6.

6 Evaluation of print products

6.1 Introduction

In brief

Two printing gamuts are similar when you talk about colour differences instead of different colours.

Reproducing images and documents normally aims for a pleasing reproduction against a virtual reference (or whatever the print buyer has in her/his mind). This involves a creative process that needs to be done before process control and quality assurance of print related workflows starts. When preparing data for a given printing condition, defined by a reference characterization data set, the pros and cons of that printing condition needs to be taken into consideration together with the customer expectations and preferences. After the data is defined by means of an output referred (print related) colour space (and an appropriate reference such as a softproof, a contract proof or a validation print) it is up to the print service provider to print the expected. The evaluation of print conformance as defined in the PSD always applies a full reference schema, i. e. it will be measured how close a given reference has been met.

In the case, a print service provider has to process data that is not prepared for a printing condition such as RGB image content they are urged to take the responsibility to perform this ambiguous step. In that case the print service provider should inform the print buyer about that process since it might involve a significant image difference. It is recommended to use modern ways of visualization for that purpose such as softproofs within the webshop or a URL to a lowres version of the ripped data. This might also help to raise customer satisfaction. Meeting the requirements of "pretty reproductions" can therefore only be accomplished when the print buyer has a chance to inspect the final print product. In cases where this way of approval, from a visual representation of the ripped data all the way to a contract proof, was not chosen it is a indication that quality is not of primary concern. Here the service provider might consult the provisions outlined for the conversion of Office PDF document in chapter 3. The described schema is illustrated in Figure 6.1.

Hint:

What is well defined image content?
Image date that is output referred is well defined since it defines colour by means of an print related output. In other words most of the RGB-based image data is picture or scene referred and therefore not well defined.

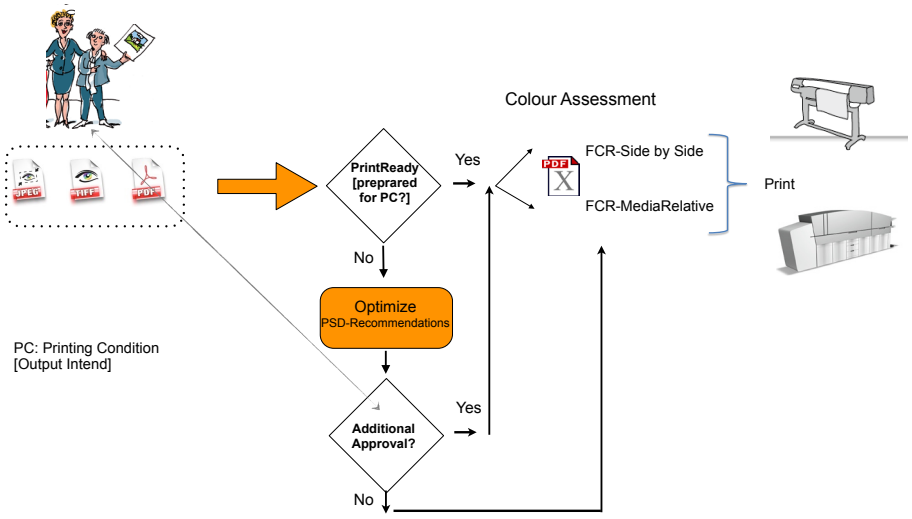

Fig. 6.1: Schematic workflow of the colour reference to be choosen according to PSD. Incoming data will be checked for being print ready or not. After an optimization according to chapter 3 and an optional but recommended approval the reference printing condition (e.g. FOGRA51) can be matched either media relative or absolute (Side-by-Side).

