GREYBALANCE in colour picture reproduction

In the last few years, there has been a move by the American institute IDEAlliance to match the appearance of offset litho print jobs by concentrating on printing CMY halftone process control patches to greybalance i.e. with the inking levels adjusted so that the print control patches print as grey. The halftone patches are composed of specific dot area combinations that are defined in a table as part of their "G7" calibration method.

Dr. David McDowell, Kodak and NPES, has published such a table in a TAGA paper:

C%	M%	Y%
0	0	0
2	1	1
4	3	3
6	4	4
8	5	5
10	7	7
15	11	11
20	15	15
25	19	19
30	23	23
35	27	27

C%	M%	Y%
40	31	31
45	36	36
50	40	40
55	45	45
60	50	50
65	55	55
70	60	60
75	66	66
80	72	72
85	78	78

Fig. 1 The G7 greybalance triplets[i] David McDowell, TAGA Proceedings 2007

Although the G7 table continues to 100% values for C, M and Y, the higher tone values in the table are not usable for newsprint and newsinks as the total area coverage (TAC) extends beyond 240% and the combinations lose their relative proportionality as they all approach 100% and are unlikely to be grey as a result.

In addition, a means of calculating approximate CIELAB 'a' and 'b' co-ordinates for these patches[ii] increases the potential for control through colour measurement with a spectrophotometer and reduces the variability of the printing. All of this is bound up in a package of software, testformes, on-site testing and expensive consultancy fees built around the "GRACoL" concept of generating a specification for printing using a precise characterisation data set for a specific print process and substrate. IDEAlliance produces the software, trains, certifies and promotes freelance consultants to do the work, for a fee.
In GRACoL's specification no emphasis is placed on solid ink density (SID) levels, colorimetric inking target values and control of dot gain which has been the path followed by the long-standing ISO TC130 committee and which is embodied in the ISO 12647 series of standards.

While this approach to traditional ISO thinking 'ruffled a few feathers' at first, now a more conciliatory position is taken on both sides. The G7 neutral print density curve (NPDC), the ISO 12647 process control series, the ISO 2846 standard ink series, the current SNAP and SWOP standards and ICC colour management all have a role to play. Though IDEAlliance dismisses dot gain and SIDs from their specifications and leans more towards greybalance and colour measurement, many others in ISO are seeking to retain the current control methods and parameters, including colour measurement, and to extend them with the G7 NPDC.

Certainly, the halftone dot areas of process control greybalance patches have been constant in newspaper printing since the standardisation of printing first began in the early 1990's with CMY greybalance dot area values of 30/22/22 and 50/40/40. So, not much has changed, in this respect. What the investigations by various institutes and standardisation bodies, including WAN-IFRA, has brought is the realisation that a standard three-colour greybalance data set applies to virtually all four-colour printing processes, of which the offset litho and flexo processes clearly dominate.

Generic CMY greybalance for all printing processes
To quote IDEAlliance "A key benefit of G7 is that it is device independent. The G7 NPDC, grey balance definitions and calibration methodology are the same for any imaging technology, regardless of substrate, colorants, screening technologies, etc. The NPDC at the heart of the G7 greyscale definition was derived by analysing the neutral tonality of typical ISO-standard commercial offset printing using computer-to-plate technology."
The IDEAlliance G7 table appears to be very close to, if not the definitive, three-colour, CMY, halftone dot area percentage combinations for ISO 2846 offset litho and flexo inks printed under ISO 12647 conditions, at least for neutral grey tone values up to the dark shadow tones.

Dr. Günter Bestmann, Heidelberg Druckmaschinen, has taken the following values from a typical newspaper profile[iii]:

Grey Balance			
	T1%	T2%	T3%
C	10.0	30.0	50.0
M	6.5	21.1	38.6
Y	6.9	21.4	38.9
Grey Reproduction			
	T1	T2	T3
L*	77.9	64.7	54.4
a*	0.8	0.6	0.4
b*	4.6	3.2	2.4

Fig. 2 CMY dot area percentages and CIELAB colour values for a typical profile (light-, medium- and shadow grey tones)

