# Colorimetric Parameters of Lithographic Prints at Various Film Thicknesses

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**Abstract:**

The International Standards Organization (ISO) has a committee attempting to set international colorimetric standards for printed ink films. To accomplish this task, prints of representative ink sets from three areas of the world have been printed on a standard paper at a range of film thicknesses. A laboratory method for printing offset inks has been developed and was used to prepare these prints. The resulting prints have been measured on spectrophotometers of two different geometries and the resulting colorimetric data calculated. A technique has been devised for cross-plotting the color parameters versus film thickness, which should allow ink manufacturers to more easily formulate process ink sets which will meet the proposed standards. Examples of such plots are given here.

**Introduction:**

The need for digital transmission and exchange of colorimetric data in prepress operations, requires precise knowledge of the color of the printed films of the inks to be used on the press. Obviously, standardization of the colors is highly desirable, not only nationally, but also internationally. Individual committees of experts presently exist in several sections of the world, as does an International Standards Organization (ISO) committee (ISO/TC130/WG3/WG4) to accomplish the task of setting colorimetric standards for printed ink films.

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Because the colors to be standardized are those of the prints on paper, a set of detailed specifications is required describing how the prints that will be measured must be made. This requirement is dictated by the fact that a given ink can produce hundreds of different colors, by varying substrate, printing conditions, and film thickness as well as other parameters that can affect the micro distribution of ink on the substrate. In order that ink manufacturers may be able to develop inks that are capable of printing films of a specified color, a standardized laboratory proofing method as well as a standard substrate is essential. Colorimetric data for the resulting proofs are then obtained using a specified measuring procedure.

Initial meetings of (ISO/TC130/WG3/WG4), where representatives from Japan, Europe, and the U.S. were present, have resulted in agreement on specifying the use of a number of important printing and color measurement procedures. In order to assess how much color variation exists among these three parts of the world, a project was undertaken to prepare standard proofs of the three ink sets from these regions.

The National Association of Printing Ink Manufacturers (NAPIM), a U.S. industry trade association, agreed to fund the preparation and measurement of proofs of the U.S. set (SWOP) and a set of European inks supplied by FOGRA. The Japanese Printing Ink Association has agreed to prepare proofs and measurements on a set of inks representing the current Japanese standards. The National Printing Ink Research Institute (NPIRI), the research arm of NAPIM, contracted with Lehigh University to prepare the prints of the U.S. and European inks, using agreed upon procedures. Color measurements on the resulting prints have been made by a number of industry NAPIM members as well as other graphic arts research organizations, using several spectrophotometers with two different geometries.

One of the authors (J.L.), headed the NPIRI project at Lehigh University that was given the assignment to prepare the standard proofs. The procedures and conditions used are described in the following sections.

**Preparation of Standard Prints:**

Standard prints were prepared on the Prufbau Multipurpose Printability Tester in the direct printing mode using SWOP and FOGRA lithographic inks and ISO standard paper [This paper was agreed upon by ISO 130 WG3/4 during 1991. It is APCO II and is manufactured by Scheufelen Paper Company in Germany. Supplies of this paper are available from Dr. Schlapfer of EMPA/UGRA in Zurich, Switzerland.] Duplicate prints were made from each ink to contain wet ink film thicknesses of approximately 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, and 1.3 micrometers. Optical density was measured.

**Printing Conditions**

1. Printing speed 3 m/s.
2. Pressure setting 800 N.
3. Green rubber covered printing cylinders (2) and blanket on sled with Durometer readings 80-85 and distribution roll, Durometer 40.
4. Prufbau temperature maintained at 25°C.
5. Room maintained at TAPPI conditions, 22°C and 50% RH.
6. IGT ink pipet with a scale readable to 0.01 $cm^3$ and plastic tip.
7. A 5-place analytical balance for weighing the cylinders before and after printing.
8. Pure VMP Naphtha for cleaning. (CAS# 8032-32-4, boiling point range 100-160°C).

**Printing Procedure**

1. The rubber covered cylinders and distribution roll were conditioned every time a new ink was tested and between two tests with the same ink if the time interval was more than 1 hour.

2. Conditioning consisted of applying approximately 0.20 $cm^3$ ink to an inking

station on the distribution roll and allowing the ink to distribute for several seconds before putting the cylinder in contact. Distribution was continued 5 min. longer.

3. Wash up consisted of using a minimum amount of solvent on a rag held against the two metal distribution rolls to remove most of the ink. Contact of the rubber rolls with solvent was minimized. The cylinder was removed and carefully cleaned further to maintain constant weight on the balance. The length of time required for the cylinder to reach constant weight ranged from 5-10 min.

4. Paper was cut into 4.5 x 20 cm. strips. One edge was placed in the metal clip on the trailing edge of the sled and the other edge taped on the leading edge of the sled.

5. For the first weighed print, 0.20 $cm^3$ ink was applied in two stripes (each composed of 0.10 $cm^3$ ink) horizontally across the inking station. The stripes were 1 cm apart and about 1 mm from the edges of the roll. Distribution time was 30 seconds.

6. The clean weighed cylinder was placed on the distribution system to be inked for 15 seconds.

7. The inked cylinder was reweighed and then placed on the left printing station. The speed motor was turned on, and the sled with paper guided forward for printing.

8. Immediately after printing, the cylinder was reweighed.

9. The cylinder and distribution rolls were cleaned.

10. The density of the ink was calculated by

determining the weight of 2.00 $cm^3$ ink pipeted on a piece of pre-weighed glass.

11. The following values were obtained: weight of ink on the paper equal to difference in the cylinder weight before ($W_1$) and after printing ($W_2$), percent transfer of ink from cylinder to paper, ink density ($D_i$), and wet ink film thickness on the 4 x 20 cm (80 $cm^2$) print.

Ink film thickness on print (micrometers)

$$= \frac{W_1 - W_2 \ x \ 10^4}{80 \ x \ D_i}$$

12. A duplicate print was made with percent transfer equal to that for the first print ± 1% and with film thickness equal to that of the first print ± 0.02 micrometers. Minimizing the time interval between the two samples promoted reproducibility.

13. The amount of ink applied to the distribution system was varied systematically to obtain film thicknesses within the range of 0.7 - 1.3 micrometers on the print.

14. Optical density readings were taken with a Macbeth densitometer. Using a template, 8 readings were taken down the center of each print avoiding the areas 1 cm on each side of the unprinted bar corresponding to the seam on the cylinder and 1 cm from each end of the print. An average optical density and a standard deviation were calculated.

Subsequent meetings of ISO TC130 WG3/4 agreed upon some slight revisions in the above test procedure in order to obtain international agreement. Further tests made in several US ink company laboratories have found no significant variation in print color due to these revisions.

However, they are expected to help achieve better inter-laboratory agreement, by improving the reproducibility of the test prints.