6.2 From colour to the print image

Conformity of print products is most restricted toward the accuracy to which the colours have been reproduced. Prior definition of expected image and product quality can be based on specific print image quality criteria. These criteria address colour rendition, homogeneity (uniformity), resolution, artefacts, in addition to permanence aspects such as light fastness or rub resistance. These four (five) categories are the columns of the process independent evaluation of printed matter.
Certainly, colour accuracy plays a dominant role. In chapter 2.6 it was shown that the established way of colour reproduction and viewing does not well reflect typical uses cases. Hence the colour reproduction according to PSD will be extended by taking into consideration the following aspects, which are also part of ISO 15311:

- Evaluation of print image quality based on process independent image quality attributes. Print quality attributes are categorized into colour and surface finish, homogeneity, resolution and artefacts, plus permanence requirements.
- Consideration of different colour reproduction/viewing types namely: Side-by-Side and media relative.
- Face the different needs of different market sectors by providing alternative tolerance bands termed A, B and C

Those additional information requires prior agreement and negotiation between the print buyer and the service provider. Though a exemplary job sheet is provided in section 1.3.

6.3 System-Check and Print-Check

Evaluating print products quickly results in the finding that it is impossible to address different use cases with only one set of requirements. In light of different market requirements different requirements will be stipulated both for the manufacturers needs to rigorously test an full systems and the printer needs to test their individual print job:

Manufacturer: To check if an entire system, comprising representative machine and material parameters, meets the criteria set out for one of three quality types for typical industrial printing machines or system applications (**System Check**). The system check is not part of PSD. Please consult the DPWG mailing list to stay up to date.

Printers/Print buyers: To check if a specific combination meets the defined for a typical industrial print job (**Print Check or PSD Print Check**)

The PSD only requires the print check and not the system check!
Each print check shall comprise:
OK-Sheet
- Colour Accuracy (to be done by measuring the Fogra Media Wedge V.3)
- Uniformity (to be done by visual assessment)
- Mis-registration (to be done by visual assessment)

Print Run evaluation

The results of the visual assessment should be reported in the job sheet or within the online reporting and quality tracking system.

Hint:

In the area of proof or Validation Print creation the three levels (manufacturer, creator and user) have been established. The PSD-certification corresponds to a so called site-certification whereas the print check refers to a manufacturer system certification and the print check refers to a user/job level evaluation.

6.4 Image Appraisal: Side-by-Side and media relative

Concrete methods for evaluating colour rendering between an original and a reproduction are known since the publication of 1931 CIE standard observer - hence more then 80 years. They are referring to an image appraisal that assumes a simultaneous viewing of both the original and the reproduction - positioned juxtaposed. This way of appraisal is called "Side-by-Side". The plethora of devices and substrates in digital printing and the corresponding variety of use cases challenge that concept of colour reproduction/viewing. The most prominent nature of the absolute reproduction is the paper simulation, which is needed to compensate for the different paper shades. Such a paper simulation, however, is often not needed for many use cases or applications. Contrary often print products with a paper simulation are often refused by the print buyer. That is the case since the print product won't ne seen direct next to the original in a "Side-by-Side" fashion. Hence print service providers are faced or demanded to switch off the paper simulation. The established "PSO-like" evaluation would most likely result in non conformance due to the colour difference in the paper colour.

For that reason, an old-fashion method, e.g. known from densitometry, will be used which normalizes or adapts for the paper colour. This approach is simplified by considering colours relative to white. Allowance is made for the fact that observers tend to perceive not in isolation but with reference to a framework provided by the environment. Such a framework is often the (unprinted) substrate. The media relative approach is intended for those applications where the final print product is subject for individual viewing or observation. It assumes that the observer fully adapts to the individual substrate what is practically the case for most not colour media. While keeping a certain level of predictability this media relative reproduction (and evaluation) is not applicable without limits. For instance it makes no sense to render from FOGRA51 ("premium coated offset") to IFRA26 ("newspaper printing"). For that reason there are details requirements for the source and destination gamut to make sure that both gamuts are similar in size and shape.

Hint:

While the quality of the established reproduction method (side-by-side) results from the simultaneous comparison of two adjacent prints under norm light, the media relative approach is conducted as follows:

- Test person sees reference (proof, softproof or Validation Print)
- Test person takes a break while the reference is removed.
- Test person sees the reproduction (by itself) and compares the quality with their memory.

