PRODUCT BULLETIN

Colour management in the digital graphic chain

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www.**hexis-graphics**.com

Assistance contact: **assistance@hexis.fr**
Printing Division contact: **profils@hexis.fr**

Reproduce precise colours

Colour is **one of the fundamental elements of visual communication**, so it is widely used by marketing.

Spotting a laundry package in a supermarket shelf, recognising a brand due to its logo, signifying a brand philosophy, all of these depend mandatorily on a choice of colours knowledgeably realised.

For a large format printer, it is therefore imperative to be able to **accurately reproduce the colours requested**, and this effectively in a **logic of productivity and consumables gain**.

The large format printer's reality

Anyone who had to do with large format printing in a professional manner has been confronted with multiple cases where the printed colours did not match or were too approximate to what had been expected.

Often we experience printing results that may seem to be random and we are happy longer with just approximate colours, but one day the final customer may no accept the work.

So we put in place empirical solutions, multiply tests, and waste time as well as consumables.

By a lack of confidence, we even forbid ourselves sometimes to target more ambitious markets.

Colour management

However, methods and tools exist. They provide with **precise control over production workflows**, in terms of printing quality, ink consumption or colorimetric accuracy.

This is called **Colour Management** and **ICC profiles method**.

These words which often sound difficult to understand tend to intimidate while the basic principles are quite simple.

You do not have to be a champion in colorimetry to understand them and apply colour management in a large format digital printing workflow.

1. What is colour?

«Sensation resulting from the impression produced on the human eye by a light emitted by a source and received directly (colour of a source: flames, etc.) or after having interacted with a non-luminous body (colour of a body).» Larousse dictionary definition.

Colour is a **sensation** resulting from a complex perceptual phenomenon, an interaction between a **light source**, **an object** that absorbs and reflects a part of that light, and **an observer** who perceives the reflected light.

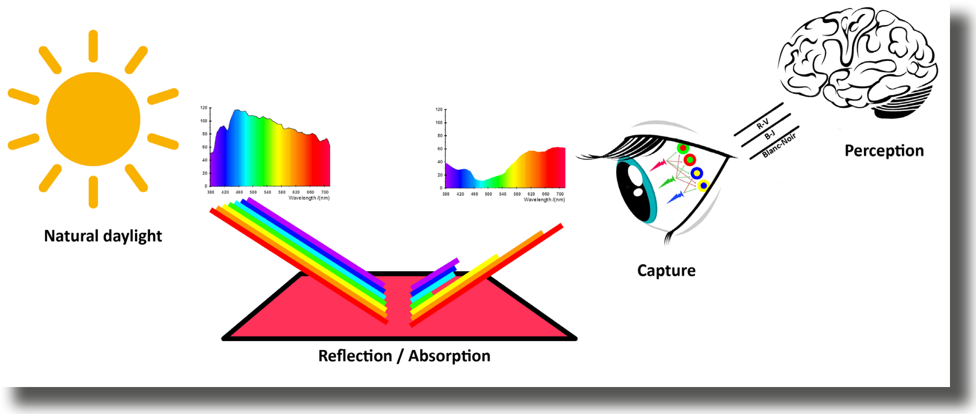


Fig. 1: Layout of the colour perception principle

These three elements must be present and have their influence so that an object's colour exists in the generally known sense.

2. Apparent colour

Charles Baudelaire (Paris 1821-Paris 1867)
« Les parfums, les couleurs et les sons se répondent. »
«Perfumes, colours and sounds correlate.»
Les Fleurs du Mal, Correspondances (Flowers of Evil, Correspondences)

It is a component of a larger subject than that of appearance described by **chromatic characteristics** (tint, saturation and luminosity) and **geometric characteristics** (brightness, texture, shape, opacity, etc.).

This is called **perceived colour**. It only exists in our brain as mental meaning. It is intimately linked to physical (light, object), physiological (visual system) but also psychological (achievement, cultural, language, memory, etc.) phenomena.

Seeing is believing! No, unfortunately our perception sometimes plays tricks on us.

Reality and perception are two different things. But in the end it is rather what is perceived that counts.

Thus, the same reality can be perceived in different ways, and different realities can be perceived in an identical way. This can be a source of problems, but it also allows us to invent colour reproduction processes that will work as a «trompe l'œil».

