REASONS AND WAYS FOR THE REVISION OF THE INTERNATIONAL STANDARD FOR FOUR COLOR OFFSET PRINTING

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Abstract: The colorimetric characteristics of a set of printing inks for multicolor offset printing are specified in the International Standard ISO 2846 :1975. This standard evolved from the European Color Standard which on its part served for national standardisation in ten European countries. Although the standard was drafted for the production of offset inks it has gained significance also in the prepress area, in color management and computer publishing. However, a couple of years ago it becomes apparent that the color values of commercial cyan, magenta and yellow inks had drifted away from those specified in the standard. Therefore, revision of the standard was set about by a joint working group ISO TC 130 WG 3/4 aiming at colorimetric specifications which are representing world wide commercial four color offset process ink sets within reasonable tolerances. The paper will show the background, methods of testing and actual colorimetric data of inks such as EUROPEAN COLOR SCALE, SWOP and JAPAN COLOR serving as basis for the revision.

Introduction

Multicolor printing i.e. 'the formation of a color mixture by overprinting solid tone and/or screened primary colors' had its rudiments in the early 20th Century.

Color mixture in printing can occur subtractively i.e. 'by the overlay of two or more solid tone primary colors' or additively i.e. 'by mixture of light reflected from two or more primary colors screened to small dots and located close together so that the human eye cannot resolve them'. Both, subtractive and additive color mixture are combined in what is called autotypical mixture. It occurs everywhere in modern multicolor printing when dots are printed partly one upon another and next to each other.

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For a chromatic image the number of primary colors in multicolor printing is optional. The aim is always to yield the greatest possible color gamut using a widely applicable printing process at reasonable costs.

Although several attempts have been made to apply up to seven primary colors, four color printing has gained the greatest technical and commercial significance in all major printing processes (letterpress, offset, gravure). It is also true for most of the electronic printing processes when color is applied.

For the technique of multicolor printing the colorimetric characteristics of the primary colors are very important. Additional important aspects in choosing pigments for primary printing inks are processing properties and fastnesses as well as commercial availibility and/or a reasonable price.

Standardized colorimetric characteristics of primary inks will allow lithographic printers to obtain different sets of inks both for proof and production printing which will produce a similar color when printed on the same substrate at the appropriate ink fim thickness.

History of Color Sets

The first attempt for laying down colorimetric specifications of three chromatic primary colors in a standard was made in 1954 in Germany which resulted in the "Old DIN Scale" i.e. DIN 16 508 (letterpress) and 16 509 (offset printing).

In this standard the three primary colors yellow, magenta and cyan and the secondary colors yellow + magenta, yellow + cyan and magenta + cyan are specified by the CIE chromaticity coordinates x, y, and the tristimulus value Y for standard illuminant A and C and the 2° observer. For visualisation a plot in the chromaticity diagramm and examples of printed colors are included in the standard. The printing sequence is black, yellow, red, blue.

The a*, b* gamut resulting from the primary and secondary colors defined in this standard, together with those defined in DIN 16 539, CEI 30-89 and the new ISO proposal, which is specified later in this paper, is shown in Fig. 1 (for better comparison the standard values x y and Y were recalculated into the CIELAB Coordinates L*,a* b* for illuminant D 50). Black is not specified in this standard.

Since transparency of the yellow pigments at that time was not as good as nowadays yellow had to be printed as first of the chromatic inks. For the red ink the more purple fanal pigment is used giving a high brillance to the printed primary and also to the secondary blue resulting from overprinting the primary blue. Unfortunately the fastnesses of this pigment e.g. to light, solvents, alkali and acids doe not correspond to todays commercial applications.

Nevertheless these standards are still valid in Germany and corresponding inks for printing products where fastnesses are not a major aspect are ordered every now and then.

To satisfy requirements of better fastness and processing properties of pigments for standard four color offset process inks the "Experts' Group: Test Methods and Technical Studies" (ETT) of the "European Confederation of Paint, Printing Ink and Artists' Colors Manufacturers' Associations" (CEPE) elaborated in 1966/67 new European Standard recommendations. On the basis of results of a round robin test among the European ink manufacturers they worked out two documents which served as basis for national standardisation in ten European countries and therefore was called "European Color Scale" or more simply "Euroscale". It was specified for letterpress (CEI 12-66) and offset (CEI 13-67).

