Munich, January 2016
Fogra Research report 10.057

Standardization concept for colorimetrically motivated data preparation and reproduction in the Print Media Industry

Andreas Kraushaar
Philipp Tröster
Peter Karp

AiF Member

Supported by:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Standardization concept for colorimetrically motivated data preparation and reproduction in the Print Media Industry

Andreas Kraushaar
Philipp Tröster
Peter Karp

Fogra-FB/DE--2015/11--DE+10.057

Keywords:
FOGRA51
FOGRA52
common colour appearance
colour names

This project was supported within the programme of the Federal Ministry of Economics and Technology for the support of "Industrielle Gemeinschaftsforschung (IGF)" via the German Federation of Industrial Research Associations (AiF, no. 17873N).

Industrielle Gemeinschaftsforschung

The complete Research report under the title of Fogra no. 10.057 "Entwicklung eines Standardisierungskonzepts für die farbmetrisch motivierte Datenaufbereitung und Reproduktion in der Printmedienindustrie" is available in German language as a PDF file or can be printed on demand.

This project was carried out by the Fogra Graphic Technology Research Association e. V., Munich. Fogra is registered as a non-profit making association with the Munich Tax Office (Reference: 143/843/18952).

Forschungsnetzwerk Mittelstand

Contents

Acknowledgement

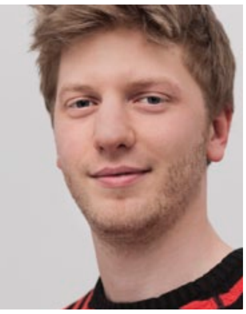
The authors would like to thank the committee overseeing the project as well as the Technical Committees Prepress and Digital printing of Fogra for supporting this project work. Special thanks go to all the companies which have supported this project with test measurements.

In particular, we want to thank the following companies for their support:
- basICColor
- CGS
- Color Logic
- GMG
- Jochen Günter Color Consulting

Furthermore, the authors would like to thank Karl-Michael Meinecke (bvdm), Dr. Hanno Hoffstadt and Jürgen Seitz (GMG), Dorin Pitigoi (Color Service Transilvae) and Florian Süßl (zipcon) for their intensive cooperation.

Imprint
Fogra Research reports publish the key findings of research projects carried out by Fogra. They are published by the Fogra Graphic Technology Research Association e.V., Streitfeldstraße 19, 81673 Munich and post box 80 04 69, 81604 Munich. Tel. +49 89. 431 82 - 0, Fax +49 89. 431 82 - 100, E-mail info@fogra.org
Internet www.fogra.org

Dr Andreas Kraushaar



Dr Philipp Tröster

Peter Karp

Extract

This work introduces a new evaluation method for the reproduction of colour. It is called "common colour appearance" and determines the colorimetrical consistency between several different reproductions of the same reference. The various sizes and shapes of the different source colour spaces requires the assessment of large colour differences, which is not covered by established methods of colour evaluation.
Pursuing the aim of developing a process-independent colour space for larger gamuts, several gamuts of modern digital output processes have been examined. Based on several candidates, an ICC profile (FOGRA53) has been introduced as an exchange gamut.
Finally, the major sheet-fed offset printing conditions for standardized print on coated (FOGRA51) and uncoated paper (FOGRA52) have been validated for their practical use. They are the main focus of this short version. Details regarding the first two topics can be found in the long version of this research report.

1 ISO 12647-2 defines 16 printing conditions

One focus of this project was the realization of the new printing conditions (short: "PC") of the revised ISO 12647-2 – "Process control for offset lithographic processes". It defines eight print substrates (short: "PS") and therefore replaces the hitherto existing five paper types (PT 1 to PT 5), see Tab. 1.

The printing process is defined for amplitude-modulated (AM) as well as stochastic (FM) screening, resulting in 16 standard printing conditions in total. A practical realization of these printing conditions involves the creation of characterization data, ICC profiles on this basis, as well as further working tools like, for example, the bvdm/ECI Gray Control Strip "GrayCon". This was realized for both sheet-fed offset printing methods (PC 1 and PC 5). Therefore placeholders of the Fogra characteriza-

Practical hints

Make sure to use the correct measurement mode (M0, M1 and M2) for the validation of your print. Use M0 for all Fogra data up to FOGRA50, M1 starting from FOGRA51.

