A Theoretical and Experimental Comparison of the GRACoL and ISO Approaches to Press Characterization and the Data Sets Produced

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Abstract

There are many methods that can be used to set of the print appearance on a press. A proof and print calibration has been proposed by the GRACoL organization known as the G7 method, as an alternative to ISO 12647-2. This approach uses a novel concept of controlling the press calibration based on gray-balance through out the tonal range using a neutral print density curve (NPDC) rather than solid ink film and dot area as outlined in ISO. The objective of the paper is to evaluate the different methodologies.

This study evaluated the application of the two methods as a practical tool for setting up and controlling a sheet-fed offset press. This was achieved through several controlled press runs using a combination of conventional and UV cured ink sets on different presses. The press trials carried out for this investigation followed the set procedures outline in the ISO12647-2 and G7 documentation. The ink sets used were all ISO compliant. The G7 calibration test target was imbedded in the image printed and was used for all trials as the requirements of this method dictated the use of specialized targets and software.

The methodologies were evaluated using four distinct press trials. These consisted of printing using linear plate curves and then adjusting them based on the print conditions and the methodology followed. The results discussed in the paper show that the ease of use of the different methodologies varies. Each of the methodologies have shown different advantages and disadvantages and these area discussed in detail.

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Introduction

Since the invention of four-color process printing there has been a need for standards for controlling the process. Over the past years several approaches have been introduced to include those based on specific market segments such as newsprint (SNAP, general commercial (GRACoL) and publication (SWOP). Each of these approaches has taken a slightly different angle but do include many of the same control parameters.

SNAP, GRACoL and SWOP are considered the foundation for controlling the process, but these methods are only considered guidelines. The only standard for offset printing at the current time is ISO 12647-2, all of which follow the same densitometric parameters as the definition of control. Tone curves defined as tone value increase is the primary control for these approaches. Tone value increase based on mid-tone gain within these guidelines varies based on the substrate. To address the three separate guidelines, ISO 12647-2 defines tone value increase based on six separate curves to address the substrate issues. As a secondary method of control the three guidelines and the ISO standard do define gray-balance. Gray-balance for these guidelines and standards are also defined at the mid-tone and are based on a cyan (50%), magenta (40%), and yellow (40%) screen build.

The focus behind this investigation is to address the new guideline proposed by GRACoL, defined as G7, which increases the level of importance of gray-balance as the primary method of control rather than tone curves/ tone value increase. More importantly the G7 method does not just define gray-balance at the midtone, but across the entire tonal range. This approach requires a new understanding of the measurement procedures as well as a new understanding of how to adjust colour on press to achieve the desired result.

In order to test the validity of the G7 approach, several controlled press runs were performed following this method. In addition, press runs were performed following the ISO 12647-2 method. The results of the press trials will be discussed based on achieving the targets values as defined by each of the methods. A colorimetric analysis will also be discussed based on the measurements of the IT8 7/4 target printed during all of the press runs.

Experimental procedure

The objective of the investigation was to evaluate the G7 method by performing several press runs using different combinations of presses (2), inks (3), plates (3), and fountain solution (2). The same paper was used throughout the investigation as a control for defining colour as paper is a key ingredient in how colour is measured and its appearance. As a comparison, a press run following

the ISO 12647-2 method was also performed. This press run was performed using the same combination of materials as one of the G7 press runs.

To ensure repeatability and accuracy of the results, the set procedures outlined in the G7 and ISO documents were strictly followed. There are many similarities between the G7 and ISO methods as G7 has adopted factors such as ink properties (ISO 2846) and target values defined as CIELab values. It was also considered important that the presses be optimized to the manufactures specifications to include roller settings, plate and blanket packing, as well as temperature and environmental control.

The test image used for his investigation was the GRACoL standard test image. This form is a four-color process image which includes several key elements for the analysis of the G7 procedure, most importantly the gray-balance scales. Screening of the image was 175 lines-per-inch and a euclidean dot shape was used. Plate curves varied and will be discussed in the results section.