Specifically, the changes agreed upon are:

1. Printing speed set at 1.0 m/s ± 0.1 m/s.
2. Printing pressure set at 900 N ± 100 N.
3. Distribution time for heatset inks = 20 sec.
4. Inking time for heatset inks = 20 sec.

**Color Measurements:**

The prints of both the SWOP and EURO inks that were made using the procedure just described were then measured by four different laboratories using sphere geometry and two labs using 0/45° geometry spectrophotometers. This gave us a collection of data for the variation of colorimetric parameters with known film thicknesses on a standard reference stock. The colorimetric data from the various laboratories were examined for consistency and averaged to produce the data which were submitted to the ISO Committee for inclusion in the recommended standard. Deviations from the reported average for the different laboratories were all less than 0.5 Delta E units.

When a printing ink manufacturer desires to make a set of inks conforming to a proposed standard, it is necessary for him to know the film thickness required by the particular printing process since the color of the print will vary appreciably with film thickness. The proposed specification gives a range of film thicknesses which are presumed to be those that could reasonably be encountered in actual printing practice. The requirement for meeting the specification is stated as coming within a specified tolerance (in Delta E units) at any of the film thicknesses within the specified range.

For web offset lithography, this range is 0.7um to 1.3um. For sheetfed offset lithography, this range is 0.7um to 1.1um. The practical problem faced by the ink manufacturer, therefore, is comparing the single specified colorimetric values with what a given ink will produce when printed on the standard paper stock. A technique of individually plotting each colorimetric parameter versus the film thickness for both the US and Euro inks was devised in order to make this task more manageable. The ink manufacturer can thus avoid an excessive amount of test proofing each time minor changes are made in a formulation, once he has established a set of calibration curves for his particular inks using typical pigmentation.

Since the pigmentation of most modern process inks is of generally similar chemical classification, the probability of having large changes in these colorimetric calibration graphs occur is not very high. The process cyans almost universally used are a green shade of copper phthalocyanine blue (CI Pigment Blue 15:3). The process magentas used are usually a blue shade of Lithol® rubine (4B Toner) (CI Pigment Red 57:1). The process yellows used in different parts of the world do vary somewhat, in that they are all diarylide yellows, but with different coupling components. Typically these are in the US, AAA (CI Pigment Yellow 12) or OA (CI Pigment Yellow 17) and in Europe MX (CI Pigment Yellow 13). The main difference in the yellows is in transparency.

Because of these similarities, we have found that the use of such film thickness calibration charts can provide an extremely useful tool to the ink manufacturer in determining whether a given ink set will be sufficiently close to the specification values so that it will be within tolerance at any particular film thickness within the specified range.

Examples of calibration charts for both D/8 (sphere) geometry and 0/45° geometry portable spectrophotometers are given in Figures 1 through 12. If we examine these correlations, it is apparent that despite the differences in pigment suppliers in Europe and America, the correlation curves for the Euro and SWOP inks are generally quite parallel to one another with only a few exceptions. It is likely that the differences in color between the two sets of inks is largely due to strength variations between the sets. Thus, it would be possible for an ink manufacturer to predict the shape and position of a correlation curve for the L*,a*,b* values by making only one or possibly two inks at different strengths and drawing a curve parallel to the existing curve for his present inks through the new data points.

It can be seen that the fit to the data for the inks is generally very good. In most of the inks tested, the magenta data shows somewhat more scatter than for the other colors. One exception is the Euro Cyan data which also exhibits a small amount of scatter. Magenta prints have also been found to have more variation in previous studies of proofing of various colored process inks[1,2]. The color of magenta prints appears to be much more variable with any small differences in micro ink distribution on the substrate which may occur during the proofing of the ink. These differences can be due to the dynamic rheology of the ink, the surface and absorptive properties of the paper substrate and the temperature, pressure and speed at the time of printing. There always will be some unavoidable variations on a micro scale of these properties which can cause color variations in any print on paper. Magenta prints show very noticeable changes in both chroma and hue when film thickness is varied and this may be the reason why the colorimetric data show more scatter than most of the cyan, yellow, and black data.

As an example of a way in which these charts might be used, let us suppose that an ink manufacturer had developed a set of process inks which when printed at mid range film thickness e.g. 1.0um showed a color difference of about 5 Delta E units from the standard for the magenta. This would be outside of the specified tolerance range in the proposed standard. By choosing from the calibration charts several other film thicknesses, the shift in Delta E can be quickly calculated. Then it is easily seen whether any of these other film thicknesses will minimize the color difference from the specification values. Shifts in colorant strength can thus be estimated analytically rather than having to make new sets of ink in order to determine how to meet the specified color data.

Another useful function is obtaining the colorimetric data for a film thickness of exactly the same value, say 1.00um. It is frequently difficult to obtain the exact film weight on a printability tester without making several extra prints. With these charts one can read the values at any exact film weight within the chart range without the need for such extra work.

We have shown here a method that the ink manufacturer should find valuable in developing sets of process colors that will occupy certain positions in color space. This is done by creating and using calibration graphs of colorimetric data points versus film thickness for typically pigmented inks on a standard paper.