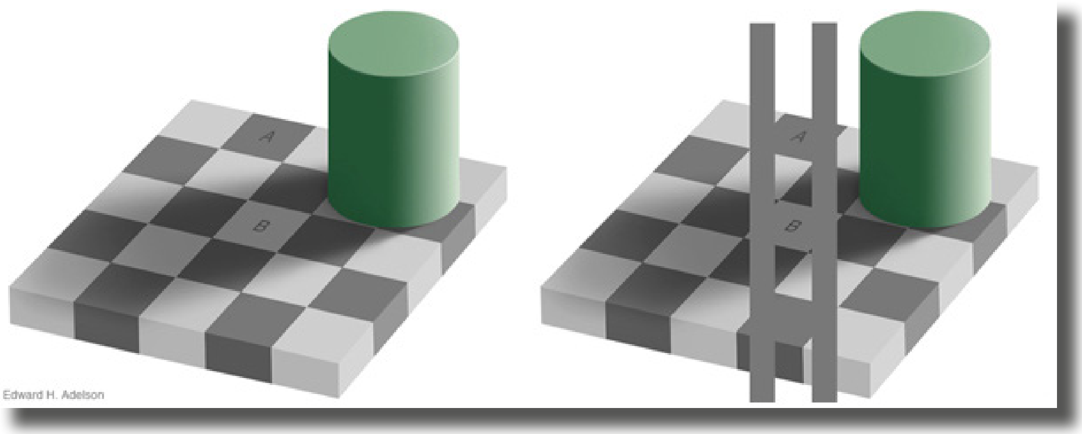


Fig. 2: Adelson's chessboard

3. Reproducing a colour

Reproducing a colour means **reproducing a colourful visual sensation**. So everything starts from the observer and its visual system.

Human vision is based on two types of eye photoreceptors: **rods** and **cones**. The rods, more sensitive to light than cones, are used for night vision; they are not sensitive to colour. However, there are three types of cones that are sensitive to colour. They are located in the retina and are respectively sensitive to **blue**, **red** or **green** lights that make up the white one.

So, a first way to reproduce colours is to mix and add red, green and blue coloured lights, in order to stimulate these three types of photoreceptors. This is therefore called **additive synthesis of colours**. All colour reproduction processes that bring light into play are based on these three R, G and B primaries.

Example: screen, projectors, cameras, scanners

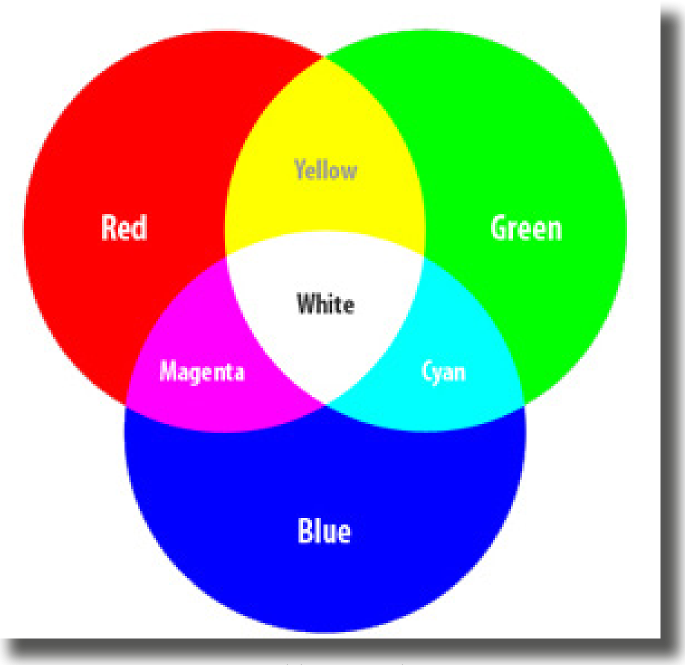


Fig. 3: Additive synthesis

Another method is to mix pigments that will absorb the red (cyan pigment), green (magenta pigment) or blue (yellow pigment) light of the white one which illuminates these pigments. This is called **subtractive synthesis**.

Example: offset, inkjet printing, etc.