In the case when image content needs to be reproduce on a gamut that is substantially smaller than the reference large colour differences can be expected. These depend on the uses gamut mapping algorithm and the actual gamut differences. If gamut mapping algorithms are used that come from different vendors the reproduction might show significant differences. That is practically termed "not consistent".

This fact calls for another approach which allows for consistent rendering across different gamuts. Such an approach is termed "common appearance" and still an active field of research. It is planed to incorporate such an approach as soon there is enough substantiation for a practical, vendor neutral implementation.

6.5 Colour accuracy for production printing

The following tolerances are part of the PSD PrintCheck. It is necessary that the Fogra MediaWedge V3 is present. In cases where imposition does not allow for a control wedge, a dedicated testform (e.g. the Fogra Image Quality testform or the process control test form including customer specific images and control elements) should be printed prior and after the print run, that undergoes the same data transformation as the pertinent image data.

Spot colours:

Spot colours typically occur in three different ways. The most prominent way is the usage of a solid, e.g. 100% Fogra-Red. The second occurrence is the usage as a tint values, e.g. 50% Fogra-Red. The most complex way is the usage of spot colours that overprint with other process or spot colours (e.g.: 30% Fogra-Red on top of 80% „Warm Grey" and 25% Cyan).

ProcessStandard Digital (PSD) currently only covers the first occurrence namely the usage of spot colours as solids. It is important for the colour communication to agree on a reference to be used. It is recommended to use either a physical sample or the colour definition as part of a PDF/X file (colorants dictionary entry).

Here it is not of primary concern if the spot colour is reproduced by means of a separate colorant or by overprinting of the process colours. However for process control reasons it plays a vital role due to screening effects and risk of higher variation within the print run.

Accuracy of evaluation

When evaluating prints it is important to take the correct rounding into considerations. The basic rule is that the measurements shall be rounded to the precision of the given tolerance. Two examples are given in the following tables:

Rounding	Value ΔE^*_{ab}	Tolerance: $\Delta E^*_{ab} \leq 3$ - Result
Not rounded - **wrong**	3.451	Wrongly rounded, outside tolerance
Rounded to two decimals - **wrong**	3.45	Wrongly rounded, outside tolerance
Rounded to one decimals - **wrong**	3.5	Wrongly rounded, outside tolerance
Rounded to zero decimals (integer) - **right**	3	Rounded correctly, compliant (within tolerances)

Tab. 6.1: Example for how to round measurements. Since the tolerance is an integer the rounding shall be done with zero decimals.

Rounding	Value ΔE^*_{ab}	Tolerance: $\Delta E^*_{ab} \leq 3$ - Result
Not rounded - **wrong**	3.451	Wrongly rounded, outside tolerance
Rounded to two decimals - **wrong**	3.45	Wrongly rounded, outside tolerance
Rounded to one decimals - **right**	3.5	Rounded correctly, outside tolerance
Rounded to zero decimals (integer) - **wrong**	3	Wrongly rounded, but erroneously within tolerances

Tab. 6.2: Example for how to round the measurements in order to assess conformity. The measurement value must be rounded to one decimal (as defined by the tolerance). In this case there is no compliance.

Hint:

It is recommended to use both visual images and test elements for the test form prepared in CMYK. The Fogra testform can be used to get some ideas.

Hint:

Simulating spot colours with process colours requires often the usage of tints instead of solids. Depending on the used screening that might result in unwanted uniformity problems. In addition the interplay of 2 or more colorants is prone to higher variations than only one ink.

6.5.1 OK-Sheet: Side-by-Side Evaluation

Hint:

New tolerances for side-by-side and media relative evaluation!

The new tolerances shall be denoted "PSD 2016" and the old ones "PSD 2011".