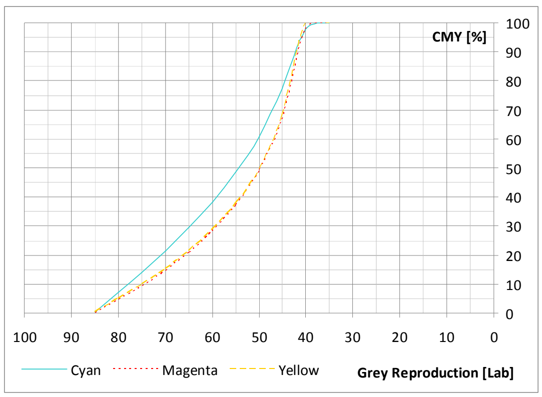

Fig. 3 Greybalance in IFRA's "ISOnewspaper26v4.icc" colour profile

This data is supported by our own experiences and research investigation published in the IFRA Special Report 02.2007, "Inter-instrument agreement in colour and density measurement".

G7 greybalance halftone combinations are expressed in dot area percentages and can be – but need not be – absolutely colour-specific; that depends on the colour of the paper/ink combination. Using ISO 2846 1-5 greybalanced inks, the G7 combinations will deliver an apparent neutral grey colour in relation to the other printed colours. The effect of the chromatic adaptation behaviour of the normal human visual system adjusts the colour of a picture relative to the paper. A white shirt will appear white, particularly if there are other memory colours like skin tones also present – regardless of whether the base paper colour is white, pink, green, blue or yellow. This is the reason that newspapers which print on coloured newsprint (e.g. The Financial Times, Il Sole 24 Ore) don't make extra special colour adjustments to the images presented on the standard sRGB-calibrated monitor screen – for them it's greybalance as usual on a white-to-black greyscale. (This is probably a revelation to a large number of people, except to those working with coloured newsprint.)
It is also the reason why it's possible to print on coloured newsprint using the same process calibration as for whiter newsprint stocks. In our own ICCnewspaper26v4 newspaper profile, the gamut mapping model is based on a colour appearance model that incorporates the effects of chromatic adaptation.
The established ink manufacturers refer to the ISO 2846 standard and standardised spectral curves that infer standard CMY greybalance combinations. The ICC profile

makers follow the same standard spectral curves. There are no special newsinks for printing on coloured newsprint. The ISO 2846 Part 2 news ink standard applies. However, G7 CMY greybalance component values are only realistic as synthetic process control strip elements at the printing stage. In reality, virtually all three-colour greys in an image would be replaced by a single black halftone of an equivalent tonal value by the GCR process.

