An Improved Method for the Routine Measurement of Ink Colorimetrics

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Keywords: ink, colorimetric, transparency, flexo, test method

Abstract

An essential part of four process colour printing, is the need to use inks of a consistent colour and to have a reliable method of defining the ink colorimetrics. Ink colours and transparency measurements recently reported to ISO TC 130, have highlighted several areas where an apparent inconsistency could occur, particularly with high viscosity inks, such as UV flexographic inks. A significant amount of the difference can be attributed to the execution of the methodology proposed in the ISO2847_series of standards.

This paper describes an improved methodology for measuring the colour and transparency of the inks, which has been developed to enables a quick, accurate and repeatable measurement. The method uses a preliminary evaluation to define press ready ink and the extension limits. This is then used to produce a further series of colour and transparency measurements that enable the printing range to be accurately covered. The use of a polynomial interpolation, enables an accurate resolution of the colorimetric curve to be obtained with the minimum number of measurements. The influence of the number of samples on the accuracy of the results is discussed. The problems associated with the use of Meyer bar draw down systems for high viscosity inks is highlighted and alternative approaches suggested.

Results are presented for different flexographic ink types provided by a range of suppliers. Good agreement was achieved for the measurement of colour and transparency as defined in ISO2847. These results show that the same colorimetric targets could be used for all flexographic process ink sets.

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Introduction

The evaluation of the colour and transparency of inks is crucial in ensuring the quality of printing. The ink colour has an obvious impact on the printed image. The transparency, which dictates how other colours can be seen through the ink, is of particular relevance for half tone printing. In order that the proof, production print and production run can be matched and that the images produced by different print companies will match, then there is a need to ensure an ink can be adjusted by adding extender base or varying the ink film thickness, to achieve the desired colour. As this is a cornerstone of achieving consistent repeatable prints, there have been significant efforts on the part of ISO to develop standards for process inks.

The UV Flexographic inks rely on shear thinning to reach the desired viscosity on press. This causes them to be too viscose to use the simple draw down test procedure. This presented a difficulty in obtaining a series of prints of an appropriate density that cover the range sufficiently to characterise the ink. This difficulty also served to highlight a measurement interpretation issue that is probably a cause of much inter laboratory disagreements with regard to ink colour and transparency.

After briefly outlining the methodology recommended by the ISO 2847 series of standards for evaluating ink colorimetrics, this paper then discusses the different methods for obtaining a consistent film of UV ink. A revised method is then proposed for evaluating ink colour. This is applied to all types of flexographic ink. Similarly, a revised method is proposed for obtaining and interpreting the transparency measurements. These results are discussed and compared with the ISO aim data. The influence of viscosity on colour is also briefly considered.

Measurement of Ink Colorimetrics

Changing key settings in the ink duct in offset printing, controls the printed ink film thickness and hence the colour strength, i.e. optical density. This has been simulated in test methods by using a series of drawdowns with different K-bars to vary the ink film thickness. However, this is not appropriate for processes such as flexo and gravure, where to control the printed colour extender or solvent is mixed into the ink to dilute the pigmentation and hence vary the colour strength.

For the purpose of colour characterisation of gravure and flexographic inks, it is feasible to select one K-bar or proofing process, which gives the required film thickness and to mix in extender base to vary the colour strength. The use of extender, which is in effect the ink carrier without pigment, varies the colour strength without changing viscosity, so the ink film thickness remains constant.

The first step in the method is to prepare press-ready ink, (Zawacki 2000). This ink has all necessary components and it is at press viscosity. A balanced extender is then also prepared to press viscosity. This is a clear extender that has all the necessary components to reduce the pigment concentration without significantly influencing the rheological properties of the ink. The ink and extender base are mixed on a mass basis to 5 predetermined ratio to form a series of ink extensions from 90%/10% to 50%/50% (ink to extender base). The ink extensions have progressively more extender base and less pigment and therefore less colour strength. The prints of the press ready ink and the five extensions are prepared on an APCO II/II reference substrate. This is a white paper manufactured specifically for ink colorimetric testing and has consistent white colour with no optical brighteners. A printability tester for flexographic inks is used to prepare the prints, ensuring that an appropriate anilox roller, rod or engraved plate has been used to cover a range of ink densities as specified in the standard. The printed samples are measured using a 0/45 spectrophotometer. The position within the CIELab colour space for each ink extension is plotted. The aim is generate a locus that passes through a tolerance around a defined target. This can be shown as an a* b* plot, (Figure 1), which shows how the ink colour approximates to the target value in hue and chroma, but does not include lightness.

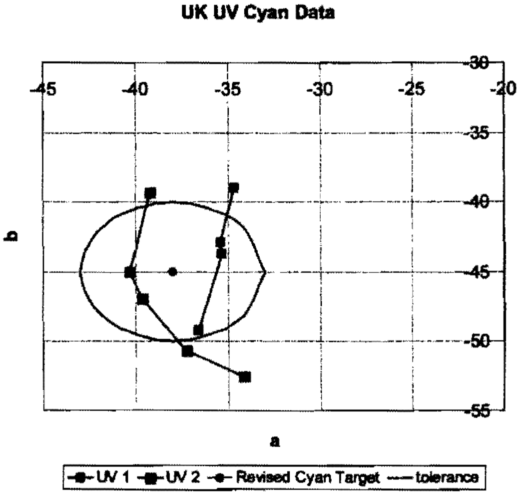
UK UV Cyan Data

Figure 1 Sample of data for UV inks plotted on CIE a* Vs b*

Alternatively, the results can be plotted as ΔE, the difference between the actual colour and the target value against extension or ink film thickness (Figure 2). This includes the component due to lightness. For an ink to be in tolerance the value of ΔE must fall below the tolerance at some point during the extension series. For each of the process colours there are density ranges that will ensure that the locus has sufficient length to accurately assess the ΔE from the target.