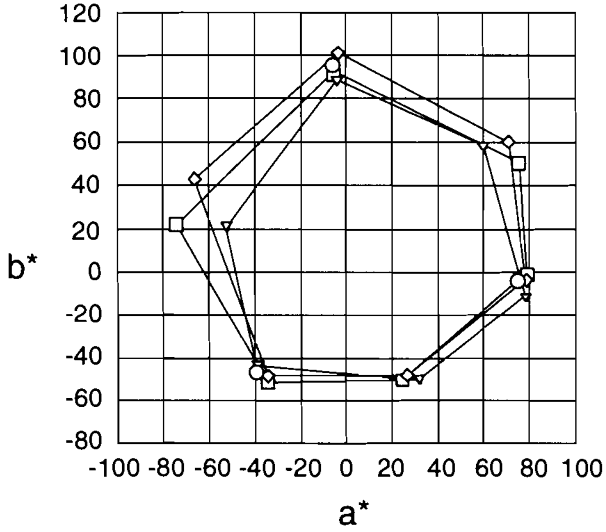

Fig.1 a*, b* gamut of DIN 16 509 —▽—, DIN 16 539 —□—
CEI 30-89—◇— and coordinates of new ISO O
45°/0° geometry, 2° observer, D50 Illuminant

In this standard the magenta of the former DIN 16 509 standard was replaced by a new magenta i.e. using a relatively cheap pigment showing excellent fastnesses and good processing properties. Since this pigment is not only a little more reddish but also exhibits a lower lightness, the secondary color resulting from overprinting cyan and the new magenta is darker and/or less brillant than that resulting from cyan and magenta of the old DIN Standard.

Nevertheless, the commercial availability of the rhree pigments phtalocyanin, (Color Index (C.I.) 15-2) Lithol-rubin (C.I. red 57-1) and Diaryl-yellow (C.I. yellow 13) helped the European Color Standard to achieve also worldwide significance and the ISO Standard 2846 "Set of printing inks for offset printing - Colorimetric characteristics" agreed to in 1976 is in complete conformity with it. Even for developements in electronic publishing it served for reference.

In this standard the primary colors and the secondary colors printed on a coated paper free from optical brighteners (APCO II/II) at a reference ink layer thickness within a range from 0.7 µm to 1.1 µm are specified by the CIE tristimulus values X, Y, Z and the CIE UCS-1964 values U*, V*, W* including tolerances for color difference 'ΔE'. The values are based on 45°/0° measurement geometry and specified for standard illuminant C and the perfect white diffuser. An additional table related to magnesium oxide reference white is added.

The a*, b* gamut recalculated for D 50 from the standardized data is also depicted in Fig. 1. The shift from the more blueish purple to the more reddish magenta is evident. The same is true for the shift of the old greenish blue to the cyan.

New CEPE Standardisation Activities

It is not surprising that within 20 years, technical progress in production and quality of pigments led to a shift of their colorimetric properties:

- The transparency and chroma of the yellow inks increased dramatically due to improved methods of pigment manufacture which, on its part, resulted in better dispersion and/or easier dipersibility in the vehicle. So, the chroma of the yellow specified in the standard for usual ink layer thickness range (0.7 µm to 1.1 µm) in offset printing was too low in comparison to that of modern commercial inks. The slight shift to the red observed at these inks is a result of higher chroma also.

- The magenta shifted only slightly to the red and lower chroma.

- In the case of cyan the chroma specified in the standard turned out to be too high so that the ink layer thickness to be printed for reaching a chroma comparable to that specified in the standard was too high.

These findings led the CEPE Experts Group to the conclusion that a revision of the standard was needed to adapt it to todays' commercial inks.

The new recommendation CEI 30-89 comprises four parts:

Part 1: "European Color Standard for Multicolor Printing"

This part is applicable in general for inks in every multi-color printing process. It includes principal aspects which are valid for all following parts and the colorimetric specifications of the old standard as starting point for the new recommendation.

