five types of paper.

❒ Prescribed **Lab** nominal values and tolerances for halftone values of the process colors with five types of paper.

What is remarkable here is that most of the prescriptions were based on colorimetric variables which shows that human color perception was placed in the foreground for the first time. Because what colorimetry does is to measure and evaluate colors in the same manner as they are perceived by the human eye.

## Summary

### Densitometry and colorimetry

For commercial printing (brochures, leaflets, catalogues, etc.) using process colors, regulation is done solely in accordance with the nominal ink density value. The printer visually compares the copy with the printed sheet in order to give the regulating system the correct nominal value. Colorimetry plays no part in this.

### Standardized commercial printing

Thorough implementation of the DIN/ISO 12647-2 concept is only possible through a combination of densitometry and colorimetry.

### Color regulation with special inks

Densitometry is needed here to control ink metering in accordance with a nominal ink density value. And colorimetry is also needed here to provide the density regulation system with the correct nominal ink density value.

### Quality control with special inks

If quality control is the only consideration, colorimetry is used to measure the color deviation on solids compared to the desired nominal color. Densitometry is of no use in this case.

Consequently, a combination of densitometry and colorimetry is the ideal solution.

### ColorPilot at a glance

❒ Supplements the proven CCI densitometric measurement and regulation system with colorimetrical quality analysis.

❒ The proven method of regulating based on densitometrically measured values is retained.

❒ Simultaneous measurement of densitometrical and colorimetrical values in the print control strip.

❒ The only standard-compliant solution: densitometry with polarization filters, colorimetry without polarization filters.

❒ Integrated in the color matching desk to save space.

❒ Measures from very small patches in print control strips located at the sheet front or tail edge.

❒ High measuring speed.

❒ Fast, precise and simultaneous regulation of all ink slides.

❒ Intelligent regulating algorithm, trend display, quality reports.

## Glossary

CIE system
A color definition standard of the Commission Internationale de l'Eclairage.

Colorimetry
A theory where colors are measured as they are perceived by the human eye.

Densitometry
A method for determining density values.

$\Delta$E color deviation
The difference between two colors in the Lab color space. $\Delta E = 1$ defines a scarcely noticeable color difference.

Ink density (D)
The variable that can be measured by a densitometer.

$$D = \log \frac{\text{Intensity of applied light}}{\text{Intensity of reflected light}}$$

Ink film thickness
The thickness of the ink film applied to the substrate. On coated paper, the thickness lies between 0.7 and 1.1 thousandth of a mm but it can be as high as 2.5 thousandth depending on substrate and ink.

Inking
A general term for transferring the ink film to the substrate in the printing process.

Ink metering elements
Mechanisms in the ink fountain for metering ink feeding. Instead of the ink blade customary in the past, MAN Roland sheetfed presses now have 30 mm wide ink slides which control ink feeding in each zone without influencing the neighbouring zones.

Inking zones
Demarcated areas of the ink fountain that permit inking across the width of the print to be matched to the requirements of the form.

ISO 9000
An international standard for a company-internal quality assurance system. ISO 9001 describes the manufacturing path of a product from design through to after-sales service, whereas ISO 9002 is confined to production.

Lab color values in the color space of the CIE (Commission Internationale de l'Eclairage) System
A system for defining color values. 'L' describes brightness, 'a' describes the red/green value and 'b' the yellow/blue value.

Metamerism
Two colors may appear identical under one and different under another illuminant.

Polarization filter
A filter to eliminate reflections that would otherwise falsify the result of measurements made of a dry specimen sheet.

Author

**Dipl.-Geophys. Joachim-Manfred Müller**

was born in Berlin in 1939 and studied geophysics at the Humboldt University in Berlin from where he graduated in 1962. After being engaged in research projects in the field of geophysics in Berlin, Munich and Stockholm, Mr. Müller carried out development work for an appliance manufacturer for three years.
He was self-employed for ten years, developing measuring equipment for the printing industry among others. Following this he was employed by the Grapho Metronic company from 1983 to 1986 where he worked on the development of densitometric measuring methods. He has been working in the R & D operations at MAN Roland on a free-lance basis since 1986.