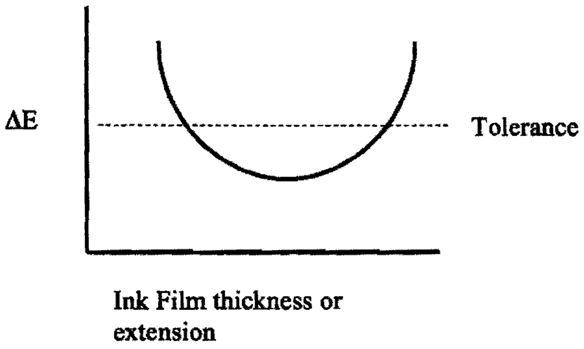

Figure 2 Schematic diagram of ΔE from target value plotted against extension

The problems associated with the ΔE measurement method can be seen in Figure 3. There are two inks that as they are extended move towards the tolerance, one eventually meeting the standard. The other ink is moving away from the target as it is extended. The main problem that this indicates is that the ink density is too high, i.e. the ink film is too thick. Also, although the draw-downs have been prepared as per the standard they have insufficient density range. It is approximately 0.3, when a range of at least 0.6 is required.

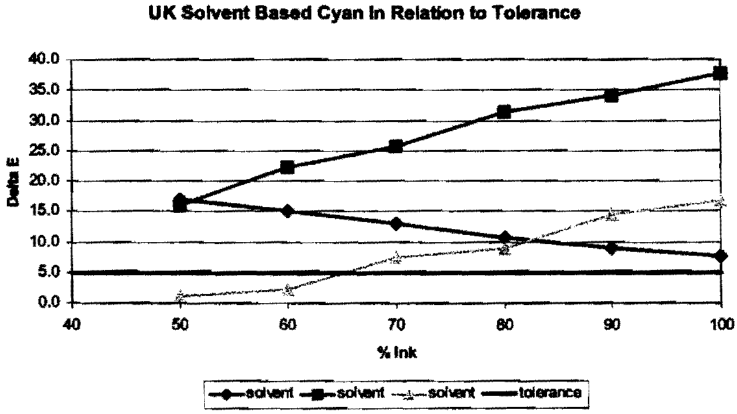

Figure 3 ΔE versus % ink for solvent based cyan ink

The transparency is also important because most inks are over printed, therefore one ink has to be seen through another. The transparency of the ink is evaluated using the same series of ink extensions and the same ink film thickness as was used to evaluated the ink colour. This time the ink film is applied to a coated black and white card, normally a Lineta 105C. The Lineta card has a dense black printed area (lightness (L*) of less than 6) and a white area. The card is opaque which eliminates the effect of the colour of the backing substrate on which the print is measured. The black is measured before the prints are prepared using a 0/45 spectrophotometer. The card is marked to indicate every location where the black has been measured. After the ink film has been applied each card is measured again at the same locations (this is to eliminate the influence of any variation in the density of the solid black). The difference in ΔE between the unprinted and the printed card is calculated. A large change in visibility of the substrate colour with change in colour strength, i.e. extension means the ink has a high transparency value, while a small change means it has a low value. The ΔE value for each ink extension is plotted versus percentage ink (Figure 4). The graph should be linear. The slope of the graph gives the change in ΔE per percentage change of ink strength. The transparency is given by 1/slope, or the change in percentage ink needed to give a change in ΔE of 1.

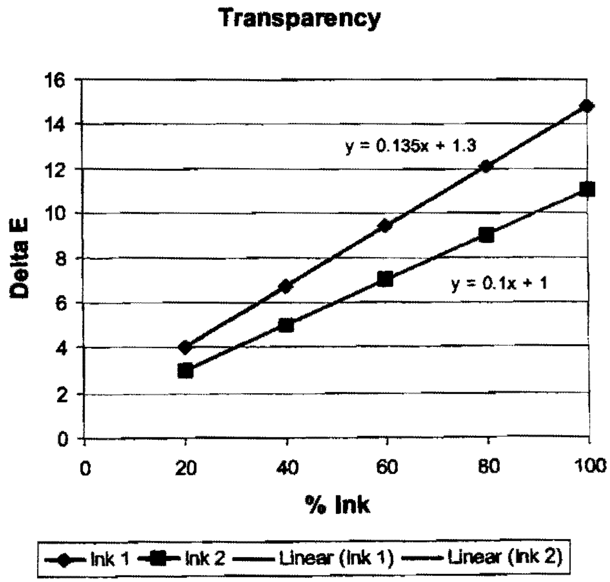

Figure 4 ΔE plotted against % ink to calculate transparency

Problems are also encountered with the measurement of transparency if the ink film is too thick or the density range is inadequate. If the ink film is too thick, then the ink appears to be opaque and changing extension has no effect on the transparency measurement. A similar effect is obtained if the density range is insufficient, as then the difference in density between successive extensions is so slight that the slope of the transparency graph tends to 0.

Therefore the problems associated with the colorimetric characterisation of ink can be attributed to the need to apply a consistent, thin ink film and to sufficiently extend the ink to produce prints that cover the required range of densities.

Consistent Ink Film

Colorimetric characterisation relies on changing the ink strength while not changing the ink film thickness, therefore a consistent method of film deposition is required. One of the simplest is automated draw down with a K-bar. While this method is appropriate for solvent inks, it does not deposit either a thin or sufficiently consistent ink films when using inks of high viscosity, such as UV Flexo inks. During trials, it proved impossible to get densities lower than 2.0, even when using the finest wire K-bar. The surface contours of the film were measured using a white light interferometer (Figure 5).

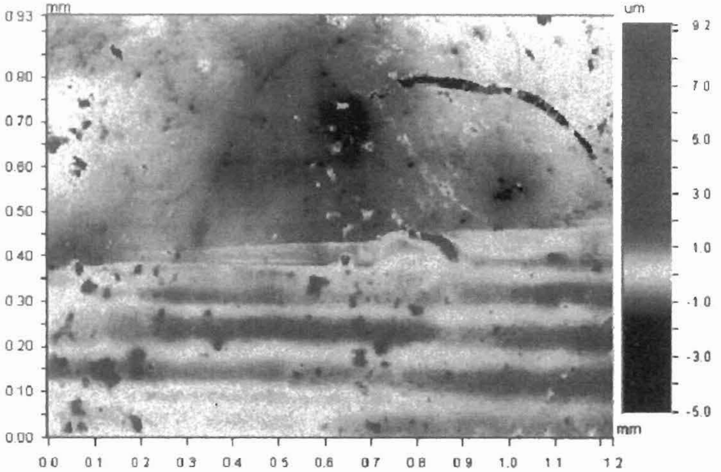

Figure 5 White light interferometer picture of edge of ink film drawn down.