Part 2: European Color Standard for Sheetfed Offset Printing
Part 3: European Color Standard for Web Offset Printing
Part 4: European Color Standard for Newspaper Web-Offset Printing

Not only part 1 but also parts 2 to 4 include a detailed description of all experimental procedures necessary for testing inks so that each part is more less self sufficient. Optionally further parts could be added later as e.g. for gravure inks, flexo inks and screen inks.

The main aim of the revision was the adaption of the color values to modern offset inks. At the same time it tried to keep a well defined reference to the still existing color standards, which, as already mentioned, was based on large amounts of experimental data from all major european ink manufacturers. Since it turned out, after comparison between the standard color values and modern inks, that the color shift concerned almost exclusively saturation, new color values were calculated from the old ones on the basis of a reference ink layer thickness shift with the help of spectral color density $D(\lambda)$. The new spectral values were calculated as follows

$$D(\lambda)_2 = \frac{d_2}{d_1}(D(\lambda)_1 - D(\lambda)_p) + D(\lambda)_p$$

with,

$D(\lambda)_1$ spectral color density at ink layer thicknes d_1
$D(\lambda)_2$ spectral color density at ink layer thicknes d_2
$D(\lambda)p$ spectral color density of paper

The new tristimulus values were evaluated from the spectral curves corrected in 10 nm steps according to the above equation. Computation of the tristimulus values X,Y,Z together with the CIELAB and the CIELUV coordinates was performed for the 2° observer for standard illuminants D65 and C.

By these means

- saturation of cyan was decreased according to a 20% ink layer thickness decrease
- saturation of yellow was increased according to a 20% ink layer thickness increase
- saturation of magenta was decreased according to a 10% ink layer thickness decrease.

The color gamut of the new CEI proposal is depicted in Fig. 1 in comparison with the other standards and/or proposals . In Fig. 2 to 4 the new values are plotted together with the old ones. For comparison the latter were recalculated for D50. They clearly show the shift described above for each color.

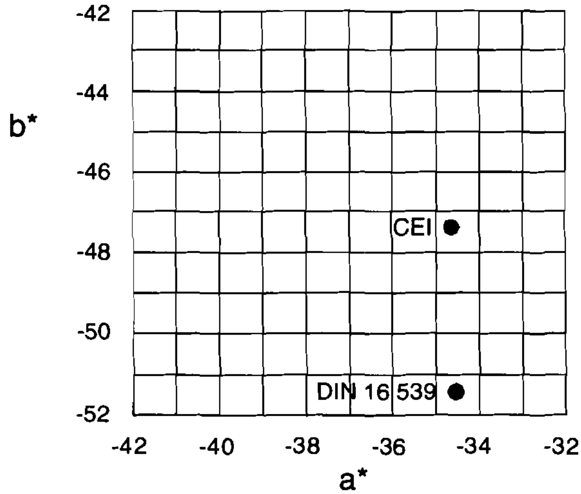

Fig. 2 Colorimetric shift of cyan in comparison with the old DIN 16 539 (and ISO 2846). Measurements: 45°/0°, D50 illuminant, 2°observer

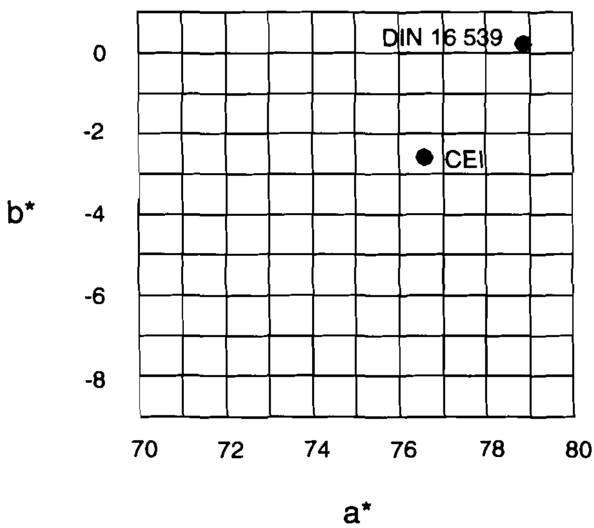

Fig. 3 Colorimetric shift of magenta in comparison with the old DIN 16 539 (and ISO 2846). Measurements: 45°/0°, D50 illuminant, 2°observer