## References

1. NPIRI Color Measurement Task Group, TAGA Proceedings, 1991, pp490-512.

2. NPIRI Color Measurement Task Group, TAGA Proceedings, 1992, pp490-512.

3. Committee Proceedings ISO/TC130/WG3/WG4

4. Proposed Revision of Color Specifications-ISO 2846

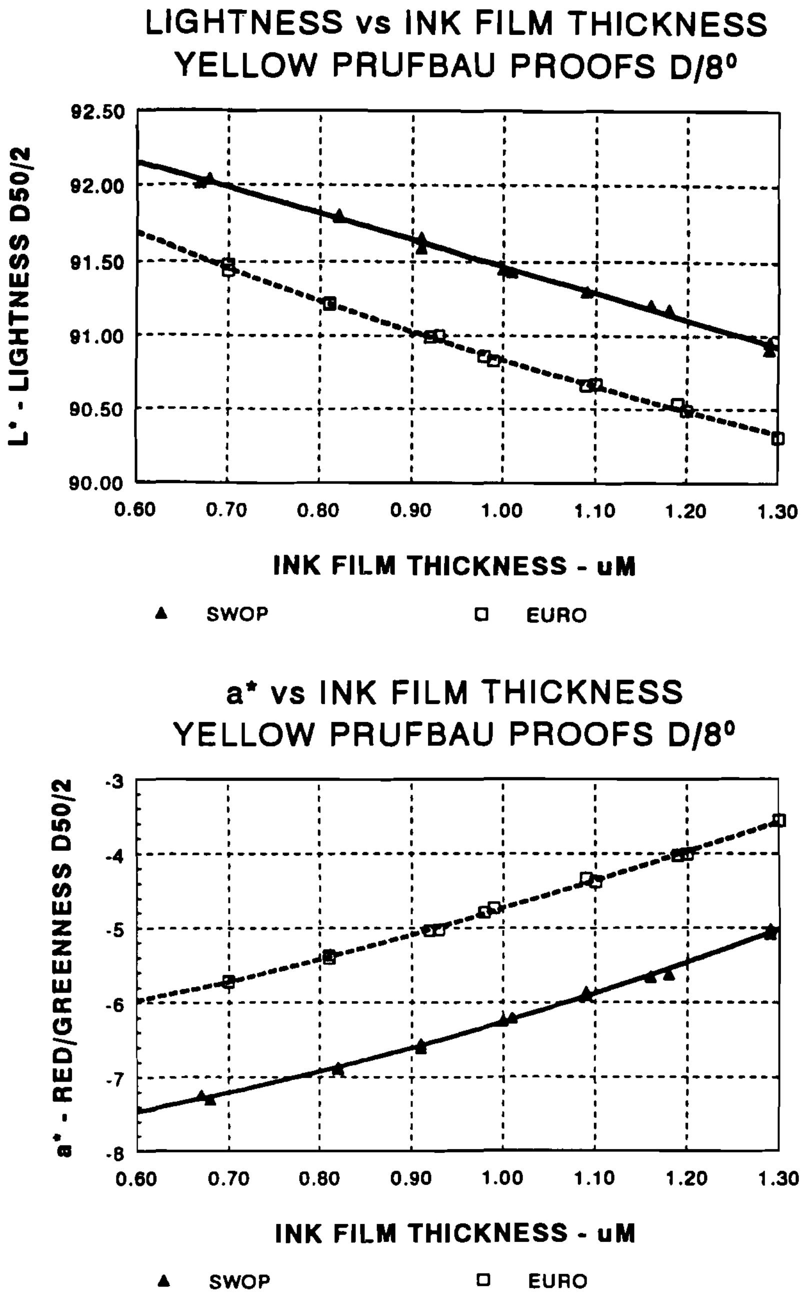
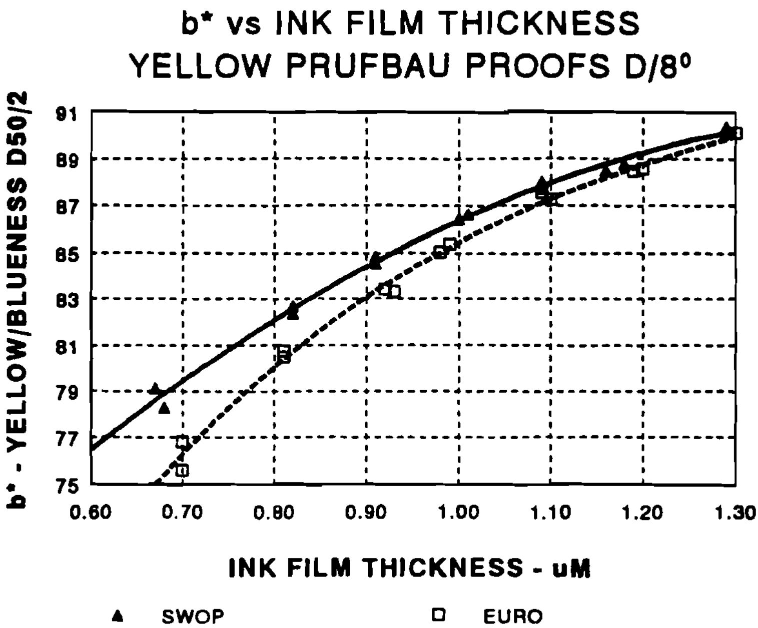

LIGHTNESS vs INK FILM THICKNESS
YELLOW PRUFBAU PROOFS D/8⁰
L* - LIGHTNESS D50/2
92.50
92.00
91.50
91.00
90.50
90.00
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO
a* vs INK FILM THICKNESS
YELLOW PRUFBAU PROOFS D/8⁰
a* - RED/GREENNESS D50/2
-3
-4
-5
-6
-7
-8
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

**Figure 1**


b* vs INK FILM THICKNESS
YELLOW PRUFBAU PROOFS D/8°
b* - YELLOW/BLUENESS D50/2
91
89
87
85
83
81
79
77
75
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

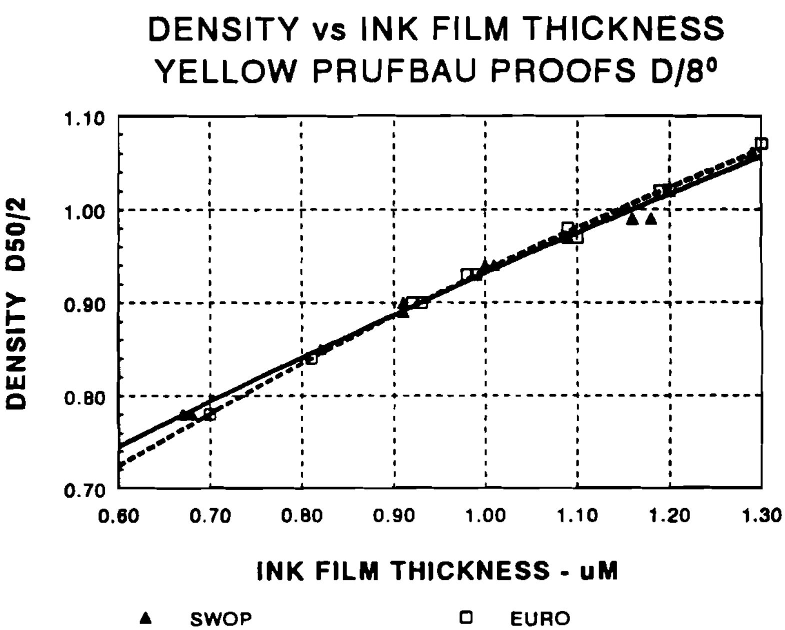
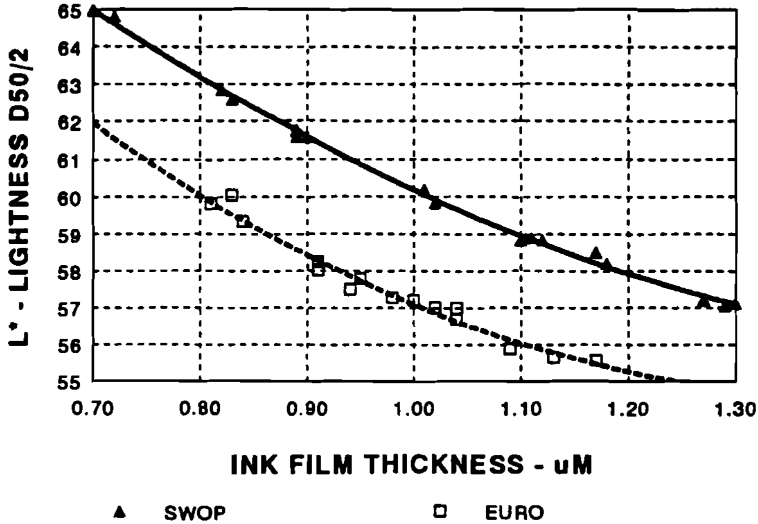