The image shows the edge of the film. The top half of the image represents the APCO paper substrate used for the test. The average ink film thickness is over 12 µm. The ink spreads as it is forced under each successive wire on the K-bar. The ink is so viscous that the impressions of the K bar have created undulations of 8 µm in the ink film. So the ink film is both too thick and inconsistent.

A first alternative to the K – bar, the K-Lox (produced by RK Print Coat Instruments Ltd) was also evaluated. . The K-Lox consists of an engraved roller acting as an anilox and a rubber transfer roller in a frame with weights to maintain contact pressure (Figure 6). This is attached to the automatic draw down machine in place of the K bar. However the K-Lox requires approximately 3 rotations of the rollers to stabilise the ink transfer, which is effectively longer than the travel of the machine. Therefore, the print obtained suffered banding and inconsistent ink transfer (Figure 7). It can also be used as a hand held device, which allows a longer draw down length, although this then introduces operator effects that cause inconsistency.

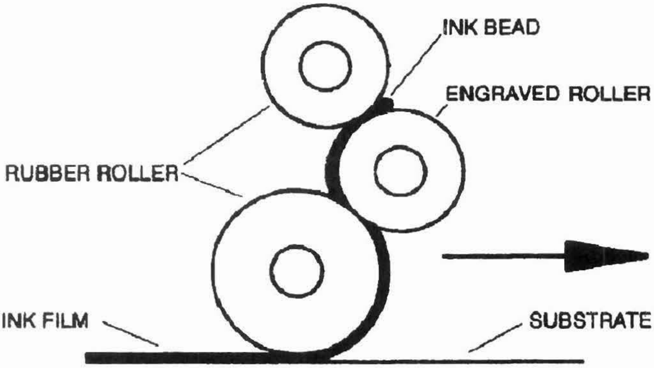

Figure 6 Schematic diagram of K Lox

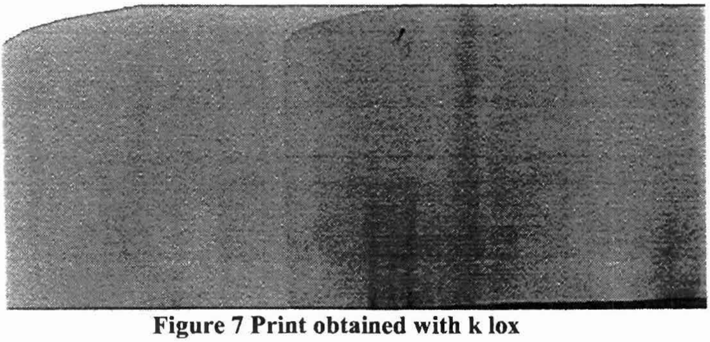

Figure 7 Print obtained with k lox

As a second alternative, an IGT AIC2-5 multipurpose proofing and testing device, along with a high speed inking unit was used to produce a constant ink film (Figure 8). The high speed inking unit consists of a rubber ink carrying roller, driven steel distribution cylinders and four control panel activated arms to carry the ink transfer rollers. The volume of ink required for the desired ink film thickness was precisely metered onto the ink-carrying roller by means of a calibrated pipette. A relatively long distribution time (45 – 60 seconds) and inking time for the transfer roller was used because UV inks do not set on the inking unit. The AIC2-5 has a central, driven, impression cam, on to which the substrate is clamped and ink transfer rollers. The speed of the driven impression cam can be set at either constant speed or accelerating. The printing speed was set at approximately 1m/sec, to avoid damage to the surface of the substrate due to the tackiness of the ink. The printing force between the ink transfer rollers and the impression cam can also be set. Best results were obtained with a low force (75-100N). The print was dried immediately to reduce ink absorption into the substrate. The AIC2-5 was found to give a consistent ink film thickness even with UV flexo inks. The ink film thickness was approximately 4 µm. Although all the results reported in this paper were obtained with the AIC2-5, similar consistency in ink film thickness has also been obtained with a "F1", the IGT dedicated flexographic proofing device.

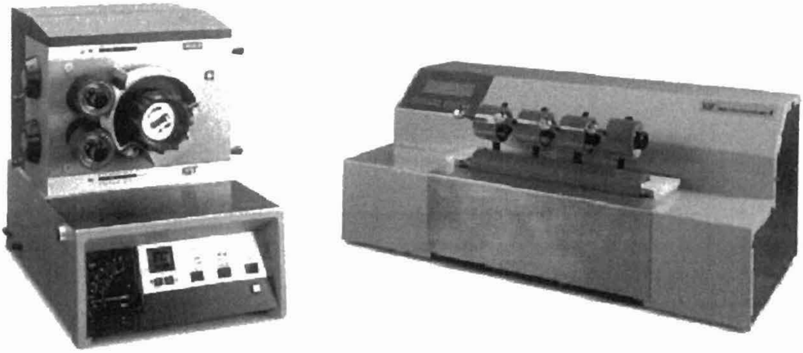

Figure 8. IGT Multi purpose tester and high speed inker

Revised method for measurement of ink colour

One of the primary problems that measurements of ink colour highlighted is the definition of press ready ink. It was decided to define press ready in terms of print density, press ready being the upper limit of density as prescribed in the draft standard. Once press ready ink had been defined, it was then necessary to arrange to prepare a series of prints at a range of extensions that covered the whole of the density range prescribed by the draft standard. A methodology was developed that ensured the prints covered the desired range, while still keeping the number of tests to a minimum.