Determine the target values of the solids and the tone value increases on the dry sheet only.

The inline, respectively the offline process control can be carried out as usual by using densitometrical measurement devices. The relation between "wet density" and the $L^*a^*b^*$-values of the dry sheet is important.

For proof creation with FOGRA51 / FOGRA52 use (tested) proof papers containing optical brightener agents (OBA) only.

When choosing the proofing substrate, take the surface characteristics into consideration, i.e.: glossy proofing papers for simulating glossy production papers and semi-matte proofing papers for simulating satin or semi-matte production papers.

Actively discuss the printing condition with your customer – hereby you show your understanding of colour communication and secure its optimal implementation.

Ensure the availability of an ISO3664:2009 compliant viewing booth for the validation in the printroom as well as for the prepress department and for the demo room.

	Print Substrates (PS)			
	PS1	PS2	PS3	PS4
Type of surface	Premium coated	Improved coated	Standard coated glossy	Standard coated matte
Typical process	Sheet fed offset, Heat set web offset	Heat set web offset	Heat set web offset	Heat set web offset
Typical papers	Wood-free coated (WFC), High weight coated (HWC), Medium weight coated (MWC), glossy/semi-matte/matte	Medium weight coated (MWC) Light weight coated (LWC Improved)	Light weight coated (LWC), glossy/semi-matte	Machine finished coated (MFC), Light weight coated (LWC), semi-matte
	PS5	PS6	PS7	PS8
Type of surface	Wood-free uncoated	Super calendered	Improved uncoated	Standard uncoated
Typical process	Sheet fed offset, Heat set web offset	Heat set web offset	Heat set web offset	Heat set web offset
Typical papers	Wood-free uncoated (WFU)	Super calendered (SC-A, SC-B)	Uncoated mechanical improved (UMI), Improved newsprint (INP)	Standard newsprint (SNP)

Tab. 1: Overview of the new print substrates. An extensive description of the changes has been published as part of this project in the Fogra Extra 30.

tion database, FOGRA51 and FOGRA52, have been used, which shall be illustrated further in the following. Establishing further web-fed printing methods is currently the subject of ongoing discussion within the responsible ECI working group (WOWG, Web Offset Working Group).

2 FOGRA51: Printing on glossy and matte premium coated paper

Information for the print service provider

The following requirements need to be fulfilled for printing on coated illustration printing paper (PS1, Premium Coated Paper):

- Perfect, (optimal) reproduction of the target values defined in ISO 12647-2 (paper white, solid colours and tone value increase)
- Universal basis on M1-based measurement values
- Traceability to NIST (Unification of the "industry standards" GMDI and XRGA)
- Feasibility by using market-typical material combinations (inks and practical papers)
- Achievement of a good visual and metrological correlation between proof print and production run (proof to print match)

The last-named aspect of this selection is the most important one, since these printing condition are supposed to replace, respectively complement, the up to this date most successful and most popular printing condition FOGRA39. Being able to ensure a fast, easily presentable and better accessibility, as well as a match between proof print and production run, is a fundamental prerequisite for a successful practical implementation. Therefore, several print tests have been planned, accompanied and evaluated in the

Printing company	Substrate	Ink
Astoria Druck	Garda Caritiere (130 g/m²)	Flint Novavit Plus Bio
Aumüller	2014: BVS matt 135 g/m²	Flint Novaboard C 990 Protect Bio
	2015: LumiSilk 135 g/m², MagnoSatin 135 g/m²	Flint Novaboard C 990 Protect Bio
Heidelberger Druckmaschinen	Feb. 14: BVS glänzend	Saphira
	Nov. 14: BVS matt	Saphira
Mohnmedia	BVS Matt 135 g/m²	Serie F 15 RS von Hostmann + Steinberg
Schleunung Druck	2014: Okastar 135 g/m²	Flint Novavit F900 Extreme Bio
	2015: BVS matt	K+E
Wolfau-Druck	LuxoArt Gloss 150g/m²	Heidelberg Saphira Oxi Dry
Fogra (3x)	BVS glänzend	Huber Rapida
Fogra	Luxo Satin	Huber Rapida

Tab. 2: Overview of the conducted test prints.

course of this research project. Furthermore, several print tests have been conducted in the Fogra in-house test print centre. Tab. 2 shows an overview of the conducted test prints.