DENSITY vs INK FILM THICKNESS
YELLOW PRUFBAU PROOFS D/8°
DENSITY D50/2
1.10
1.00
0.90
0.80
0.70
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

**Figure 2**

## LIGHTNESS vs INK FILM THICKNESS
## CYAN PRUFBAU PROOFS D/8°




## a* vs INK FILM THICKNESS
## CYAN PRUFBAU PROOFS D/8°

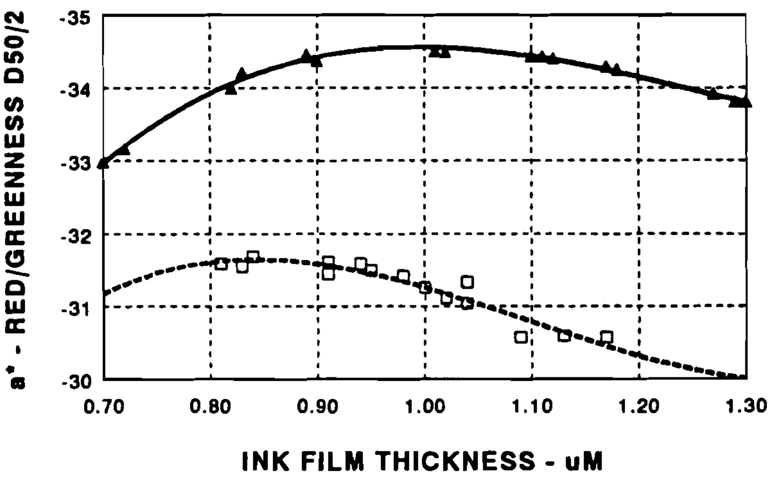
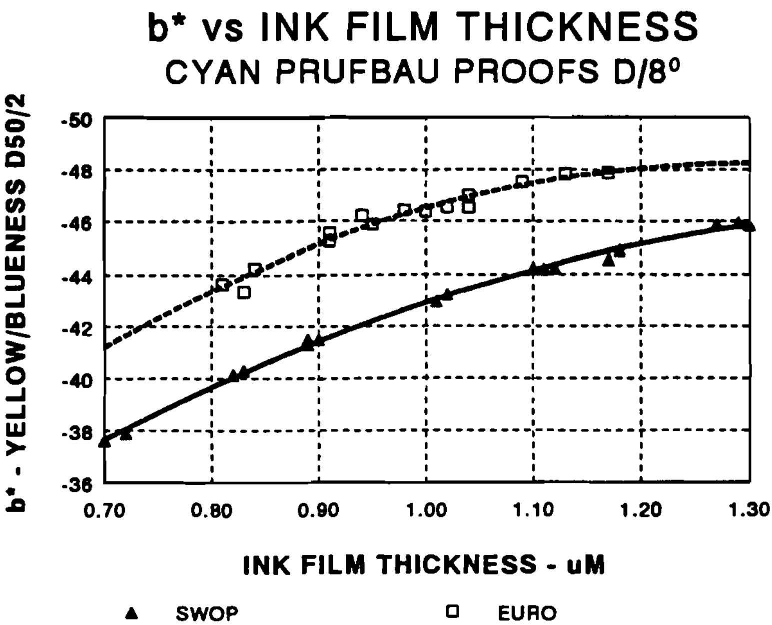



Figure 3


b* vs INK FILM THICKNESS
CYAN PRUFBAU PROOFS D/8°
b* - YELLOW/BLUENESS D50/2
-50
-48
-46
-44
-42
-40
-38
-36
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

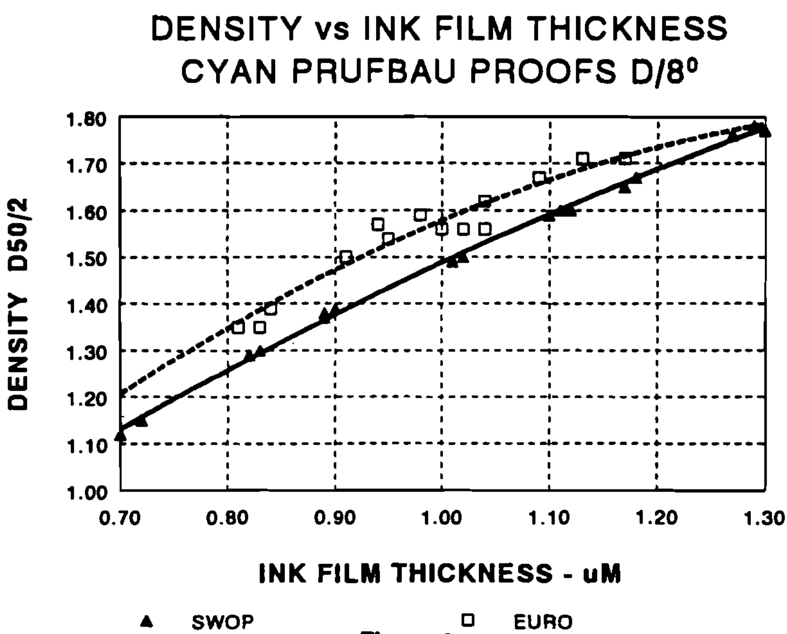
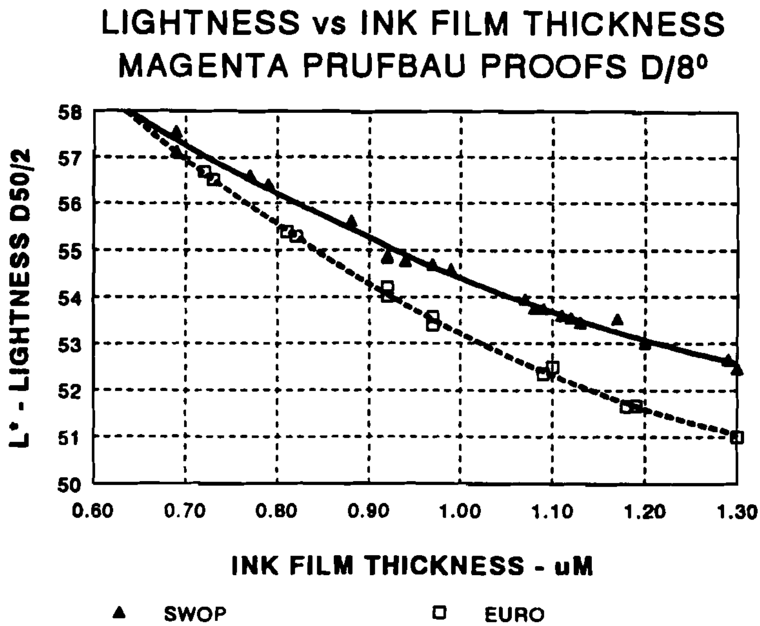
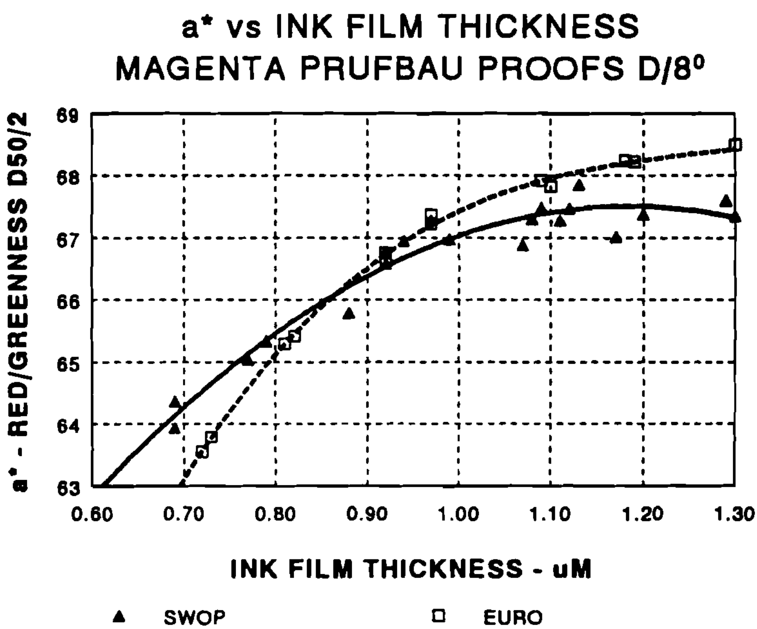