The deviation tolerances are derived by comparing the OK-print with the corresponding values of the reference printing condition. It could be though of the ability of a printing system to be successfully calibrated as demonstrated by the colour difference between the "first" sheet (OK-sheet) and the reference characterization data set. Table 6.3 lists the tolerances for the three tolerance bands A, B and C for the practical evaluation (print check). The PSD Print Checl colour accuracy evaluation is limited on the Fogra Media Wedge V3.0. An extended scruity, e.g. based on large test charts, is subject for the system check.

Patch in digital printing form	Quality Type C	Quality Type B	Quality Type A
Substrate	$\Delta E^*_{00} < 3.5$	$\Delta E^*_{00} < 3.5$	$\Delta E^*_{00} < 3.5$
All patches	Maximum $\Delta E^*_{00} < 10.5$ Average $\Delta E^*_{00} < 6.5$	Maximum $\Delta E^*_{00} < 8.5$ Average $\Delta E^*_{00} < 4.5$	Maximum $\Delta E^*_{00} < 6.5$ Average $\Delta E^*_{00} < 2.5$
Grey Balance patches	Average $\Delta C_h \leq 4.5$[b]	Average $\Delta C_h \leq 3.5$[b]	Average $\Delta C_h \leq 2.5$[b]
[a] Due to the sign character of ΔH the absolute values ought to be used before averaging. [b] ΔC_h is explained in chapter 2.3.			

Tab. 6.3: Deviation tolerances for Side-by-Side reproductions.

The reproduction of spot colours shall meet the requirements stipulated in Table 6.4.

	Quality Type C	Quality Type B	Quality Type A
Maximum colour difference	$\Delta E^*_{00} < 5.5$	$\Delta E^*_{00} < 3.5$	$\Delta E^*_{00} < 2.5$

Tab. 6.4: CIEDE2000 tolerances for spot colours.

It is recommended to check the spot colours coverage of the typical production printing combinations in order to identify and use a combination that allows for an appropriate spot colour match.

Note: Spot colours are typically distinguished between "process ink emulation" and "real spot colours" using an additional ink. The latter one often results in a more uniform reproduction since there are no screening effects. Spot colours not within the gamut of the chosen printing combination are handled the same way as CMYK content which lies out of gamut. The benefit of using "real spot colours" will automatically become obvious when saturated spot colours ought to be reproduced to a high degree, i.e. comprising a small colour difference.

6.5.2 OK-Sheet: Media Relative Evaluation

The control strip shall be the Fogra MediaWedge CMYK V.3. The media-relative evaluation is only applicable for actual printing gamuts similar in size and shape to the gamut of the reference printing condition, see Table 6.5. In order to evaluate the gamut difference the following 10 patches need to be measured for both the reference and the actual printing condition:

- Process colour black for the reference (Ref_K100) and actual (Act_K100),
- Composed Grey for the reference (Ref_CMY100) and actual (Act_CMY100) and
- Overprints of the chromatic process colours for the reference (Ref_CK100, Ref_MK100, Ref_YK100) and actual (Act_CK100, Act_MK100, Act_YK100).

Based on the minimum CIEL* lightness values for the reference (Ref_Min_CIEL_Dark) and the actual printing condition (Act_Min_CIEL_Dark) it will be checked if the shadow parts are comparable. In order to compare the highlight areas, the CIEL* lightness difference of the measurements of the substrate patch of the reference (Ref_paper) and the actual printing condition (Act_paper) will be computed.

Hint:
Use the free Excel spread-sheet: www.fogra.org/en/fogra-standardization/digital-printing-2-48/digital-printing-standardization.html

	Black point difference	White Point difference
Tolerance Quality A	|Act_Min_CIEL_Dark, Ref_Min_CIEL_Dark| < 3.5	ΔE^*_{00} *(Ref_paper, Act_paper) < 6.5 (5.5)
Tolerance Quality B	|Act_Min_CIEL_Dark, Ref_Min_CIEL_Dark| < 10.5	ΔE^*_{00} (Ref_paper, Act_paper) < 8.5 (7.5)
Tolerance Quality C	|Act_Min_CIEL_Dark, Ref_Min_CIEL_Dark| < 15.5	ΔE^*_{00} (Ref_paper, Act_paper) < 11.5 (10.5)

Tab. 6.5: CIELAB tolerances for gamut differences to check if media-relative is applicable. The colour differences for the white colour are very similar when using ΔE^*_{ab} or CIEDE2000. The CIEDE2000 tolerances shall take precedence. CIELAB 1976 colour differences are given in brackets.