The inks' similar spd curves determine even more generic features

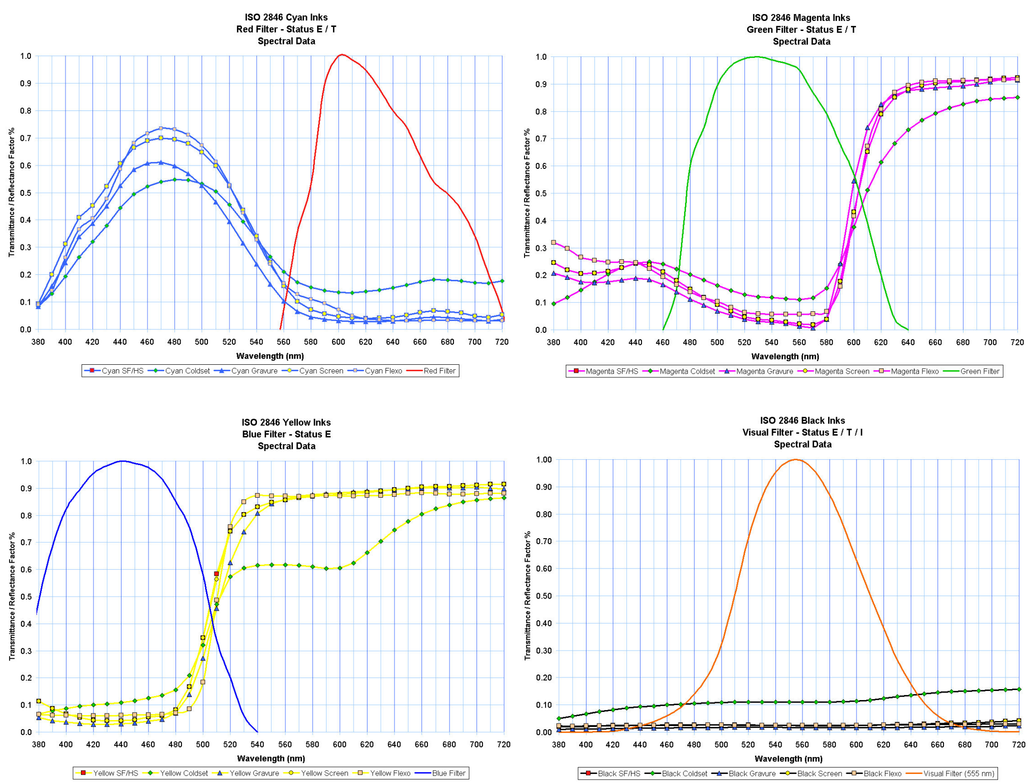

Fig. 4 Spectral power distribution (spd) curves of the inks for the sheet-fed/heatset litho, coldset newspaper, gravure, screen and flexo processes

The diagrams show the spectral power distribution (spd) curves of the different four-colour printing process inks covered by the ISO 2846 Parts 1-5 standards, together with the wide-band spectral response curves of the ISO 5-3 status E densitometer filters. The curves cover the sheet-fed and heatset web offset-litho, coldset (newspapers), gravure, screen and flexo printing processes.
What these ink curves show is that, regardless of the printing process and disregarding the rheological differences in the inks:
- The spectral reflectance and absorption characteristics of the inks for all printing processes, the spd curves, are very similar and, perhaps, could be unified.
- A common standard set of densitometer colour filters, status E, and a single density metric can be established for the graphic arts.
- The three- and four-colour greybalance combinations for these printing processes are nearly identical, certainly for the offset litho and flexo processes.
- Colour separation software use the same basic spd/greybalance data and pictures made for one process are usable for any four-colour printing process.
- While the absolute colour values of these "neutrals" will vary, depending on the colour of the paper on which they are printed, standard greybalance dot area

combinations will appear relatively grey in comparison to other colours, whatever the paper colour.

The greybalanced workflow

While "greybalance" is often used in the context of an individual colour-processed- or printed image, a better way to consider greybalance is as a pre-condition for an inherently colour-neutral chain of processes at each stage of imaging. Each processing stage requires a different calibration process to maintain an inherently colour-neutral greybalanced workflow:

a) Still- or video camera white balance – the colour temperature setting of the camera should match the colour temperature of the light falling on the subject
b) Monitor display at the picture editor's desk, and
c) Monitor display at the colour enhancement pre-press stage – LCD, the colour temperature setting and the brightness of the backlighting should be calibrated to a standard e.g. sRGB
d) Colour separation software – normally, the halftone dot areas are calculated by the ICC Colour Management Module (CMM) and a profile based on the standard ISO 2846 four-colour process inks
e) Platemaking – linear halftone dot area transfer
f) Soft proof monitor at the advertising clients – sRGB or Adobe RGB
g) Soft proof monitor at the press control desk – sRGB calibration
h) Print – ink density adjustment consistent with the inking requirements of the images relative to reaching a standardised inking level, tone value increase (TVI) and colour gamut.
i) Four-colour printing inks – conforming to the ISO standard

In every one of these process, there's a need to provide colour-neutral processing and transfer of the image – a colour-neutral structure to an image highway. A grey-balanced process is the colour-neutral condition needed for handling colour images. No additional colour cast should be added to the image due to the condition or colour characterisation of the camera, monitor, colour separation program, ICC colour profile, printing ink or press adjustment.