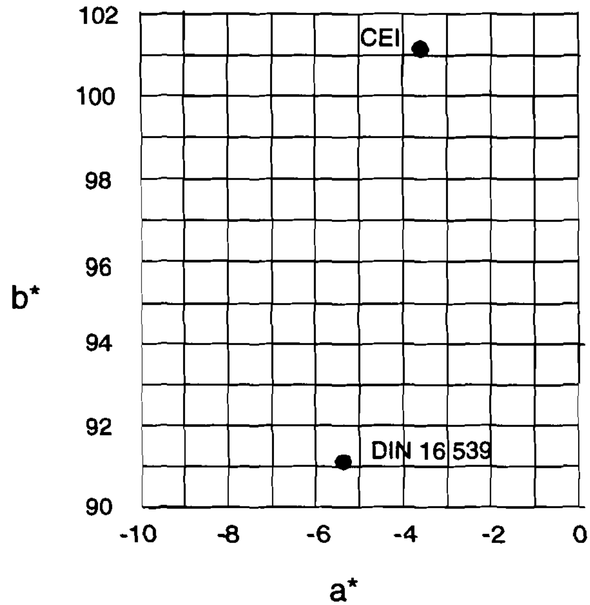

Fig. 4 Colorimetric shift of yellow in comparison with the old DIN 16 539 (and ISO 2846). Measurements: 45°/0°, D50 illuminant, 2°observer

Revision of ISO 2846

The CEI 30-89 document was just completed when ISO TC 130 decided to include the revision of the existing color standard ISO 2846 in its working programme. Since this working item touches the interests of both, working group 3 "Prepress control" and working group 4 "Media and materials", it was concluded to handle this item in a joint working group WG3 / WG4 where experts of both groups could bring in and discuss their arguments.

Structure of the new Standard

In December 1991 this group met for the first time in Washington DC. The CEI 30-89 document served as basis for discussion. But very soon the concept was changed and a draft was elaborated including six sections:

Title: Set of printing inks for offset printing - Colorimetric characteristics

0 Introduction
1 Scope and field of application
2 References
3 Definitions
4 Testmethod
5 Specifications for Color, transparency and ink film thickness ranges

one normative Annex:

A Reference Substrate

and four informative Annexes:

B Original ISO 2846 specification and reasons of change

C Spectral data

D Tristimulus values for 8°/diffuse geometry and illuminant D65

E Extended explanation of the test procedures, including examples

The introduction gives a brief information on history and background for the revision of the original standard and on the input sources. Additionally all changes and additions to the original standard are mentioned

References and definitions for terms used in the standard are noted as usual.

Test methods and evaluation

The method for evaluation of an ink is based on color measurement of test prints made from the ink to be tested with the help of a printability tester at different ink layer thickness on a test paper (APCO II/II) specified in Annex A. Test print preparation according to ISO 5737 is described in detail and color measurement is performed in accordance with ISO CD 13655, except with white backing. The samples are measured spectrally with a 45/0° (or 0/45) instrument geometry and the CIE tristimulus values are computed for the 2° observer and D50 standard illuminant. The tolerance range is expressed by ΔE_{ab} values.

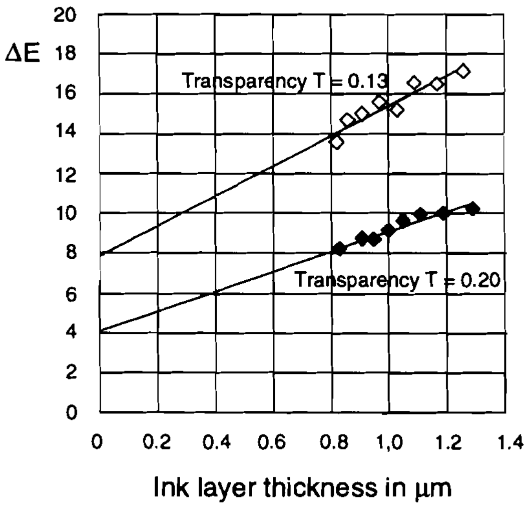

Fig. 5 Evaluation of transparency of two different magenta inks both exceeding the lower limit of 0.12.