For these test prints, a test form has been developed and refined successively. This test form is depicted in Fig. 1. The evaluations have been conducted with all measurement devices capable of M1 measurement, particularly the FD7 from Konica Minolta, the Spectro Dens from Techkon, and the eXact and the i1Pro2 by X-Rite. Thus, a representative measurement was ensured.

Results

In the following, the results of the work on the characterization data of the conducted test prints shall be summarized shortly in bullet point form:

- The target values of ISO 12647-2:2013 PC1 are not the average of the market-typical papers and inks, measured with M1.
- Market-typical papers, on average, have a white point of *CIELAB* = 95; 1,5; -6 (M1, wb).
- The *CIELAB* colour coordinates of the solid tones (ISO 12647-2:2013 PC1) do not match the paper colour (*CIELAB*=95, 1, -4). A conversion, e.g. using the XYZ-transformation defined in ISO 12647-2 Annex B, is necessary.
- The conversion of the paper colour values based on the XYZ-transformation ("Annex B of ISO 12647-2") is only precise for small adjustments. Major changes, especially concerning the amount of optical brighteners, require a model-based transformation.

The model-based development of the characterization dataset conducted by the companies GMG and Heidelberg Printing Machines AG finally resulted in a candidate meeting the practical requirements. Obviously, deviations between ISO 12647-2:2013-compliant prints can be found, but the proof print never fails to provide a good "visual average" (Fig. 2).
In the light of the – in this case – unfortunately inevitable incompatibility of practicality and ISO-conformity regarding a 100 % match of the full-tone colouring, it is necessary to point these differences out in the communication of printing conditions. They are shown in Tab. 3.
Within the typical deviations of the printing process or the used materials, those differences can be regarded as negligible. For a conformity assessment in the strict sense of a "within the standard" versus "not within the standard", however, this difference can turn out to be crucial. Trying to provide a compromise, the following approach shall be recommended:

- If no contract proof is available, the ISO-values (wb) shall be used as reference in all instanceses such as setup and control.
- If a contract proof (FOGRA51) is available as reference, a visual fine adjustment shall be conducted by the printer during the setup phase in order to match the proof print in an optimal way. In this case, the values of FOGRA51 shall serve as a reference for conformance assesment.

In order to determine the required solid coloration, the absorption characteristics (ink setting and drying) need to be taken into consideration during the process calibration. The wet density and the colour values (the so-called "wet dataset") for each of the primary colours need to be determined, which result in an optimal match of the solids in their dry state. Aim values for process control can as well be determined on black backing. Here the paper opacity is used to derive the black backing readings that lead, when measuring or viewing the dray sheet over white, to

Fig. 1: The test form developed within this project and in collaboration with ECI (especially Prof. Florian Süßl) and GMG (Dr. Hanno Hoffstadt). The targed based on the ECI2002 also allows for a quick control of the uniformity.

Fig. 2: Example for visual matching during a meeting of the project comittee. The proof print is in the middle. On the left and right side one print sample is shown each. The visible variation can be attributed as industrial typical.