In newspaper printing, a high speed workflow requires a smooth and fast transition from image capture to image on paper. Like any transport system, for images, text or consumables, standardised processes form the highway for the transformation of the newspaper components into a finished product. If every element is made to a strict standard, the assembly work runs smoothly with a minimal application of time and effort.
ISO and other standards already exist that provide colour control for all stages of imaging for newspapers:
Camera JPEG files in the sRGB colour space – Exif 2.2 (2009) for JPEG, IEC/ITU BT.709 and IEC 61966-2-1 sRGB
[Nearly all digital cameras have an automatic white balance (awb) capability, but the accuracy of the compensation has to be verified. This can be supplemented by adding an ICC profile taken at the scene, though ICC profiles are usually stripped away by nearly every news agency. Nevertheless, this would work for a local workflow.]
Monitor – sRGB calibration to IEC/ITU BT.709 and IEC 61966-2-1 sRGB
ICC profiles – ISO 15076-1 and TS 10128 (not a standard, but incorporating an ICC proposal)
Plate – linear calibration to ISO 12647-3
Soft proofing environments – ISO 12646 (under review)

Press – calibration to ISO 12647-3
Paper – ISO 12647-3. For other processes and paper grades refer to others in the ISO 12647 series. In addition, national standards such as FOGRA 39, ANSI/CGATS TR001 (spectral data), TR002 (SNAP, coldset), TR003 and TR005 (SWOP), TR006 (GRACoL) and TR007 (FIRST/Flexo) are helpful. (See http://www.npes.org/standards/tools.html)
Inks – ISO 2846-2

Spectral measurement data is the preferred source data for generating ICC colour management profiles that subsequently produce the colour separated images. Having a standard spectral response data for the inks, on a standardised reference paper, forms the "backbone" in determining the dot sizes needed to match the colour of the image to the halftone dot sizes in the separations. The ink manufacturers make the inks to conform to the standard spd curves. The ICC profile makers assume the same spd data as the foundation for the CMYK colour separations, but adjusting the colour through the halftone values to compensate for the colour gamut differences of the materials and the image transfer characteristics of the plate and press. In generic ICC CMYK profiles, these adjustments are standardised through using statistically averaged data, with generally good results. In custom ICC profiles, the prevailing measured colour reproduction conditions are used in the transformation to CMYK.

The default behaviour for all imaging processes should be colour-neutral, without contributing any colour bias. Colour changes needed in colour gamut mapping, between different colour spaces or colour- or tone correction edits should be relative to this colour neutral condition.
The concept of neutral greybalanced processing applies just as equally to RGB image processing as it does to CMYK colour separation and printing.
The sRGB colour space is a good example of a balanced colour space in that equal amounts of the RGB primaries will indicate a neutral colour – black, white or a grey. For example, on an 8-bit monitor having primary colours scaled from 0-255, a mixture of R(127)+G(127)+B(127) will display as a neutral mid-tone grey.

Why grey for process control patches
Greybalance affects all colours and tones of the image. In the CIELAB and many other colour models, the central axis of the model is a white-to-black greyscale in which there is no colour component, only a lightness scale. If an image is not "greybalanced", it means that not only the axis has shifted away from neutral but that the whole gamut has moved and acquired a chromatic colour bias and a general colour cast.

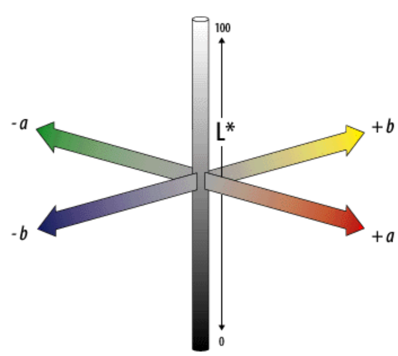

Fig. 5 Structure of the CIELAB colour model

The central axis of the CIELAB visual colour space is the L* lightness scale, ranging from white-to-black with a smooth grey level gradation in between – referred to as the achromatic neutral colours or "neutrals". These "neutrals" can be displayed as RGB values. Alternatively, they can be printed as halftone values using just black ink, K, a specific combination of CMY or an almost infinite number of CMY+K combinations, as shown in the wide range of GCR settings that are possible in software programs for making colour separations e.g. "light", "medium", "heavy" or "maximum" GCR, or a GCR setting in the range from "0-100%".
In a four-colour CMYK reproduction, black doesn't add more colourful colours *per se* but extends the gamut in the darker colour tones i.e. colours with lower L* values in CIELAB.