DENSITY vs INK FILM THICKNESS
CYAN PRUFBAU PROOFS D/8°
DENSITY D50/2
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

**Figure 4**

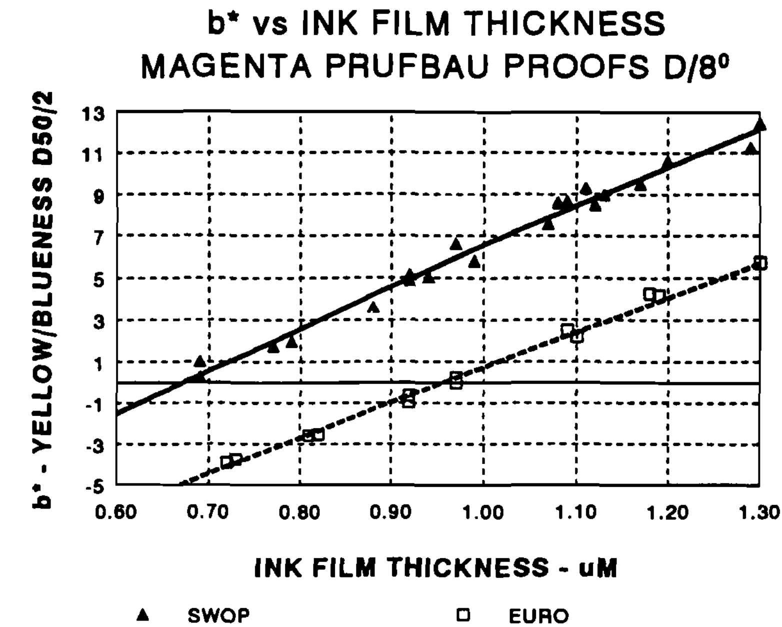


LIGHTNESS vs INK FILM THICKNESS
MAGENTA PRUFBAU PROOFS D/8°
L* - LIGHTNESS D50/2
58
57
56
55
54
53
52
51
50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

a* vs INK FILM THICKNESS
MAGENTA PRUFBAU PROOFS D/8°
a* - RED/GREENNESS D50/2
69
68
67
66
65
64
63
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO


**Figure 5**


b* vs INK FILM THICKNESS
MAGENTA PRUFBAU PROOFS D/8⁰
b* - YELLOW/BLUENESS D50/2
13
11
9
7
5
3
1
-1
-3
-5
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

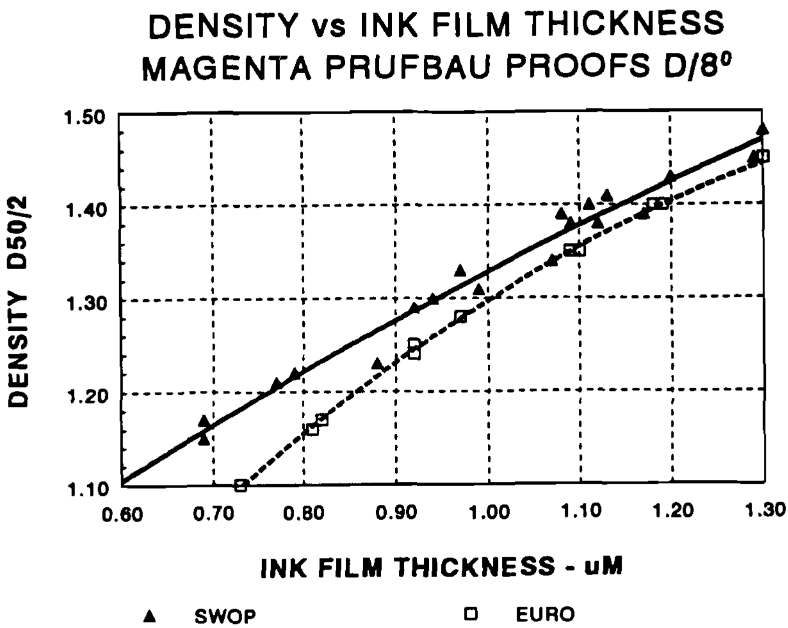
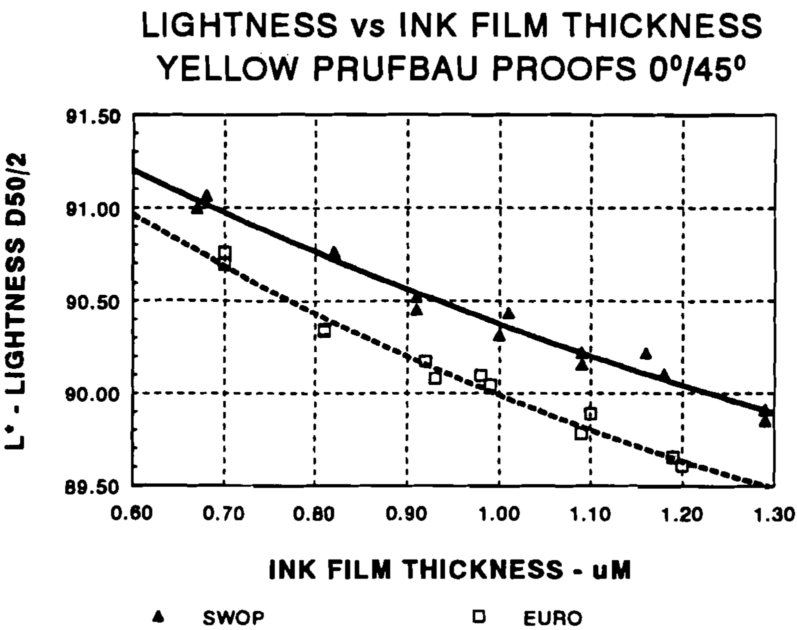