	ISO 12647-Premium Coated (M1, wb)			FOGRA51 (M1, wb)			Differences			
	*L**	*a**	*b**	*L**	*a**	*b**	*ΔL**	*Δa**	*Δb**	*ΔE*
Paper	95,0	1,0	-4,0	95,0	1,5	-6,0	0,0	-0,5	2,0	2,1
Cyan	56,0	-36,0	-51,0	56,1	-34,9	-52,5	-0,1	-1,1	1,5	1,9
Magenta	48,0	75,0	-4,0	48,1	75,3	-5,2	-0,1	-0,3	1,2	1,2
Yellow	89,0	-4,0	93,0	88,9	-4,0	92,4	0,1	0,0	0,6	0,6
Black	16,0	0,0	0,0	16,0	0,1	-0,3	0,0	-0,1	0,3	0,3
Red	48,0	68,0	47,0	48,0	69,3	45,9	0,0	-1,3	1,1	1,7
Green	50,0	65,0	26,0	49,5	-65,9	24,3	0,5	0,9	1,7	2,0
Blue	25,0	20,0	-46,0	24,7	21,1	-47,5	0,3	-1,1	1,5	1,9
C+M+Y	23,0	0,0	-1,0	23,3	-1,4	-1,7	-0,3	1,4	0,7	1,6

Tab. 3: Comparison of the *CIELAB* full-tone colouring (M1, white backing). Left: ISO 12647-2:2013 PC1. Middle: FOGRA51. Right: Differences of the components, as well as the total colour difference *ΔE*.

the aim values, which are always given for measurement over white (wb).
Subsequently, the tone value increases (TVI-curves) are measured and averaged across the format as well as across the print run. If necessary, new "RIP characteristics" need to be created by comparing these values to the desired tone value increase (curve "A"), see Tab. 4. These values should be reached with a tolerance of ± 2 %. It might be necessary to create a second test run ("iterative process calibration").

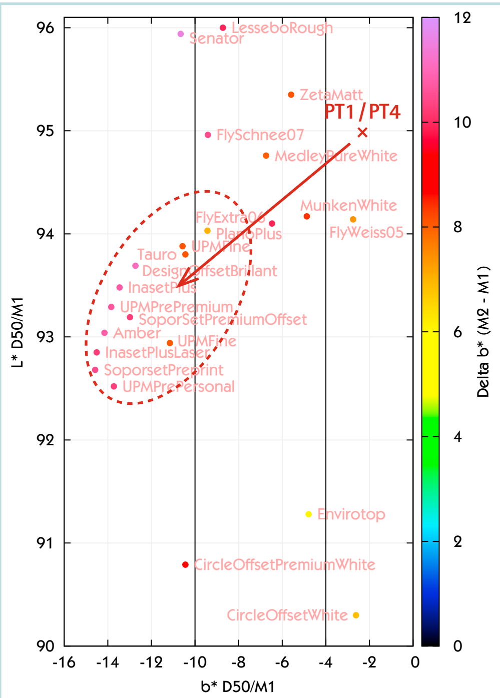
Information for customers (agencies, print buyers, publishers...)

Based on these characterization datasets, the ECI created the necessary ICC profile named "PSOcoated_v3.icc". The calculation of the profile was conducted with the profiling software ColorTool Version 17 by Heidelberg Printing Machines AG with the following settings: black-length 9 (threshold 10 %), black-width 10, maximum area coverage (tone value sum) 300 % and maximum black 96 %.
The profile is available as a free download on the website of ECI:
➚ www.eci.org/de/downloads
Instructions for installation and usage can be found in the PDFX-ready guidelines and "cooking recipes". Furthermore, it is recommended to adjust the creation of the proof print to FOGRA51.
In case you want to create contract proofs by yourself, an intern (built in the proofer) or extern measuring device capable of M1 measurements, as well as proofing paper with optical brighteners is necessary. You can find certified substrates on the Fogra website:
➚ www.fogra.org/en/fogra-fogracert-en/fc-materials/papers/proofing-substrates/

TV in %	TVI in %	TV in %	TVI in %
5	3,3	55	15,9
10	6,1	60	15,6
15	8,5	65	14,9
20	10,5	70	14,0
25	12,2	75	12,7
30	13,5	80	11,0
35	14,6	85	9,0
40	15,3	90	6,5
45	15,8	95	3,5
50	16,0	100	0,0

◀ **Tab. 4:** Tone values in dataset (TV) and the respective tone value increase (status E) for the printing conditions PC1, ISO 12647-2 (FOGRA51) for all 4 printing colours.