For transparency evaluation a series of test prints is prepared on a black substrate. The color difference ΔE_{ab} between each print and the substrate is measured and plotted as a function of ink layer thickness. As a measure for transparency the reciprocal slope calculated from the 'best fit' straight line through the measured points is taken (Fig.5). Alternatively the reciprocal value of the regression coefficient can be calculated directly from the measured data.

This method is based on the measurement of light scattered from pigment particles in the ink film. It is evident that it increases with decreasing transparency and increasing ink layer thickness. Therefore this method is looked at as being more reliable than the one point measurement method described in the German standard (DIN 55 988) for transparency evaluation of varnishes.

The conformity of an ink to the standard is assured only if the measured color meets the defined specifications at some ink film thickness within the specified tolerance range and if the transparency value exceeds that specified in the standard. In practice the colorimetric test is done by color measurement of a series of test prints and by plotting the color difference ΔE_{ab} between each sample and the standard values as a function of the ink layer thickness. The ink meets the standard if values of the resulting curve are located within the specified color difference range (Fig.6). If it is located outside one can, from the position of the curve relative to the tolerance range, get information on wether the ink differs from the standard in hue or in pigment concentration.

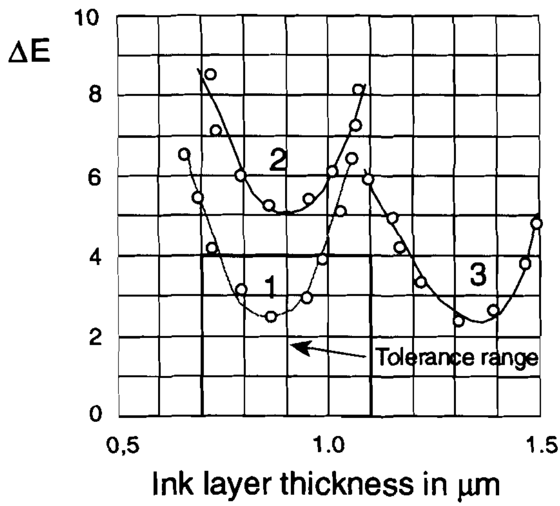

Fig. 6 Evaluation of conformity of ink color with a standard value. An Ink showing curve 1 is in full conformity. Curve 2 indicates a difference in hue but correct saturation and curve 3 vice versa.

Colorimetric Specification

While a consensus on the concept of the standard and the test methods was reached quickly among the experts it was much more difficult to find out colorimetric specifications of the inks which experts of all three main commercial areas, USA, Europe and Japan, could agree on within reasonable tolerances.

Whereas the European proposal was deduced from the old standard trying to adapt it to modern offset inks, there is no national standard at present in the United States. Commercial four color primary inks were assumed to be represented by SWOP Inks ("Specifications for Web Offset Production"). These specifications, first published in 1975, were for the purpose of controlling the quality of magazine printing on web presses. They concentrated on the control of supplied material (film and proofs) specifically for four color separations and progressive proofs. Since 1986 guidelines for web printing have been included.

Today US ink manufacturers supply process inks for heat set web offset matching the colors of the SWOP/NAPIM Official Process Inks which are specified as proofing inks for Standard Ink Colors.

The colorimetric properties of these inks are specified relative to a certain color density rather than to an ink layer thickness. In 1993 NAPIM and the SWOP Committee revised the colorimetric specifications of SWOP inks. The main result was an increase in color strength for yellow and cyan. Printed at an ink layer thickness within the tolerance range specified in the draft ISO standard the color strength now is comparable to that of the european standard inks.

In Japan a set of standard process colors was jointly established by the Japanese Printers Association and the Japan Printing Ink Makers Association in 1964. However it was not adopted as a national standard at that time. In 1990 a task force of the Japan Printing Ink Makers Association performed measurements on process ink sets of the eight major ink manufacturers who represent more than 80% of the ink market in Japan. The average figures of these measurements were adopted by the board of the Association as a standard color set and it was named "JAPAN COLOR INK SF-90.