DENSITY vs INK FILM THICKNESS
MAGENTA PRUFBAU PROOFS D/8⁰
DENSITY D50/2
1.50
1.40
1.30
1.20
1.10
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

Figure 6


LIGHTNESS vs INK FILM THICKNESS
YELLOW PRUFBAU PROOFS 0°/45°
L* - LIGHTNESS D50/2
91.50
91.00
90.50
90.00
89.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

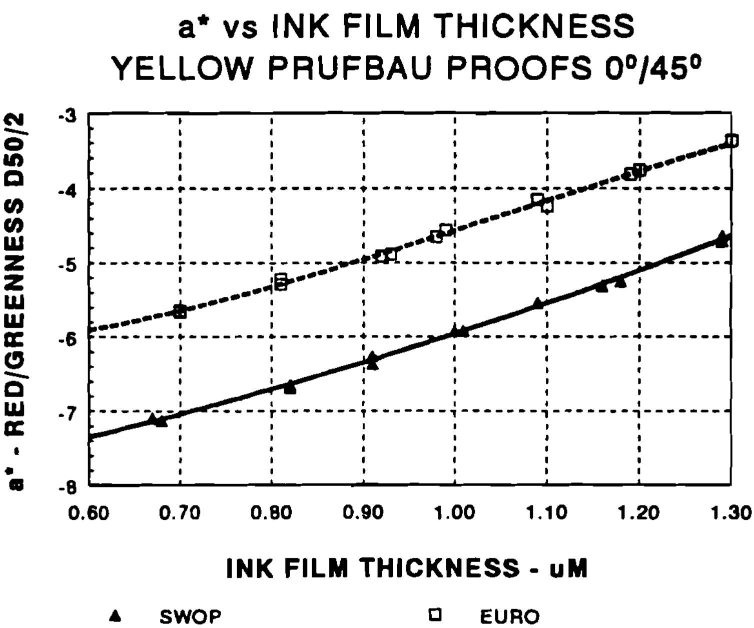
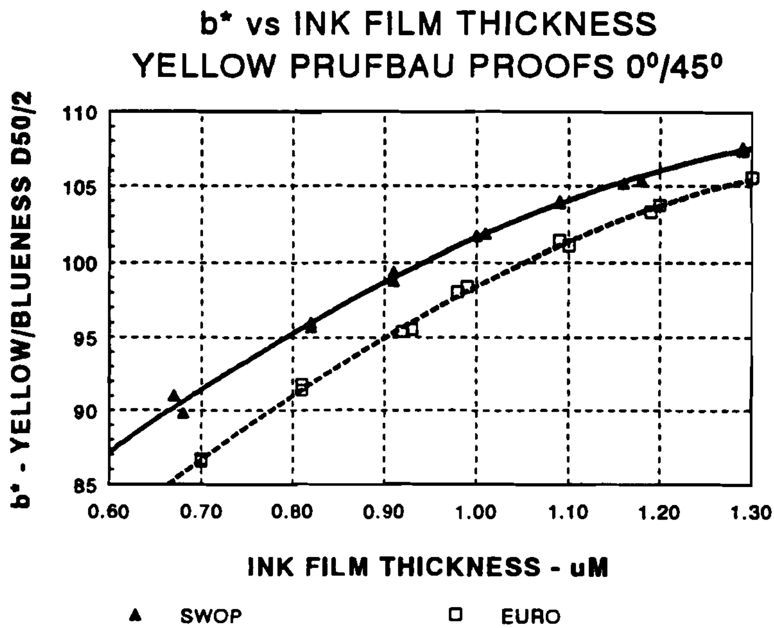

a* vs INK FILM THICKNESS
YELLOW PRUFBAU PROOFS 0°/45°
a* - RED/GREENNESS D50/2
-3
-4
-5
-6
-7
-8
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

**Figure 7**


b* vs INK FILM THICKNESS
YELLOW PRUFBAU PROOFS 0°/45°
b* - YELLOW/BLUENESS D50/2
110
105
100
95
90
85
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

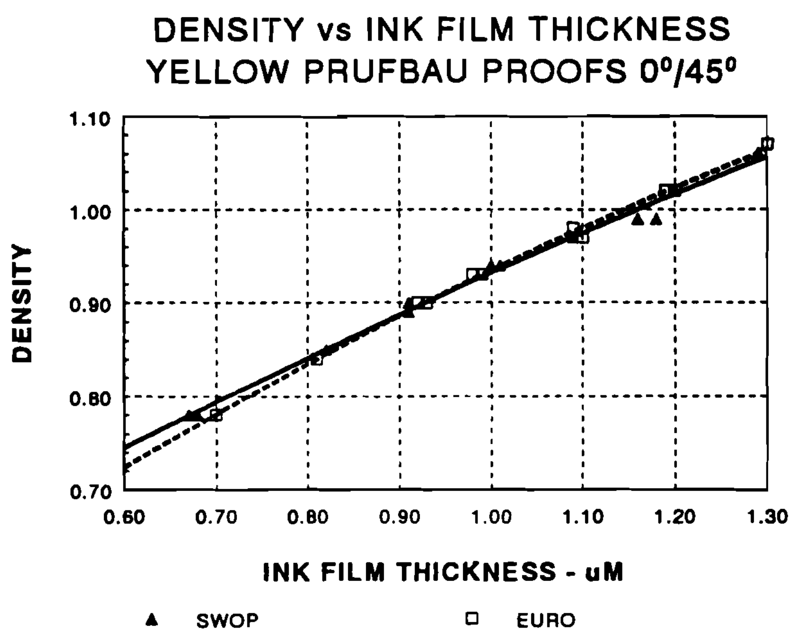
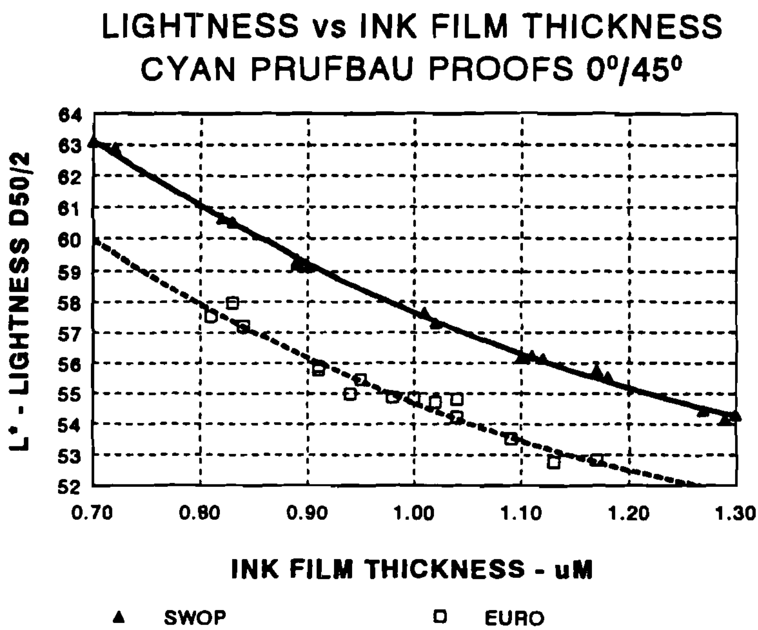