You can find here as well certified proof suppliers:
➚ www.fogra.org/en/fogra-fogracert-en/prepress-en/proof-/proofcreation/contract-proofing-certified/
The transition phase from FOGRA39 to FOGRA51 is expected to last several years, therefore the conversion between old and new data and vice versa should be part of the standard repertoire of prepress and print service providers. Therefore, efficient colour servers with suitable device link profiles are necessary.



▶ **Fig. 3:**Illustration of the colour coordinates of paper whites of uncoated offset papers by means of the *CIELAB*-brightness and the *CIEb'*-values (M1). Source: H. Hoffstadt, GMG.

3 FOGRA52: Printing on wood-free, uncoated papers

Information for print service providers

Establishing characterization datasets for uncoated papers basically follows the same boundary conditions as the procedure for coated papers (described in the previous chapter). The difference to the printing condition PC1 is based on the fact, that the definition of the printing condition PC5 is ambiguous. The reason for this originates from the formation process of the ISO norm and the technical and economical constraints prevalent at that time, and will not be subject to further explanation at this point. The ambiguity lies within the lack of correlation between the specified high amounts of optical brighteners ("high", i.e. $\Delta B > 14$) and the specified colouration of the substrate. This is shown in Fig. 3.
The illustration clearly shows that the paper colouration defined in ISO 12647-2 (*CIELAB*=95,1,-4) does not match the colouration of papers typical for the market. There are in fact papers of this colour, but they are very rare. Therefore, in consultation with the project committee, the focus lies on working on a practice-oriented candidate – even if the printing condition PC5 is not matched exactly (spot on).

In fact, the characterization dataset ("FOGRA52") developed for the completed Fogra research project "Development of methods to compensate the differences between proofing and production stock" (60.055) meets these demands very well already. Two questions arise, however, for the practical use in terms of consolidation:

- Is the determined colouration practicable and typical for the industry in terms of its achievability by using different substrates and inks?
- Is the paper colouration as defined in annex B of the norm suitable for achieving results based on the full-tone colouration values as defined in PC5?

For this project different test prints have been conducted in the Fogra in-house test print center (Tab. 5). The first step of these tests always was the adjustment of the colouration, trying to achieve an optimal full-tone colouration according to PC5.
The visual assessment of the print results is depicted in Fig. 4. It is clearly shown that due to the huge variety of substrates the variance of the visual impressions is equivalently large. Subdividing the paper types further would reduce this problem. This would result, however, in a larger variety of profiles for the data creator – who even now already seems to be lost in the "profile jungle". Therefore the term "uncoated paper" can have three different meanings in this context, whereby the *CIEb**-axis is used for clustering. Firstly, it refers to bluish papers, which account for a good proportion of the practical papers currently in use. They are the focus of this project and portrayed by FOGRA52, as previously described. The second category comprises of the more neutral natural papers with a white point around *CIEb**=-4 ("P5-exact").

Test print	Substrate	Ink
1	Cocoon	Huber Rapida
2	Lessebo	Huber Rapida
3	Plano Plus	Huber Rapida
4	UPN Fine	Huber Rapida
5	Fly Extra Weiß	each with: Flint Novavit Supreme Bio, Huber Novavit, Sun Chemical PSO-Exakt
6	Fly Creme	
7	Fly Weiß	
8	Fly Schnellweiß	
9	Zetamatt	

Tab. 5: Overview of substrates and inks used for the conducted test prints.

◀ **Fig. 4:** Comparison of different print samples for two motives. On the bottom center is the FOGRA52 proof. The visual differences are very prominent in the skin tone of the boy, even if it has to be noted that this motive reacts to even the smallest process fluctuations already.