The method as described earlier was modified as follows: The desired ink film thickness was determined for the printability tester, the aim was to obtain a density slightly higher than that prescribed in the standard. Prints were prepared at 2 ink extensions, 50% ink /50% extender base and 10% ink /90% extender base (by weight). These extensions were chosen to ensure the print density covered the full range. The densities of the prints were measured and the results interpolated to enable a convenient extension to be selected that gave a density just higher than that required in the standard, yet was a convenient ratio of ink to extender. While this will reduce accuracy, it also reduces the likelihood of arithmetic errors caused by a complex ratio calculation. This ink extension is then defined as press ready and the scale normalised to this value. A series of prints are then produced at the ratios prescribed in the original method. However, the range is now extended in 10% steps until the full density range is achieved.

Even with a minimum of five extensions, in some circumstances the point at which the locus of the colour passes nearest to the target can lie mid way between two points on the extension curve. In extreme cases, this could lead to the colour of the ink being interpreted as not meeting the standard when it was in fact a consequence of the method. This is overcome by curve fitting the data and interpolate between points to obtain a continuous curve. When the CIE L*, a* & b* are plotted against density, then the L* is virtually a straight line (Figure 9).

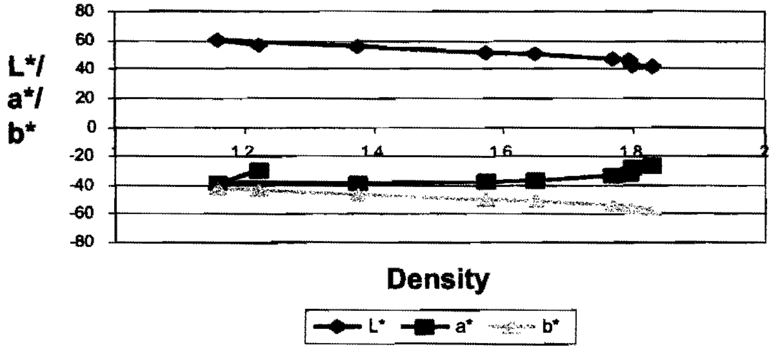

Figure 9 CIE L*, a* & b* versus Density

Therefore a* & b* can be plotted versus L*. (Figure 10). Second order polynomial curves are then provide an adequate fit to the data. The equations obtained for the curves can be used to calculate values for a* & b* for any L* within the range. Thus, the curve can be interpolated over the full range and the minimum value of ΔE to the target value can be found (Figure 11).

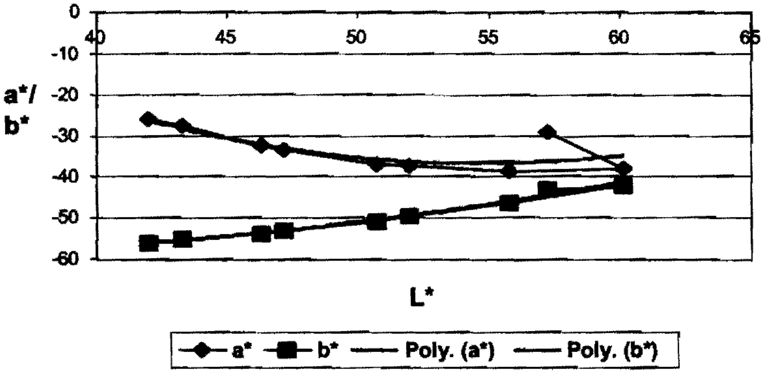

Figure 10 CIE a* & b* versus CIE L*

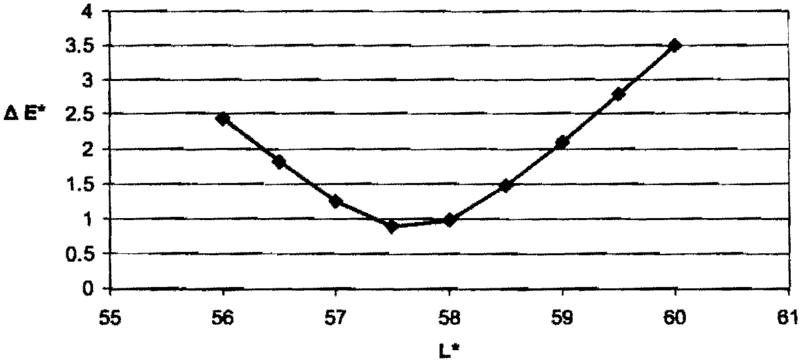

Figure 11 Interpolated ΔE versus L*

The colour of all types of flexographic inks were evaluated using this method and compared with the colorimetric values proposed for the ISO standard. Almost all the Cyan inks (Figure 12) tested achieve the target value of L* = 58.0, a* = -38.0 and b* = -45 within the tolerance ΔE of five. The majority of the water based inks approximate to one curve. The solvent inks produce curves that are all similar in shape, passing to the same side of the target value, but with a greater spread than the water based inks. This would suggest the tolerances for the water based inks and the solvent inks could be reduced, provided the target value was adjusted. The difference in colour between the two types of inks is probably due to the inherent colour of the carrier base (water versus solvent). However, the UV inks pass either side of the target point and require the full tolerance range for these inks to meet the standard. This could reflect differences in the formulation of the carrier base.