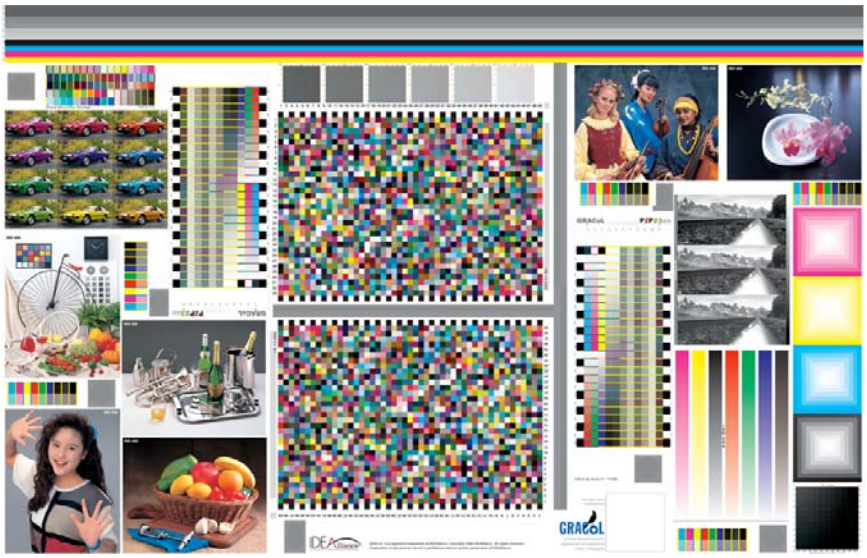


Figure 1: Test image, 28x40-inches

Due to the size difference of the two presses used in this investigation a modified version of the test image was used for the half size press (20x26-inches). This version of the test image included many of the main targets, only eliminating those in duplication to include the IT8 7/4, gray-balance scales, and some of the ISO stock images. Screening of this image remained the same (175lpi) and was passed through the same workflow as to limit any differences between these two images.

Added to both test images were colour control strips (colorbars) designed for each of the printing presses used. These colour control strips were used to ensure the targeted ink films were achieved and that the ink films were consistent across the width of the image. Both colour control strips included solid ink patches, 50% screens of each colour, and gray-balance patches.

In order to validate each of the methods it was important not to look at a single condition based on a single set of materials. For this reason several different combinations of plates, ink, and fountain solution were used. The plates used were supplied from three separate manufactures and were very different technologies. One of the plates was a positive acting thermal technology that has been on the market for several years in the United States. The second plate was a new technology that is imaged on a thermal platesetter, but is a negative acting plate. This plate is of a new technology and has been on the market for less than two years. The third plate was a negative acting process less plate based on an ablative technology. Ink sets used during this investigation all conformed to the ISO 2846 standard as specified by G7 and ISO 12647-2. Of the three sets, two were conventional ink sets with different strength levels and a hybrid set of ink which also had a slightly different strength level. Tack and viscosity of the ink sets were similar and were proposed based on the printing conditions and paper used in this study. Fountain solutions from two different suppliers were also used. These fountain solutions had similar pH values, but different conductivities by design. Fountain solution concentrate was mixed with RO water according to the manufacturers recommended dosage.

Two presses were used during this investigation to include a 4-color forty inches and a 6-color twenty-eight inch press. The forty inch press ran only conventional inks and the full size test image. The twenty-eight inch press also ran the conventional ink sets as well as the hybrid inks. When printing with hybrid inks, the press was configured with one drying lamp after the first two printed units and a second lamp after the last two printed units.

The trial procedure following the G7 method and started with what was defined as RAW plates or plates off a platesetter without any type of calibration applied. Dot area measurements of the RAW plates prior to mounting on the press rendered different results between the positive and negative acting plates. Both the positive thermal and ablative plates produced midtone values between 48%-50%. These values are what would be expected off a linearized device and shows that the platesetter's laser power and focus as been set based on these types of plates. The negative acting plates produced midtone dot area values ranging from 54%-57%. The differences between the positive and negative plates are very important as the size of the dots produced throughout the tonal range play a significant roll in gray-balance.