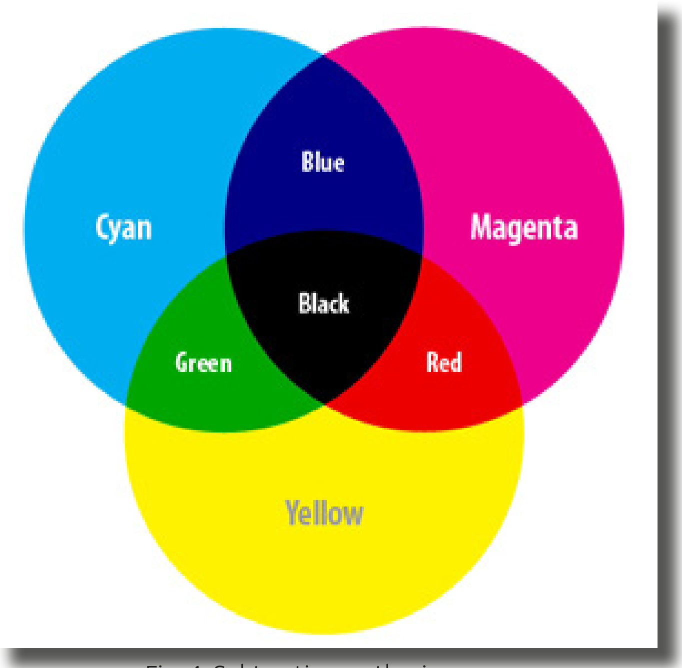


Fig. 4: Subtractive synthesis

4. Colour in the digital graphic chain

The real world around us is not digital, however we have today powerful calculation tools to analyse, apply treatments and communicate digital information.

The current digital processes that aim to reproduce the real (sound, image, etc.) are based on **the digitalisation of analogue quantities** (sampling and quantification).

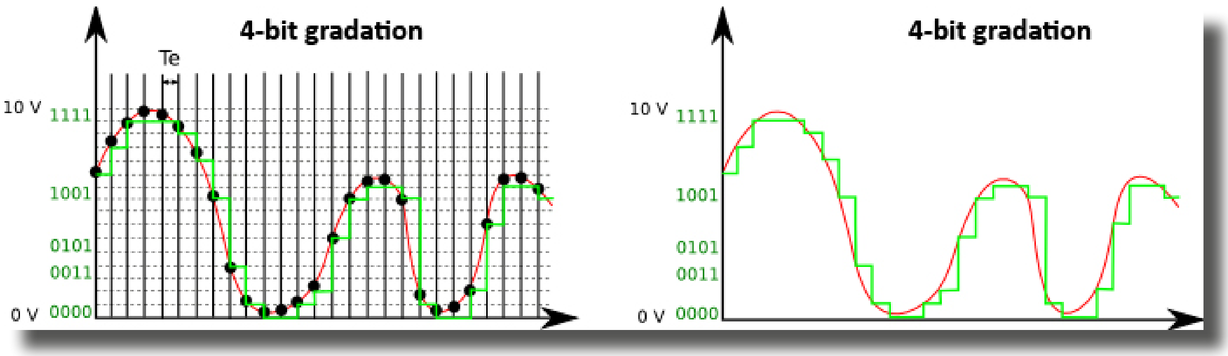


Fig. 5: Analogue/Digital Conversion

In order to be able to process, communicate, reproduce colours in a digital stream, you must therefore be able **to describe**, **express**, or even **measure the colour using numbers**.

There are several ways to do it:

4.1. The referenced colours

Each colour corresponds to **a code** or **digital reference** associated with a physical colour chart containing all the reference colours.

Ex.: Colours and Pantone NCS, RAL, Suptac colour charts, etc.