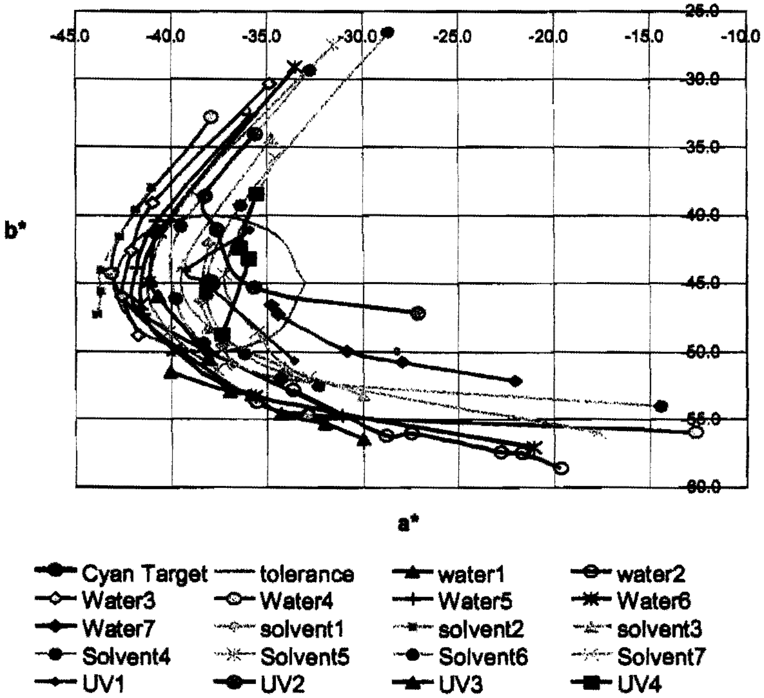

Figure 12 Colour space for Cyan data

The magenta inks (Figure 13) show a large spread in results with inks passing to either side of the target of L* = 52.0, a* = 71.0 and b* = -1 and some falling outside the tolerance ΔE of five. Most of the water based inks appear to approximate to one curve passing to the right of the target, only one of the water based inks following a curve to the left of the target. The solvent inks approximate to one of two curves, both of which correspond approximately with the two generic curves created by the water based inks. This would suggest that the inks tested were formulated using one of two pigments, leading to two distinct families of curves. However, the UV inks were the most erratic, only one UV ink achieving the standard.

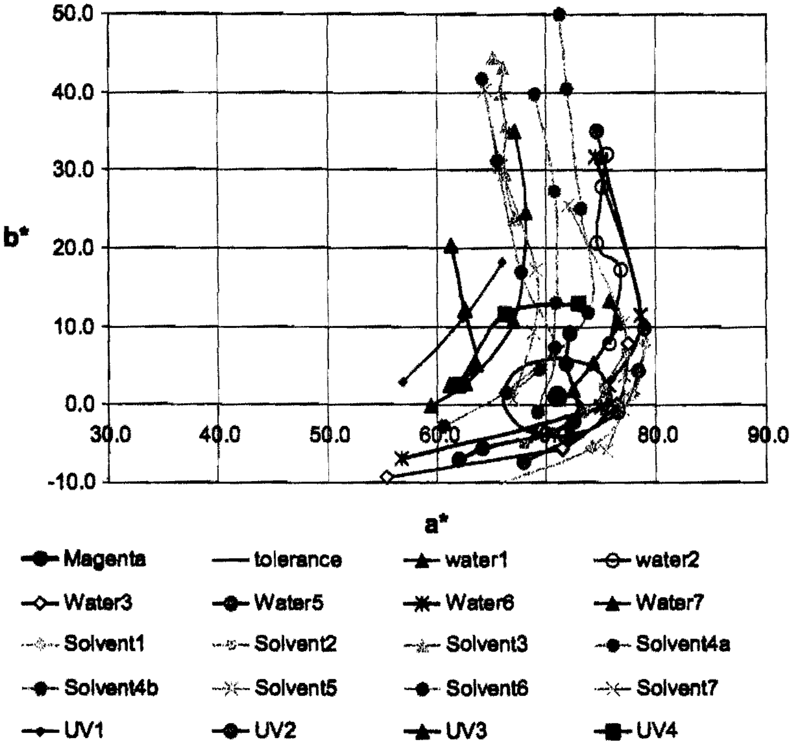

Figure 13 Colour space plots for magenta inks

All the yellow inks tested achieved the standard of L* = 91.0, a* = -5.0 and b* = -95 within the tolerance ΔE of five, with the exception of two of the UV inks (Figure 14). Most of the solvent inks approximated to one curve that passed almost exactly through the target value. The water based inks similarly approximated to one curve. However, this passed to the right of the target value. In both cases the spread of the curves suggest they could achieve a tighter tolerance than required in the standard, although in the case of the water based ink this would require the a* value of the target to be reduced to approximately – 3. While two of the UV inks tested would achieve this target and a smaller tolerance, two of the other UV inks tested fell outside the tolerance of the proposed ISO standard. Again the UV inks tended not to approximate to a single curve.

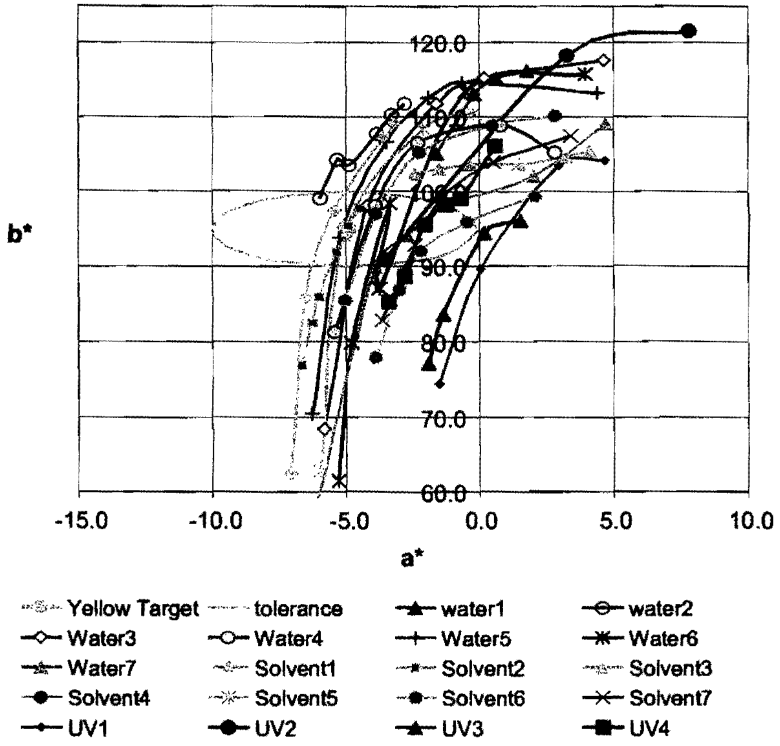

Figure 14 Colour space plots for yellow inks

All the black inks tested followed approximately the same curve, passing within the L* ≤18.0, a* = 0.5 and b* = 0 within the tolerance of $\Delta a^* = \pm 1.5$ and $\Delta b^* = \pm 2.0$ (Figure 15). The results suggest the tolerances could be smaller, yet still allow all the inks to meet the standard.