Make-ready of each press run was focused on achieving the targeted CIELab solid ink values which are the same for both the G7 and ISO 12647-2 methods, Table 1. Delta tolerances for the individual colours are ΔE 5 or less. The G7 method also defines CIELab colour values for the two colour overprints, which also must be under a ΔE of 5.

	Black	**Cyan**	**Magenta**	**Yellow**	**M/Y** (G7 Only)	**C/Y** (G7 Only)	**C/M** (G7 Only)
L	16	54	46	88	47	50	24
a	0	-36	72	-6	68	-68	17
b	0	-49	-5	90	48	25	-46
ΔE Tolerance	5	5	5	5	5	5	5

Table 1: G7/ ISO 12647-2 CIELab values

The two different presses used during the investigation have two different colour control systems. On the half-size press, measuring colour was slightly challenging as the colour control system on this press functions on densitometric measurements rather than colorimetric. For this reason a handheld densitometer was used define what the corresponding densities were to the target CIELab values and to ensure the ΔE tolerances were not exceeded. The colour control system on the full size press, based on colorimetry, was able to measure CIELab and define the match as a function of ΔE without the use of the handheld device.

Once the targeted solid values were achieved analysis of the gray-balance took place. The measurements were taken with a spectrodensitometer at D50/ 2° just as the solid measurements were. According to the G7 documentation gray-balance is not defined as a true neutral gray, but a blue shaded gray (a*= 0.0/ b*= -1.0). Adjustments were made to the solid ink films to ensure these targets were achieved. For the ISO 12647-2 press runs gray-balance was measured and an attempt to achieve an ideal gray-balance of (a*= 0.0/ b*= 0.0).

After achieving the target solid values and gray-balance, the press was allowed to run 1,000 impressions. These press sheets were analyzed to validate the targets were met and that the press operated in a stable condition.

Following the G7 method, once a series of press sheets were determined to meet the requirements and were considered stable, the gray-balance scales were measured and analyzed using the special software recommended by GRACoL. This software upon completion of the analysis produced a series of plate curves for the entire tonal range that were to be applied in order to meet the remaining G7 requirements. For the ISO 12647-2 press run the analysis of the midtone TVI was performed. Plate curves following this method were generated only at the midtone and determined based on making the cyan, magenta, and yellow TVI's match with the black TVI slightly higher, but not exceeding 4%.

A second press run for both the G7 and ISO methods was performed using the curved set of plates, determined by the two different methods. Both press runs were performed the same day under the same conditions. Target solid ink values for these press runs were based on the modified values determined during the first press run to achieve gray-balance.

Upon achieving the targeted values for each of the G7 and ISO 12647-2 second iteration press runs, the press was allowed to run 1,000 impressions under stable print conditions.

Results and discussion

The results and discussion section will first cover the process of performing each press run to include the second iteration based on the predicted plate curves. Following the findings of each press run will be a discussion of the differences between the appearance of the G7 and ISO prints.

The initial G7 press runs were performed with RAW plates or plates without a calibration curve. Dot area measurements from these plates confirm that not all the plates had the same dot area values. Positive acting plates were virtually linear without a calibration. The midtone dot area was ideal as the highlights and shadows were slightly less than linear. Negative acting plates produced a positive dot area curve as the highlights, mid tones, and show dots were slightly higher than what would be defined as linear. The thermal ablative plates which were imaged on a separate platesetter had dot area values of what would be defined as linear.

(k/c/m/y)	25%	50%	75%
Positive Acting	23/24/23/23	49/50/49/50	74/74/74/74
Negative Acting	27/27/27/27	55/55/55/57	78/78/78/78
Process less	25/25/25/24	50/49/50/49	74/74/74/74

RAW plate dot area values

The pressrun following the ISO 12647-2 standard was run using only the negative acting plates which had the same RAW dot area values as listed above.