An important point to note is that colours in printing are particularly susceptible to change when they are simply CMY combinations, but we can use this property to our advantage in print process control targets. A specific grey level is only achieved by a specific combination of CMY using ISO standard process inks. Additionally, the eye is more sensitive to colour changes close to neutral.

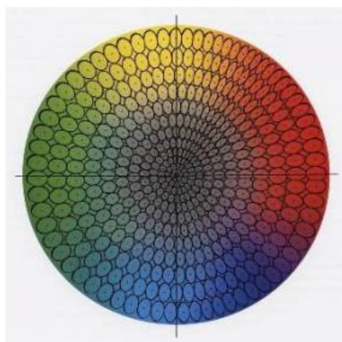

Fig. 6 MacAdam ellipses of visually equal colour. David L. MacAdam performed tests to define how well the average human eye distinguishes similar colours, 1942[iv]

If the relative proportions of each of the CMY components change, the grey loses its colour-neutrality and assumes a colour shift. The ink levels must be in balance with one another in order to produce the correct grey colour tone – hence the term "greybalance". This is why a three-colour CMY grey in a print process control target makes both a particularly good visual indicator and a less obtrusive measurement point than individual CMY full tones for monitoring press inking levels.

Why the dot areas in CMY greybalance are not all equal

Unlike the sRGB colour space, neutrals in the CMY colour space do not have equal unit values mainly because of unwanted colour absorptions – their spectral characteristics are smooth curves rather than straight-sided partitions of the spectrum:

- Magenta is deficient in reflecting blue light, appearing more reddish than it should, thereby acting as if it is also printing some additional yellow.
- Cyan is deficient in reflecting both the green and blue colours.

Because the inks do not perform ideally by absorbing one third of the visible spectrum and reflecting two thirds, the colour matching calculations used to generate the colour separations for printing using the ISO standard ink sets, compensate for these deficiencies in the resulting dot sizes. For example, in calculating a neutral grey, the cyan dot area sizes are larger in proportion to those for magenta and yellow.

Conclusion

The recent emergence of a standard table of CMY greybalance halftone dot area combinations is confirmation of a common greybalance property of all ISO 2846 four-colour process ink sets. The spectral properties of the inks, and thereby their greybalance, must be very similar for the accurate colour separation and reproduction of images. Indeed, the spectral properties of the inks are based on the ANSI/CGATS TR001:1995 (spectral data) and the recently revised TR002:2007 (colorimetric) standards. TR002 has been widely accepted and used for the newspaper industry. The same table, or it’s very close equivalent, has already been incorporated into other recent and important American CGATS standards, as well as into greybalance calibration tools, colour management and printing process control software.

Greybalance control is needed at all stages of colour image capture and reproduction to ensure that no additional colour bias is added by the processing chain. A colour cast in an image that appears at the press is not going to be removed by printing the CMY process control target to a colour neutral standard. Print process control targets only indicate the levels of inking applied and are a valuable indicator for the pressman. However, the press operator is not responsible for correcting colours that should have been produced correctly by the photographer or corrected at the pre-press stage and, to this end, a greybalanced imaging workflow will greatly facilitate the optimal reproduction of real world images.

Andy Williams
Research Manager Colour and Imaging
WAN-IFRA GmbH & Co. KG

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Endnotes

[i] David Q. McDowell, Kodak, NPES,“Method for Calibration of a Printing System With Digital Data Using Near-Neutral Scales”, TAGA Proceedings 2007

[ii] For a series of 3-colour printed control patches, the CIELAB target a* and b* values for good greybalance are found with the following formula:

a* = (L*control patch - L*paper) / (L*paper - L* Gmax) x (a*paper - a*Gmax) + a*paper

b* = (L*control patch - L*paper) / (L*paper - L* Gmax) x (b*paper - b*Gmax) + b*paper

using the CIELAB L*a*b* measurements of the paper and a 3-colour Gmax, together with the L* value of each of the 3-colour halftone control patches. Gmax is a 3-colour halftone control patch combination of C=87%, M=77%, Y=77% percentage dot areas

[iii] Günter Bestmann, Heidelberg Druckmaschinen, e-mail communication, July 2010

[iv] MacAdam, D.L., “Visual sensitivities to color differences in daylight”, Journal of the Optical Society of America, 32, 247-274, 1942