	PS5: Woodfree uncoated (M1, wb)			FOGRA52 (M1, wb)			Differences			
	*L**	*a**	*b**	*L**	*a**	*b**	*ΔL**	*Δa**	*Δb**	*ΔE*
Paper	95,0	1,0	-4,0	93,5	2,5	-10,0	1,5	-1,5	6,0	6,4
Cyan	60,0	-25,0	-44,0	58,7	-22,4	-48,1	1,3	-2,7	4,1	5,1
Magenta	55,0	60,0	-2,0	54,5	60,1	-4,3	0,5	-0,1	2,3	2,3
Yellow	89,0	-3,0	76,0	87,7	-2,7	72,4	1,3	-0,4	3,6	3,9
Black	33,0	1,0	1,0	29,8	7,7	2,3	3,2	-6,7	-1,3	7,5
Red	53,0	56,0	27,0	52,6	56,0	25,5	0,4	0,0	1,5	1,5
Green	53,0	-43,0	14,0	52,0	-41,4	11,3	1,0	-1,6	2,8	3,3
Blue	39,0	9,0	-30,0	38,5	9,8	-32,0	0,5	-0,8	2,0	2,2
C+M+Y	35,0	0,0	-3,0	34,6	0,6	-4,3	0,4	-0,6	1,3	1,4

Tab. 6: Comparison of the CIELAB full-tone colouration (M1, white backing). Left: ISO 12647-2:2013 PC5. Middle: FOGRA52. Right: Differences of the components, as well as the total colour difference *ΔE*.

The last candidates are the yellowish book printing papers with *CIEb**=9.

Analogical to the previous chapter the results shall be summarized shortly in bullet point form:

- The variation of the coloration of typical natural papers is significantly greater than of equivalent illustration printing papers.
- The paper colour adjustment as described in ISO 12647:2013 Annex B is able to predict changes of the paper colour between approx. *ΔCIEb**=3 and *ΔCIEb**=7 very well.
- Beyond this range, model-based approaches referencing to relevant practice prints are necessary.
- FOGRA52 is not equal to ISO 12647-2:2013 PC5, but is defined as an own printing condition.
- The colour values of FOGRA52 are easily achievable using inks relevant to the market in their typical layer by using typical ink film thicknesses.

TV in %	TVI in %	TV in %	TVI in %
5	5,8	55	21,3
10	10,6	60	20,3
15	14,3	65	19,0
20	17,2	70	17,4
25	19,4	75	15,4
30	20,9	80	13,2
35	21,9	85	10,6
40	22,3	90	7,5
45	22,4	95	4,0
50	22,0	100	0,0

Tab. 7: Tone values in dataset (TV) and the respective tone value increase (status E) for the printing conditions PC5, ISO 12647-2 (FOGRA52) for all 4 printing colours. One tip to remember: The "new" curves show integer TVI at TV=50 % ("formerly" TV=40 %).

In the context of ISO 12647-2:2013 PC5, the printing condition FOGRA52 can be communicated as an independent printing condition (distinctively following the principles of ISO 12647-2), unlike FOGRA51 and PC1. The shift regarding the full-tone colouration follows the change of paper colouration, as expected, towards blue. This is depicted in Tab. 6.

The specifications for process control are identical with the ones of FOGRA51. The tone value increase curve "C" for FOGRA52 can be found in Tab. 7.

Information for customers (agencies, print buyers, publishers...)

Based on these characterization datasets, the ECI created the necessary ICC profile named "PSOuncoated_v3_FOGRA52.icc". The longer name originates from the previously described issue and in order to settle the ambiguity of "printing on uncoated substrates". Specifically, confusing FOGRA52 with ISO 12647-2:2013 PC5 shall be avoided.

The calculation of the profile was conducted with the profiling software ColorTool Version 17 by Heidelberg Printing Machines AG using identical settings as for FOGRA51: black-length 9 (threshold 10 %), black-width 10, maximum area coverage (tone value sum) 300 % and maximum black 96 %. Further specifications are in accordance with chapter 2.

4 Colour communication and matching

The monitoring of extern and the conduction of intern printing tests resulted in two printing conditions, FOGRA51 and FOGRA52, which fulfill the requirements for high quality colour communication for the first time. In terms of a concerted matching (ISO 3664:2009-conform viewing booth) and a measurement based on D50 (ISO 13655:2009, M1), the visual appearance matches the metrological result very well. Especially for uncoated papers, FOGRA52 provides a characterization dataset, which makes all previous tips and tricks, and even established "gurus", obsolete.