The initial press run was performed on the half-size press with conventional inks. During the make-ready, the targeted CIELab values were achieved along with register. Meeting the targeted solid CIELab values were determined by measurements of the colour control bar located at the tail of the sheet with a spectrodensitometer set to CIELab ΔE. Reference values for the ΔE calculation were pre-programmed into the spectrodensitometer and the same unit was used throughout this investigation. Minor adjustments to the targeted solid CIELab values were made in attempts to achieve gray balance as specified by the G7 expert during initial discussions of the project. Values from this initial press run

produced a maximum ΔE of 4.17 after adjustments to achieve gray balance. Prior to the adjustments, the maximum ΔE was less that 3.50.

CIELAB	Black	Cyan	Magenta	Yellow
ΔE	1.35	3.52	2.17	4.17

ΔE values based on raw plates, trial 1

Though the adjustments were made, gray balance was still not considered perfect. When analyzed using the appropriate software, it was clear that there was a blue cast in the highlights and a yellow cast in the shadow as shown in the *CMY Gray Balance* figure below. Analysis of the *NPDC* curves shows the shadows were not ideal according to the G7 specification as the average line which represents the results from these press runs in comparison to an ideal curve. The black *NPDC* curve shows just the opposite as the results from this press run were heavier than ideal.

TVI (dot gain) calculated by the software is based on CIEXYZ rather than density. The values from these curves do not represent very well what was actually measured form the press sheets. For this reason the information was considered invalid and not used as part of this investigation.

Results from this initial press run show that in order to achieve the G7 specification, the plates would have to be curved to compensate for the colour

casts measured in the highlights and shadows. Calculating the curves was performed using the same software as the analysis. The data used to generate the curves were taken every 10% across the entire tonal range. Values predicted by the software produced results that appeared to be unrealistic for what was expected. For this reason, a G7 expert was contacting and asked to comment on what has occurred. Further in-site based on discussions led to the section of several options within the software which allowed for compensation of the plate curves to achieve gray balance as well as taking the paper colour into consideration.

The second run, based on the plate curves predict from the software was performed the same day as the initial press run under the same press conditions. This press run followed the same procedure as the initial press run as the initial make ready was based on achieving register and the modified CIELab values required to come close to achieving gray balance.

Upon meeting these requirements and ensuring the CIELab values were met, the press was allowed to stabilize and approximately 500 impressions were run. After the press run the lift was allowed to settle overnight. The next morning a statistical sampling method was followed and the sheets were measured and analyzed in the same fashion as the initial press run.

The results of the second press run were commented upon as to a visual improvement over the initial press run. Evaluation of the results provided by the analysis software show that the *CMY NPDC* of the averaged data to lye perfectly on the Ideal curve documenting that the CMY gray balance throughout the tonal. The curves predicted by the software smoothed the unwanted difference from the ideal curve in the shadows.

Analysis of the K NPDC showed average data to once again be darker than the ideal data. This result was anticipated as the analysis software only predicted a minor change to the black curve. Throughout the tonal range, a maximum of a 2% reduction in dot area was recommended.

The evaluation of the *CMY Gray Balance* results shows a shift in the gray balance more towards a neutral as desired in the highlights and continuing through the mid tones. As for the shadows, the software has appeared too failed as the reduction of the yellow cast did not occur. This result was validated by analyzing the yellow plate curve adjustments predicted by the analysis software. The new curve for yellow was not changed as only a 0.40 reduction in yellow dot area was predicted. This fine of an adjustment would be almost impossible to hold through the process of producing the plates as the accuracy of the plate making process and plate measurement systems is unable to control this minor change.