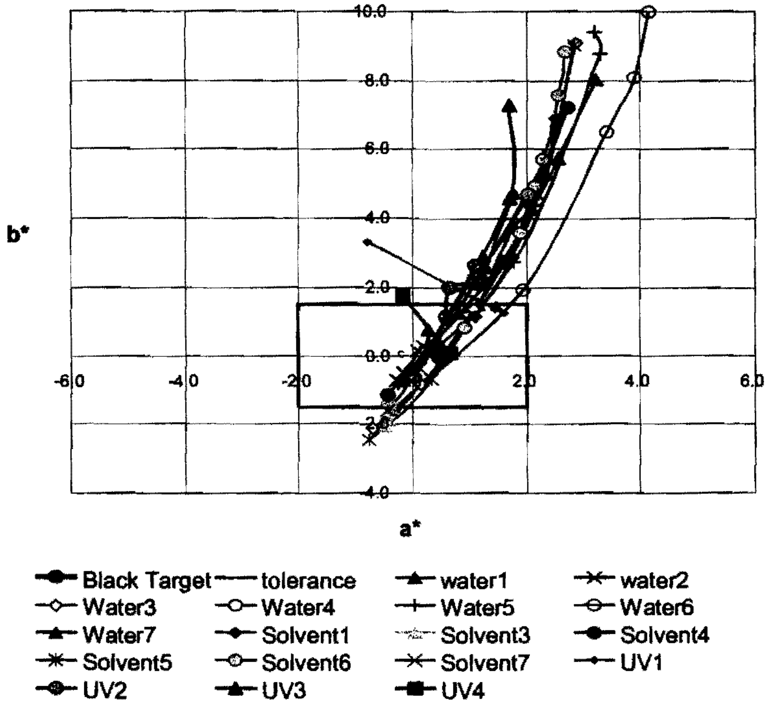

Figure 15 Colour space plots of black inks

The effect of extension on transparency

In the calculation of transparency, ΔE, the difference between the ink film colour and substrate black, is plotted against ink percentage in the extended system. This produces an approximately linear graph, the transparency equalling the reciprocal of the slope. Measurement of transparency produces a wide spread of values from inks which were used for nominally the same purpose. This can be attributed to the influence of the amount of extension required to produce the range of ink colour strengths. In order to minimise this spread, the method was modified as follows.

The same ink extensions as determined to obtain the required density range, were also then used to obtain the ΔE values used to plot the graph from which the transparency was determined. However, ΔE is plotted against absolute extension. The ink use different amounts of extension to obtain the same density range when deriving the colorimetric data. Thus, for two inks that have the same ΔE values, but where one is over a shorter range of percentage ink, then this gives a larger slope and therefore a lower transparency value. In Figure 16, ink 1 has required extension from 50% to 10% ink, while ink 2 requires an extension from 90% to 20% to obtain the same density range. As the values of ΔE are the same, then the apparent transparency of ink 1 is 8.05, while for ink 2 it is 14.06.

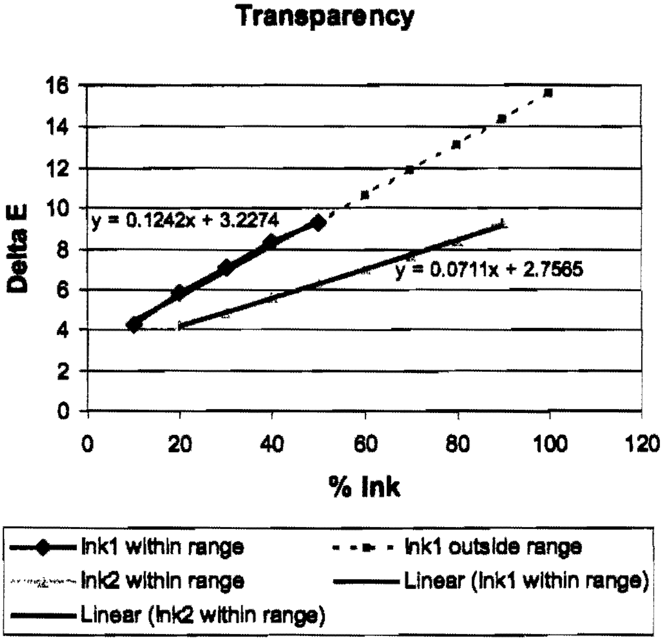

Figure 16 ΔE versus percentage ink based on original sample

There is a need to normalise the calculation of percentage ink using the definition of press ready ink, i.e. that which gives the required maximum density, used in obtaining the colorimetric values. In the previous example, for ink 1 50% ink 50% extender, becomes the new 100% press ready ink. The ink extensions were recalculated relative to this new 100% ink and plotted against percentage ink. Similarly the ink 2 was normalised to 90% ink 10% extender as the press ready system. The transparency values for ink 1 and ink 2 calculated from the reciprocal of the slope are now 16.1 and 15.6 respectively (Figure 17).