DENSITY vs INK FILM THICKNESS
YELLOW PRUFBAU PROOFS 0°/45°
DENSITY
1.10
1.00
0.90
0.80
0.70
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

Figure 8


LIGHTNESS vs INK FILM THICKNESS
CYAN PRUFBAU PROOFS 0°/45°
L* - LIGHTNESS D50/2
64
63
62
61
60
59
58
57
56
55
54
53
52
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

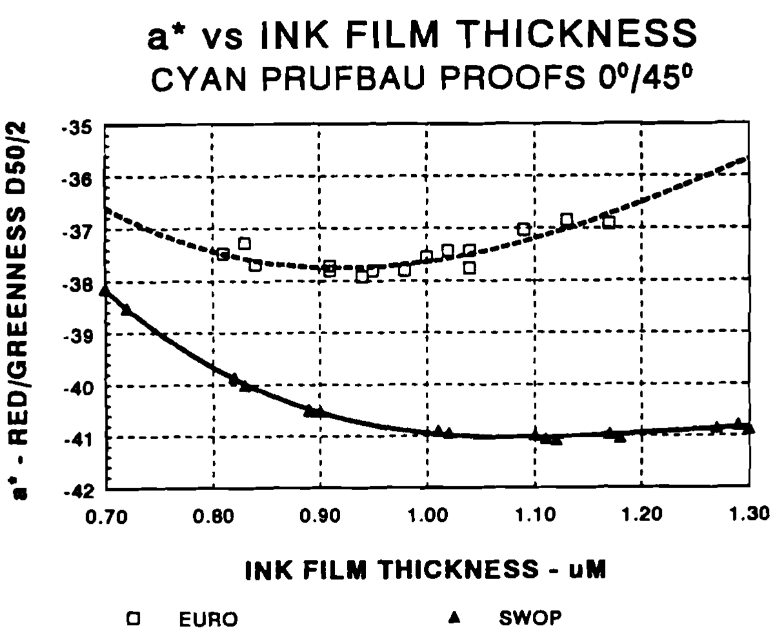
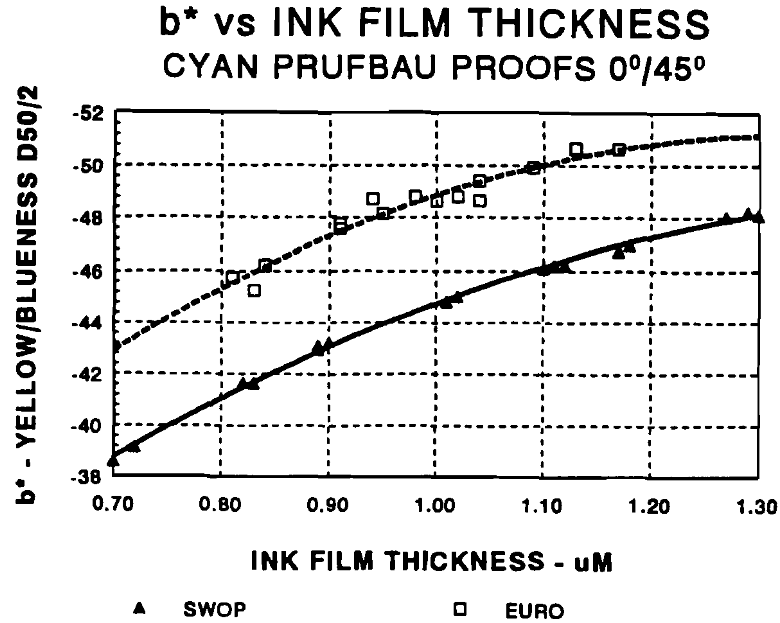
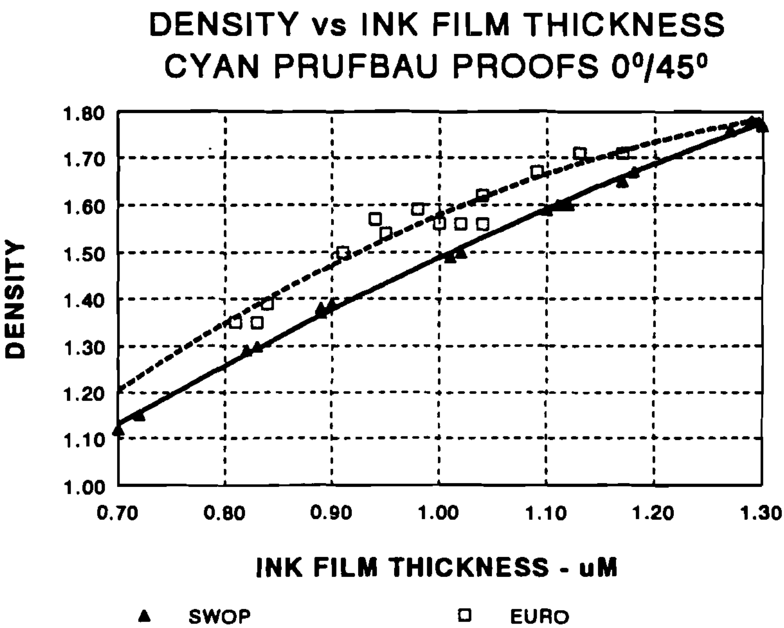

a* vs INK FILM THICKNESS
CYAN PRUFBAU PROOFS 0°/45°
a* - RED/GREENNESS D50/2
-35
-36
-37
-38
-39
-40
-41
-42
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
EURO
SWOP