Only if the criteria of Table 6.5 have been met, the media relative evaluation shall be conducted. For the PSD print check evaluation, the 72 patches of the Fogra Media Wedge V3.0 shall be used. The colour differences shall agree with Table 6.6.

Hint:
Media relative CIELAB-colour values can be detected easily when the paper has a CIELAB value of 100,0,0.

Patches in digital printing form	Quality Type C	Quality Type B	Quality Type A
All Patches	Average ΔE^*_{00} < 6.5 95% Quantile ΔE^*_{00}<8.5	Average ΔE^*_{00} < 4.5 95% Quantile ΔE^*_{00}<6.5	Average ΔE^*_{00} < 2.5 95% Quantile ΔE^*_{00}<4.5
Grey Balance patches	Maximum $\Delta C_h \leq 4.5$	Maximum $\Delta C_h \leq 3.5$	Maximum $\Delta C_h \leq 2.5$

Tab. 6.6: Deviation tolerances for media-relative reproductions.

There is no media-relative evaluation for the reproduction of spot colours.

6.5.3 Stability within the run (production variation)

Contrary to deviation tolerances, that define the difference between an OK-sheet and tabulated data, the variation tolerances refer to the differences within one print run. In ISO 12647-2 and hence PSO the variation tolerances we evaluated by taking the OK-sheet (or set-up sheet) as the reference. Print buyers look for consistent colour printed in different locations and at different times. The best way to achieve within-run color consistency is to use the average value of the print run, and not the OK sheet, as the reference. The tolerances are depicted in Table 6.7.

In addition the variation tolerance, i.˘e. the ability of a printing system to maintain consistency between the same colour patches printed in the same locations on the sheet over the press run, is assessed by checking that at least 70% of the randomly picked sheets are in conformance to the deviation tolerances. In order to evaluate a print run at least 20 samples must be randomly selected. The following patches needs to be taken into consideration.

¬ Primary and secondary colours („CMYKRGB")
¬ Midtones (40% to 50%) of primary colours („50% CMYK")

	Quality Type C	Quality Type B	Quality Type A
CMYKRGB, 50% CMYK	max (95% quantile ΔE^*_{00}) < 5.5	max (95% quantile ΔE^*_{00}) < 3.5	max (95% quantile ΔE^*_{00}) < 1.5

Tab. 6.7: CIEDE2000 tolerances of primary and secondary colour solids and primary colour mid-tones – between any print sample and the average of the 20 samples.

The "PSD PrintCheck Digital" is also available as a separate Fogra certification. Please consult the webpage for more information.

6.6 Colour accuracy for large format signagne printing

The colour accuracy requirements are currently identical to those defined for production printing.
The only difference is the imposition and the print-run evaluation. Here each print is considered as an OK-sheet.
The "PSD PrintCheck LFP" is also available as a separate Fogra certification. Please consult the webpage for more information.

6.7 Permanence and Durability

The definition of permanence requirements strongly depends on the individual use case, to be defined in further parts of ISO 15311. It is not practical to name the magnitude of available standards and procedures for physical properties, permanence behaviour and the effect of environmental factors on printing materials. Therefore the relevant requirements shall be defined by mutual agreement between the print buyer and the service provider.
Most permanence standards and practices defined by ISO/TC 42/WG 5 "Physical properties and image permanence of photographic materials". Here especially the standards provided by TG 2 (Storage & Physical properties) and TG 3 (Colour, Prints) are of importance. Important standards are ISO/CD 18938, that stipulates light stability, ISO/FDIS 18931 that defines humidity resistance or ISO 18936 and ISO 18924 that specifies thermal stability.