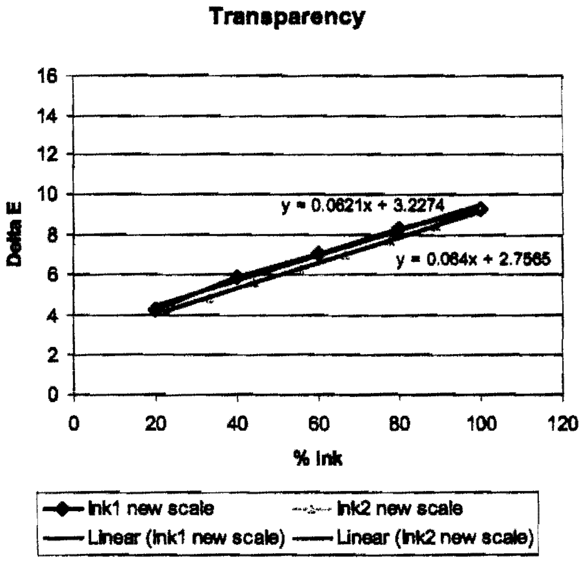

Figure 17 ΔE versus percentage ink based on normalized scale

The normalised transparencies for the water based ink sets are shown in Figure 18. The cyan inks are consistently the most transparent, while the yellow inks are in general the most opaque. The magenta inks vary in transparency from values approaching those of the cyan, to less than the yellow ink in one case.

The solvent ink sets are generally more transparent; with values almost twice those of the water based inks (Figure 19). However, the magenta inks tend to be the most transparent, while the yellows are again the most opaque.

The UV inks tested were the least transparent (Figure 20). The yellow inks are particularly opaque with transparency values of only 2 to 3. The most transparent of the cyan and magenta inks have maximum values of 15 to 25, while the most opaque are only approximately 10.

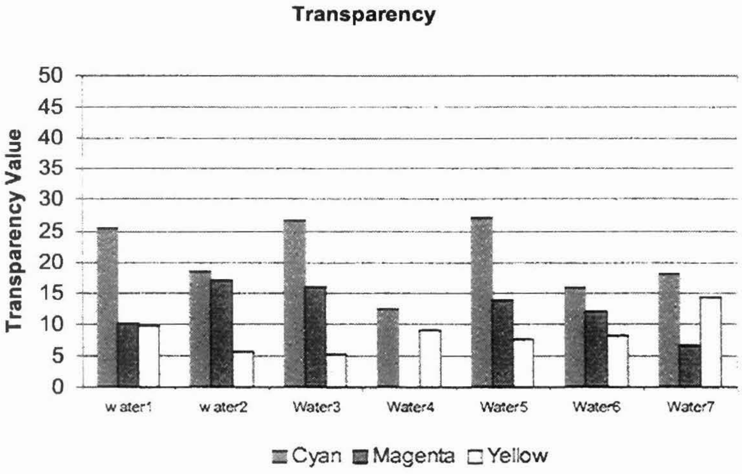

Figure 18 Transparency values obtained for water based ink sets

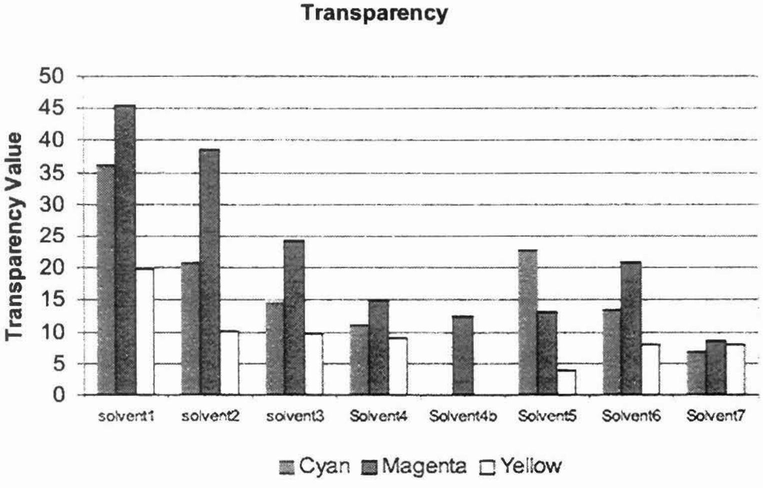

Figure 19 Transparency values obtained for solvent based ink sets

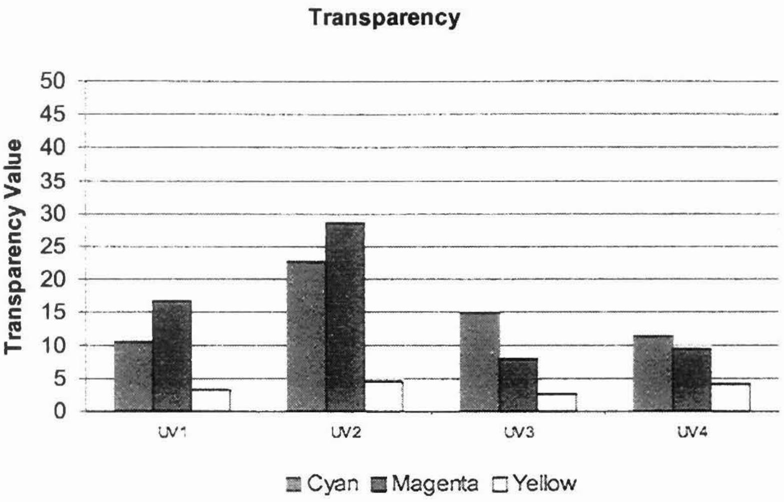

Figure 20 Transparency values obtained for UV ink sets

Viscosity

In flexographic and gravure printing, the viscosity is used as means of controlling ink transfer. This is done by the addition of solvents. The effect of viscosity on the colorimetric properties was evaluated. The effect of adding extender base has a minimal impact on the viscosity curves (Figure 21). These illustrate viscosity plotted against shear rate for a water based and solvent based ink. This shows the extender base used was identical in performance to the ink and would therefore only affect colour strength and not rheological properties, as is required when performing a colorimetric test.

The first addition of solvent caused a dramatic drop in viscosity (Figure 22), approximately halving it for a given shear rate. However, subsequent additions of solvent had relatively little impact on the ink rheology.

The addition of either solvent or extender base in the same proportion produced the same effect on colour change in the ink (Table 1).