Plotting the colorimetric data of all three proposals in an a*, b* diagramm (Fig.7 to Fig.9) shows that a consensus on averaged values between those of EURO (CEI), SWOP and JAPAN Color standard inks could only been reached if for cyan and yellow considerable color difference tolerances between each of the three would be accepted. This would have necessitated too great a tolerance range which is not in the sense of a standard. Proposals for magenta, on the other hand, do not differ much from one another.

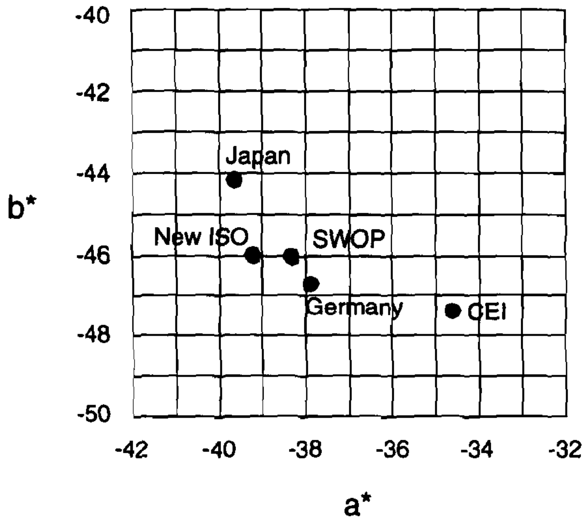

Fig. 7 Different proposals for the colorimetric characteristics of standard offset process cyan and averaged new ISO value.

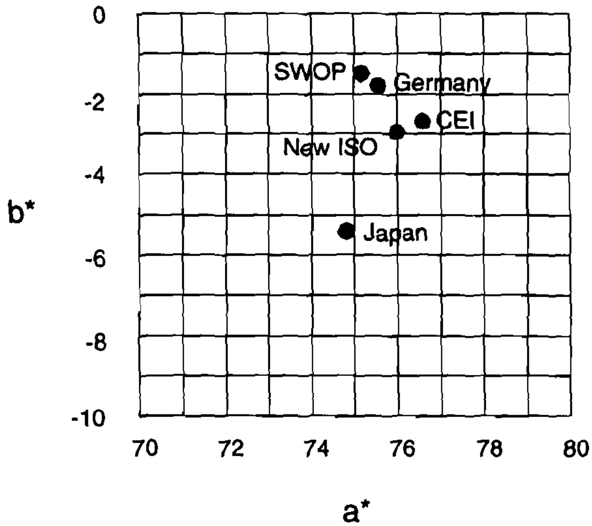

Fig. 8 Different proposals for the colorimetric characteristics of standard offset process magenta and averaged new ISO value.

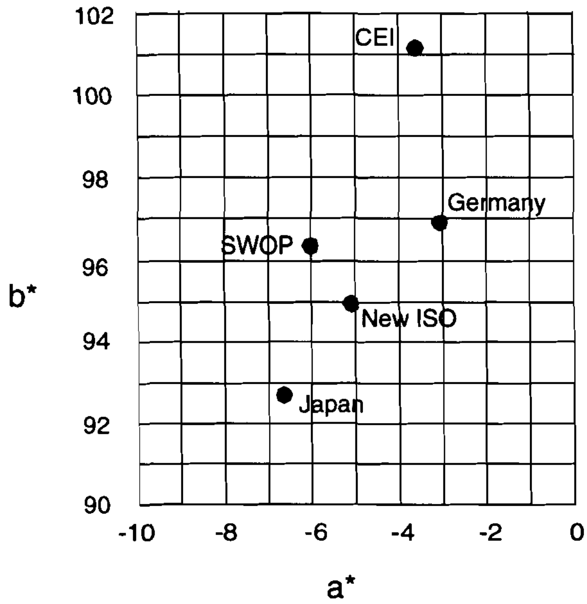

Fig. 9 Different proposals for the colorimetric characteristics of standard offset process yellow and averaged new ISO value.

Therefore new color measurements were performed on process ink sets supplied from the US, Japan and Germany. The cyan and yellow inks supplied from the eight major manufacturers in Germany showed that they have drifted away from the color values specified in the CEI 30-89 document. The commercial cyan has shifted to the green and the yellow shows a lower saturation. Nevertheless the CEPE experts group did not see any necessity to adapt the proposed values to the new market situation. It was argued that the standard should maintain some educational function and prevent primaries from drifting too far away from optimum with respect to secondary colors. A greener cyan together with a more reddish magenta as proposed in the new ISO standard would result in a secondary blue showing a lower lightness and saturation i.e. it would deteriorate in brillance.