The second press configuration for the evaluation of the G7 process was also printed on the half sized press at PIA/GATF. This press run was done with the same paper and hybrid inks instead of conventional inks. Plates used for this run were the thermal ablative plate which requires imaging on a proprietary plate setter.

Following the protocol/ G7 documentation the press was run up to the solid CIELab values and register was achieved. Upon achieving colour and register the sheets were analyzed with a hand held spectrophotometer to ensure the solid values were within tolerance and that gray balance was achieved.

Similar to the initial press run, the gray balance was not perfect at the ideal solid CIELab values. Minor adjustments were made to the CIELab values in order to get the gray balances patches to become grayer. In order be within the solid CIELab tolerances gray was not achieved at this time. It was anticipated that the plate curve process and second iteration press run would fulfil this requirement.

The analysis of this press run using the analysis software showed similar results to the initial run in the fact that the *CMY NPDC* results were close to the ideal values, but adjustments were required. The *K NPDC* also followed the findings of the initial run as the averaged data was heavier/ darker from the mid tones through the shadows.

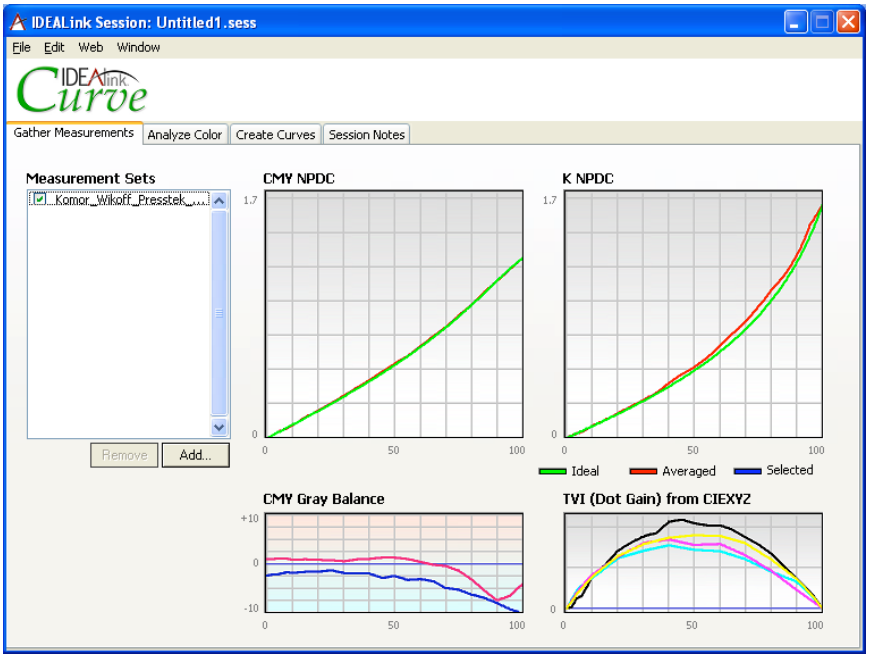
CMY Gray Balance results indicated that a slight blue cast was present from the highlights to the mid tones. In terms of the shadows, a severe green shaded blue cast was present.

Plate curve adjustments predicted by the analysis software were insignificant for the magenta and cyan as less than a 2% adjustment was predicted at any given point throughout the curve to include less than 1% adjustment at the midtone. The yellow curve prediction required an increase at the midtone slightly over 2%. Black curve prediction was less 3% at the midtone. Based on the analysis an expected change to compensate for the cast in the shadows was anticipated by the research team. An in-debt analysis of the curves showed that a predicted adjustment to the curves in the shadows was not indicated.

After curving a new set of plates based on the analysis software predictions the plates were mounted on press the same day, under the same conditions. Printing of these plates followed the G7 protocol as for achieving the solid CIELab values as the initial control point. The values targeted during this run were slightly modified and based on the modifications from the first run in order to come close to gray balance, but still remain with in the allowed tolerance for the solid CIELab values.