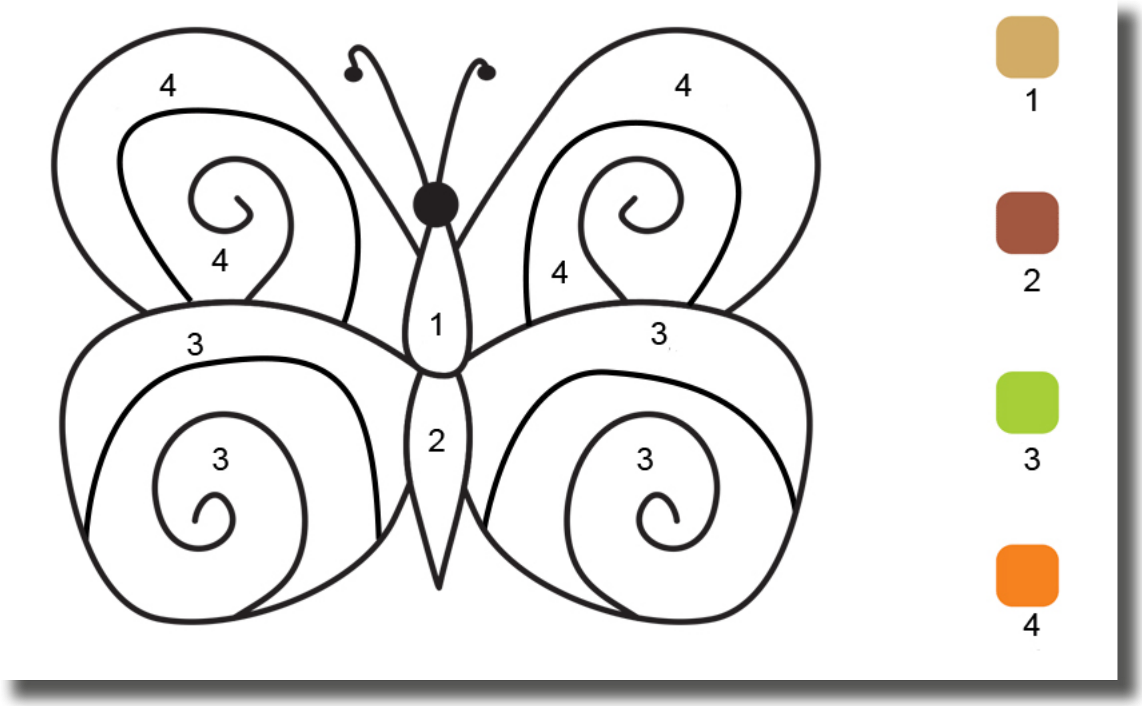


Fig. 6: Colouring with referenced colours

The advantage of this system is to have **a visual reference**.

The interest is mainly contractual because you can compare the reproduced colour with the reference and easily agree with your customer.

The limits of this system are multiple:

- You must be able to reproduce colour charts identically. They must be produced identically and must not age too quickly. This is of course not the case. Therefore, you must not take these references as colorimetric absolute.
- The **observation conditions** (illuminant) are essential for comparing colours. In the field of large format digital printing, few people have observation booths with standardised light sources.
- Historically, all these different colour systems have not been thought to be reproduced by inkjet printing. Thus many of these colours are not reproducible on a four-colour large format plotter.
- This method is only valid for **vector images**.

4.2. The colours described relative to a colour reproduction device

Another method that seems to be the most natural one is to express a colour according to quantities related to a process of colour reproduction.

Photographers work with light picture colours in additive synthesis, and express colour in **RGB** (red, green, blue). They use digital cameras and screens that are **RGB devices**, which **capture** or **emit light**.

Printers, picture colours in subtractive synthesis, and express colour in **CMYB** (cyan, magenta, yellow and black). Offset presses and large format inkjet printers are **CMYB devices** that **deposit ink on the media**.

<u>Let's take a look at the Suptac S5200B red</u>:

On my screen, this colour corresponds to R=177 G=0 B=0 (each component is expressed from 0 to 255, since it is usually encoded on one byte).

On my neighbour's screen, it corresponds to R=151 G=0 B=0.

The two screens are nevertheless calibrated, but with respect to their own capacities which are different. It is like being in a store where you can see a wall of televisions that display different colours from the same digital information. **In the absence of standardisation, each RGB device has its own colour response related to technological choices, variations in production...**

To print this colour on an offset press, I have to mix the following inks: C=15 % M=100 % Y=100 % and B=13 %.

To print on my eco-solvent inkjet plotter, I have to mix the following inks: C=0 % M=100 % Y=95 % and B=17 %.