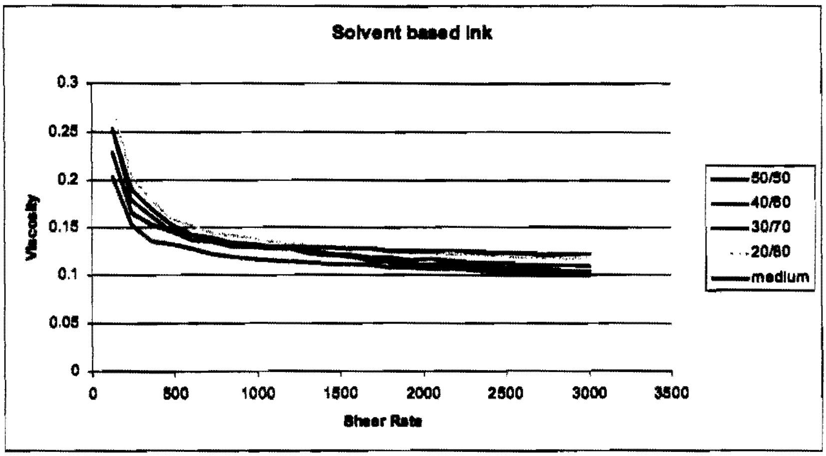

Figure 21a Rheometric curves for solvent based inks at varying extension

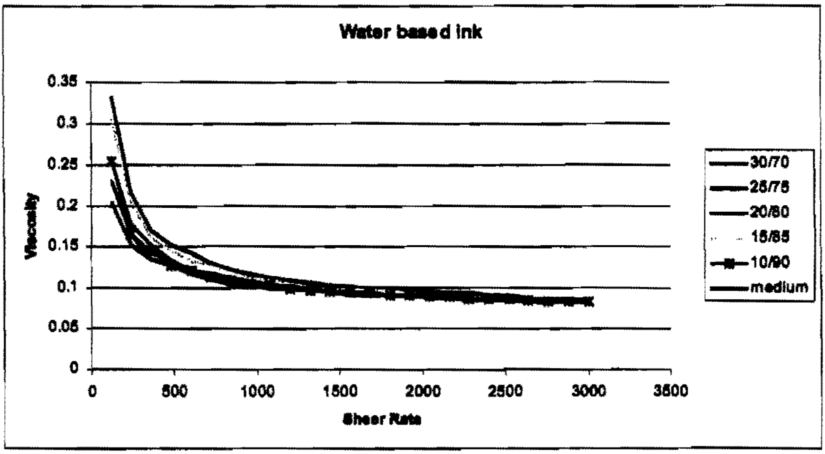

Figure 21b Rheometric curves for water based inks at varying extension

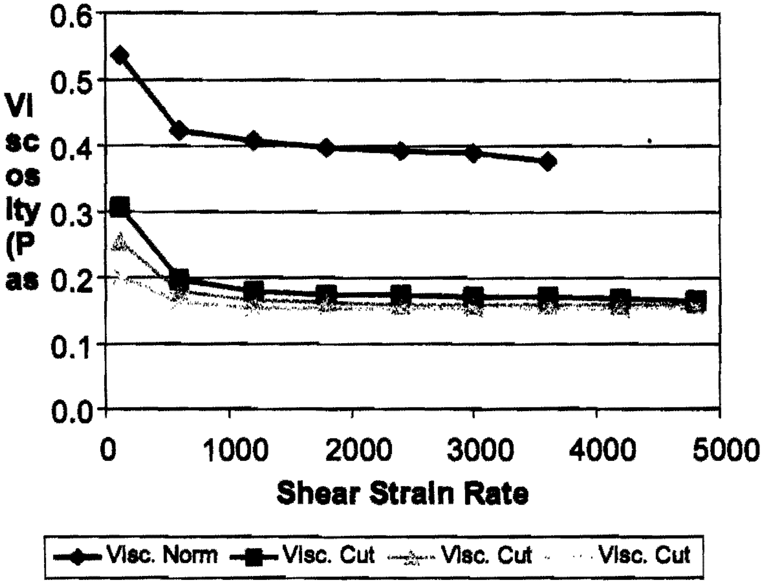

Figure 22 Rheometric curves for addition of solvent

	Density-Cyan	CIE-Lab-L	CIE-Lab-a	CIE-Lab-b	Delta E ISO2846-5
ISO2846-5		56.99	-39.16	-45.99	
100% ink	1.53	56.93	-44.75	-45.51	5.61
100% ink + solvent	1.40	58.79	-43.79	-44.39	5.21
80% ink 20%extender	1.39	58.79	-43.55	-43.73	5.26

Table 1 comparison of the effect of the addition of extender bas e with solvent on ink colour

Conclusions

The measurement methodology for colorimetric and transparency has been refined. This has produced more consistent results. Viscosity and colour strength can be adjusted independently by using solvent and extender base respectively.

The proposed ISO targets and tolerances are suitable for water, solvent and most UV Flexo inks. All the water and solvent based inks tended to produce similar compliance, while only just more than 50% of the UV inks met the tolerances. These results suggest that separate target values are not required for most inks to achieve the target values within the current suggested tolerances. Alternatively, it should be possible to redefine the targets for water based and UV inks and reduce the tolerances. This is particularly the case for cyan and yellow where each ink type follows a generic curve. The differences between the cyan curves for the different ink types could be attributed to the inherent colour of the carrier medium. The magenta inks would appear to have two distinct curves. This difference could be attributed to differences in pigments used. In order for an ink maker to manufacture magenta to a tighter tolerance, then this might require a pigment dependent colour target value. This approach could also be adopted when specifying non-process colours, the target value being dependent on the pigment.

The UV inks exhibited the most differences between inks from different manufacturers. This is probably a function of the different formulations for the carrier.

All transparencies are now directly comparable. The solvent inks, with their colourless base, tend to have the highest transparency. The water with it slight colour has slightly less transparency, while the UV inks are the least transparent. In general the yellow inks where least transparent of all the colours, while the magenta and the cyan inks were generally similar in each ink set.

Acknowledgements

The authors wish to acknowledge the financial support of the Engineering and Physical Sciences Research Council, European Regional Development Fund and the Welsh Development Agency for this work.

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