After achieving the targeted values the press was allowed to run for approximately 500 impressions in order to stabilize. Analysis of these press sheets was performed immediately after the press run for the fact that they were cured by the used of UV lamps placed throughout the press.

Findings from the analysis software show many of the same results as the first iteration press run. The *CMY NPDC* curve shows the averaged data to overlap the ideal which is desired. However, the *K NPDC* curve has the averaged data to be much heavier/ darker than the ideal curve. *CMY Gray Balance* was not corrected by the plate curves as the shadow areas still produced a green shaded blue case.



The final press run performed following the G7 process was performed on the forty-inch, four colour press at PIA/GATF. This press run was performed with the same paper as all the other press runs as part of this study. The plates used were the negative acting plates which are also processes or require no chemistry to develop. Ink used was a conventional oxidizing set which were the same inks used during the first trial on the half sized press.

The plates produced for this press run, as discussed earlier, did not produce a linear curve or close to a linear curve as the other plates when output as RAW or minus the calibration curve. Dot area was greater than linear measuring

approximately 55% at the midtone and smoothing out throughout the remainder of the tonal range with these plates.

Following the G7 protocol, this press run began by achieving register and the solid CIELab values. Modifications to the targeted values were required in order to attempt to achieve gray balance as the tolerances allowed were not exceeded. After achieving as targeted values and attempting to attain gray balance, approximately 500 impressions were run in order to all the press to stabilize.

After allowing the press sheets to dry for a period of time the analysis was performed in the same manner as the previous trials. The results of the analysis shown in the figure below indicate the *CMY NPDC* curve of the measured sheets was similar to the ideal curve. Their was a slight shift in gray balance from the 60% through on up the tonal range, which can also be identified in the *CMY Gray Balance* graph. Also observed in the *CMY Gray Balance* graph was that the shift in gray balance from the 60% screen there on up took on a yellowish red cast.

Projected plate curve adjustments by the analysis software required a 3% reduction of the cyan and magenta along with a 6% yellow reduction at the midtone. The remainder of the tonal range was a smooth transition beyond the midtone. Black did not require a curve adjustment as the analysis software only prescribed a 0.5% reduction at the midtone.

After curving the plates accordingly the were put on press and were run up to the CIELab values based on the minor modifications required to come close to achieving gray balance. Once the targeted values were reached and the press was allowed to stabilize for approximately 500 impression samples were collected and allowed to dry for a period of time.

Once dry, the analysis of the sheets was performed and loaded into the analysis software. These results show the *CMY NPDC* measured values from the press run do not to match the ideal curve. These results produced a lighter tone reproduction virtually throughout the entire tonal range. This was also the case for the *K NPDC* which also produced a lighter tone reproduction throughout the entire tonal range. The analysis of the *CMY Gray Balance* target shows that gray balance was more accurately reproduced. Both the a* and b* axis are trending along the zero point which would indicate a neutral gray.

In addition to several press runs performed in accordance with the G7 protocol was an additional press run following the ISO 12647-2 procedure. This press run was performed on the forty-inch press at PIA/GATF and used all of the same materials as the press run following the G7 protocol.

The initial press run based on raw plates produced identical results as the same press configuration following the G7 protocol. Both the ISO 12647-2 and G7 protocols dictate the same solid ink CIELab values be used as a starting point.

Modifications to the targeted values were also the same as the G7 protocol as tone value increase was attempted to be balanced on so that gray balance could be achieved. Targeted TVI values were based on the “C” curve as specified in ISO 12647-2. These curves are specifying that all four colours should be within 4% in order to achieve the print standard and the secondary print control of gray balance.

The tone reproduction adjustments for this press run were only modified at the mid tone allowing the curve software to predict the appropriate values for the remainder of the tonal range. This was unlike the G7 protocol which required toe manipulation of the plate curve at several points throughout the tonal range.