Figure 9

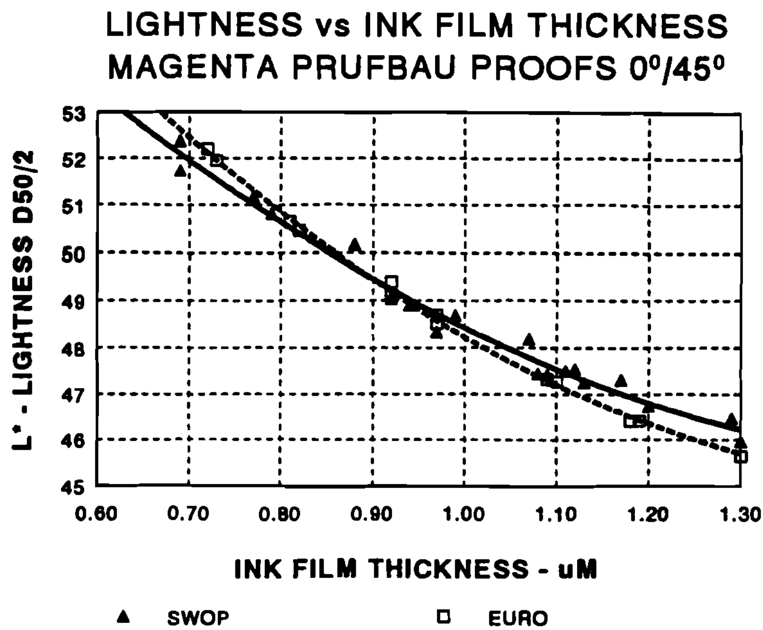


b* vs INK FILM THICKNESS
CYAN PRUFBAU PROOFS 0⁰/45⁰
b* - YELLOW/BLUENESS D50/2
-52
-50
-48
-46
-44
-42
-40
-38
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

DENSITY vs INK FILM THICKNESS
CYAN PRUFBAU PROOFS 0⁰/45⁰
DENSITY
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO


Figure 10


LIGHTNESS vs INK FILM THICKNESS
MAGENTA PRUFBAU PROOFS 0°/45°
L* - LIGHTNESS D50/2
53
52
51
50
49
48
47
46
45
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

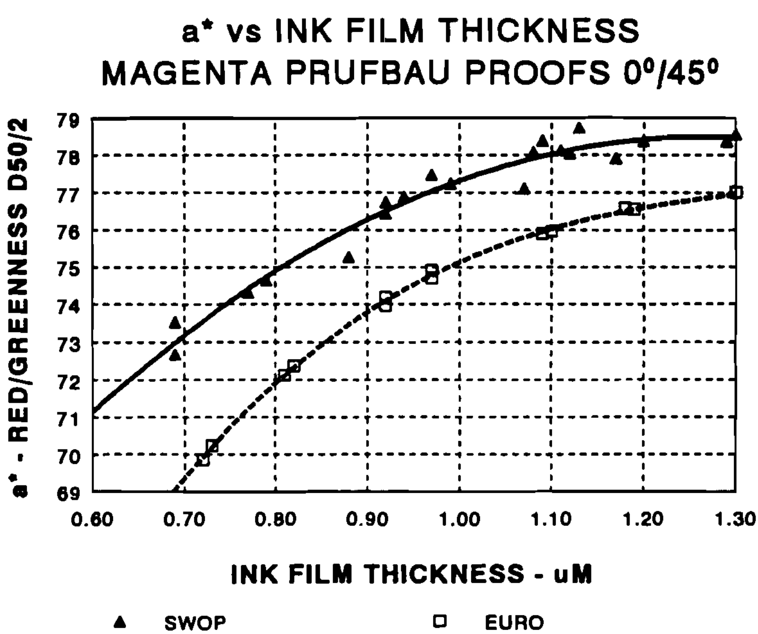
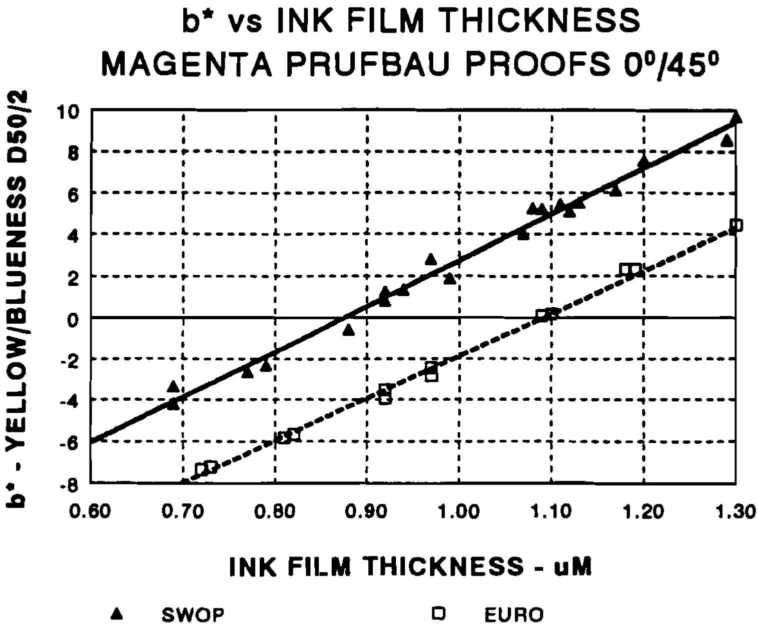

a* vs INK FILM THICKNESS
MAGENTA PRUFBAU PROOFS 0°/45°
a* - RED/GREENNESS D50/2
79
78
77
76
75
74
73
72
71
70
69
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

**Figure 11**


b* vs INK FILM THICKNESS
MAGENTA PRUFBAU PROOFS 0°/45°
b* - YELLOW/BLUENESS D50/2
10
8
6
4
2
0
-2
-4
-6
-8
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

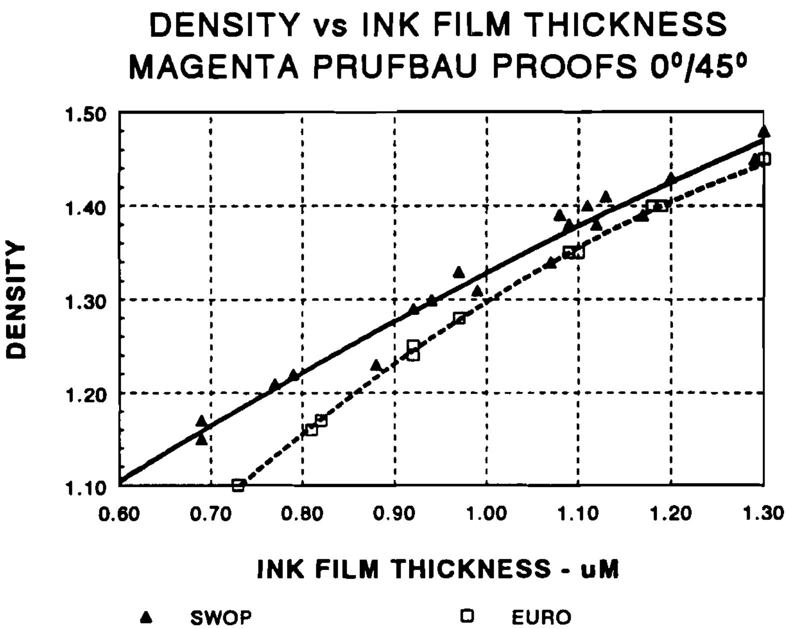

DENSITY vs INK FILM THICKNESS
MAGENTA PRUFBAU PROOFS 0°/45°
DENSITY
1.50
1.40
1.30
1.20
1.10
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
INK FILM THICKNESS - uM
SWOP
EURO

**Figure 12**