On the other hand the german standards committee revising the corresponding DIN standard adopted the new commercially oriented values since by adoption of the CEI 30-89 proposal only 20 % of the German commercial ink sets would be in conformity with the new Standard.

Although the new values reflect only the German market they are said not to differ significantly from those in other European countries so that they can be looked at as being representative for Europe. Together with the 1993 revision of SWOP inks and the data measured on JAPAN COLOR inks these findings facilitated the specification of averaged values for the three ink sets together with a reasonable tolerance range.

The colorimetric characteristics of the black are specified by limiting the lightness L*, and according to the variations in the content of blue pigment usually added in black offset ink production. For that reason the tolerance is not specified by an overall ΔE*(ab) color difference but by a maximum L*, and by a variation in Δb* (blueish to brownish) and Δa* (greenish to reddish).

The new color values together with the tolerances are specified in Table 1

	X	Y	Z	L*	a*	b*	Tolerance
Cyan	16.10	24.90	52.30	56.98	-39.23	-45.99	3.0 ΔE*(ab)
Magenta	36.10	18.40	16.40	49.98	75.98	-2.97	5.0 ΔE*(ab)
Yellow	73.20	78.50	7.40	91.01	-5.11	94.96	4.0 ΔE*(ab)
Black	2.50	2.50	2.10	17.92	1.79	-0.35	1.5 Δa*, 3.0 Δb* L*≤18

Table 1 Tristimulus values and CIELAB cordinates of revised ISO 2846

The "New ISO" values plotted together with the other proposals are also shown in Fig.7 to Fig.9. Although slight differences have remained the averaged values represent a farely good compromise that manufacturers of each of the three areas can live with.

Annex A

Since color appearence strongly depends on the substrate an ink is printed on it was necessary to specify the substrate and its properties in the standard. The paper chosen has to be free from optical brighteners and should have good light fastness and long time stability. APCO II/II, a two sided high gloss coated 150 g/m² paper supplied by Papierfabrik Scheufelen, Lenningen, Germany has turned out to have these properties and Europeans have had good experience with it. Future supply was guaranteed from the manufacturer, so it was accepted by all experts as the standard reference substrate. Additional specifications as e.g. pH, oil absorbence, gloss etc. are noted in the Annex.

Annex B:

In this informative annex the history and development of color standards in Europe, USA and Japan are discussed and the coloprimetric specifications of the old ISO 2846 are listed. Since in the previous version of the standard colors were specified for standard illuminant C using magnesium oxide as reference white the values in the annex have been recalculated for the perfect white diffuser and illuminant D50 to enable a better comparison with the new standard.

Annex C

In this informative annex spectral data for "typical" standard colors are provided. It was obtained by averaging data of measured samples from USA, Japan and Europe and it is useful for recalculation of the tristimulus values for other illuminants. There are two tables, one each for 0°/45° and 8°/diffuse (specular included) geometries.

Annex D

In this annex informative data for 8°/ diffuse geometry and D 65 illuminant is added. Two tables one each for illuminant D65 and D50, are provided for the 8°/diffuse geometry. For the purpose of the standard the 8°/ diffuse and diffuse / 8° geometries are deemed to be equivalent to each other for both specular included and specular excluded conditions. A third table for 0°/ 45° geometry and illuminant D65 is added.

Although for standard reference only the normative specifications (45°/ 0° and illuminant D50) are to be used this informative data can help when comparing measured data to the standard values if there is no normative equipment at hand.

Annex E

In this informative annex some explanatory aids to the test methods are given concerning colorimetric verification and determination of transparency. For better understanding plotted examples as shown in figure 6 are added.

Present Status of Revision

As to the present status of the standards revision a Committee Draft (CD) has been circulated to P-Members of TC 130 for voting on registration as a Draft International Standard (DIS). Incoming comments were discussed at the April 94 meeting in Baltimore and minor changes will be incorporated in the draft. Publication as DIS will be expected in 1995.