Results of the second iteration following the ISO 12647-2 method shows that though the *CMY NPDC* of the averaged data from the printed sheets did not match the ideal G7 curve. It did however produce a fairly linear transition throughout the tonal range. The *K NPDC* followed a similar trend through the highlights and mid tones, but the shadows tonal reproduction was lighter than the ideal G7 curve. Analysis of the *CMY Gray Balance* results show that following the ISO 12647-2 methodology, a neutral gray could be reproduced throughout the tonal range. Also shown by the measurements of the tone reproduction measurements was that allowing the plate curve software to predict the majority of the tonal range created a smoother transition, especially through the shadows.

The final analysis of the press sheets confirmed the four individual press trials met the solid CIELab values or within the allowed tolerances. Results of the ΔE calculation for the solid primary colours did not exceed a ΔE of 4.2 for any single colour.

	Black	Cyan	Magenta	Yellow
Trial 1 (G7)	1.35	3.52	2.17	4.17
Trial 2 (G7)	2.95	3.52	1.55	2.37
Trial 3 (G7)	2.06	2.90	2.92	2.52
Trial 4 (ISO)	1.97	2.98	2.95	2.47

CIELab solid patch ΔE results

Tone reproduction characteristics of the final run press sheets produced inconsistent results. Trials 1 and 2 which were both printed on the same half size press were expected to show differences as the inks for these two trials were different as were the final plate curves.

The differences between trials 3 and 4 were only due to plate curves as these two trials were run with the same ink. The drastic differences in mid tone dot area was due to the methods of adjusting plate curves. The G7 (trial 3) approach only made minor adjustments based on the need to achieve gray balance. Much more significant changes for trial 4 were required in order to meet the specific tone reproduction characteristics of the ISO 12647-2 process.

	Black	Cyan	Magenta	Yellow
Trial 1 (G7)	23	14	16	12
Trial 2 (G7)	21	16	17	19
Trial 3 (G7)	16	12	9	11
Trial 4 (ISO)	23	21	19	18

Mid tone TVI results

Though the solid ink values attained were similar for all trials the visual appearance of the images was significantly different. A portion of the colour difference has been contributed to the tone reproduction. The other factor influencing the colour differences was believed to be ink trapping. Trial 2, which was run with UV cured inks, had the best overprint trapping properties. This was also the press run that had the greatest impact on the visual appearance of the images as well. The measurements of the overprint traps shows that the UV inks had overprint trap values 10 units higher than any of the conventional print runs.

Conclusions

Three controlled press runs were performed following the "Calibrating, Printing and Proofing by the G7™ Method". Each press run was performed under controlled conditions using materials that met all required specifications as outlined in the documentation. In addition to the three press runs following the G7 method, an additional press run was performed following the ISO 12647-2 standard. This press trial used the same materials as the G7 press trial, but was controlled by a separate set of criteria as specified in the documentation. The results can be summarized as:

- Solid ink film thicknesses of all for press trials met the CIELab requirements as outlined in the documentation.
- Minor deviations from the targeted values were required in all cases in order to come close to achieving gray balance.
- Plate curve adjustments prescribed by the G7 method analysis software compensated for gray balance from the highlights through the mid tones, but did not adjust for gray balance above 50%.
- Plate curve adjustments made to the plates used for the ISO 12647-2 second press run were based on the mid tone as the remainder of the tone curve was allowed to be compensated for by the calibration software.
- Final print quality of the press runs following the G7 methodology did meet all requirement, but did not produce images that would be considered an acceptable match amongst the three press runs.
- Final print quality of the ISO 12647-2 press run met all requirements as outlined in the documentation.
- Significant colour differences were observed between all for press runs regardless of subject matter.

References

1. International Standards Organization (ISO) 12647-2:2004 *Graphic technology- Process control for the production of half-tone colour separations, proof and production prints.*
2. IDEAlliance, General Requirements for Applications in Commercial Offset Lithography (GRACoL) Aug. 2006, version 6. *Calibrating, Printing and Proofing by the G7™ Method.*

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