In the same way as for different RGB devices, the response of different CMYB devices differs, depending on technology, inks, media, standards, etc.

In RGB or CMYB, the digital values allowing to obtain the desired colour depend on this device.
Thus, in RGB and CMYB, we will code the colours in relation to a device taken as a reference.

4.3. Colour expression or measurement with respect to human perception

Colorimetry is the field of science that is interested in **colour measurement**. In fact, only the light is really measurable, not the perceived colour.

Over time, scientists have introduced light measurement devices (emitted, transmitted or reflected by an object) and mathematical models to relate these measurements to perceived colours.

This was possible thanks to the implementation of key elements:

- **Standard illuminants** (D50, D65) that consolidate quality (spectral power distribution) of reference light sources for colour observation.
- A **standard observer** corresponding to the average perception of the human observer.
- **Mathematical models to identify colours** by 3 numbers and to represent them in 3-dimensional geometric spaces generally.

These models are not perfect and have their limits, but they are effective enough to help us manage colour in the digital graphic chain. In colour management methods, the most used colorimetric space is the **CIELAB space**.

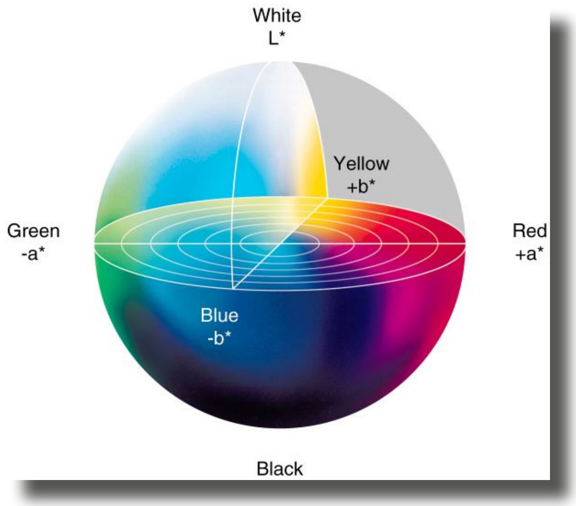


Fig. 7: Representation of the CIE L*a*b* space

Using a spectrophotometer, we can measure the colour perceived by the observer under well-defined observation conditions, for a given illuminant, and express it through 3 values, namely L, a and b.

In the case of our Suptac S5200B, the values are L=35,6 a=66,5 and b=51,2 (standard illuminant of graphic arts D50 and observer 2°).

4.4. Colour and numbers

"Dark Red"																		
Reference	CIELAB			RGB 1			RGB 2			CMYK 1				CMYK 2				
	L*	a*	b*	R	G	B	R	G	B	C	M	Y	K	C	M	Y	K
SUPTAC S5200B	35,6	66,5	51,2	177	0	0	151	0	0	15%	100%	100%	13%	0%	100%	95%	17%
"true" colour, perceptual description				Description of the colour in relation to an input or output device considered as a reference														

To sum up, there are two main ways to define colours using numbers:

- Either they are described with **respect to human colour perception through colour charts or colorimetric samples**. In this case, there is no ambiguity.
- Or they are described with **respect to the devices that make it possible to reproduce them**. In this case, the digital RGB or CMYB values only make sense in relation to a device taken as a reference.

5. Colour management, principles and operation

5.1. Why do we need colour management?

People who process digital image have an experience, a culture related to a process (photography, printing…), so they work in RGB or CMYB. Very few people are able to directly process image chroma whose colours are coded in Lab.

However, it must always be borne in mind that **the digital RGB and CMYB values of a digital image correspond to real colours only through the response of an input** (camera, scanner) or **output** (screen, printer, etc.) **device**.

There are as many RGB and CMYB encodings as there are different RGB and CMYB devices.

So as devices of the same values will give different colours, and in order to get identical colours on different devices, we need different values.

In a simple production workflow with an input/output like that of the printer, we do not need colour management. The digitalisation (scanner) is carried out so that the CMYB values obtained correspond to the response of the offset press which is standardised. The system is closed. As soon as we want to use another output, we are faced with a conversion problem for the CMYB values. In the current graphic chain, there is a great number of possible inputs (n) or outputs (m). The system is open. So we are required to handle (n x m) conversions between these devices.

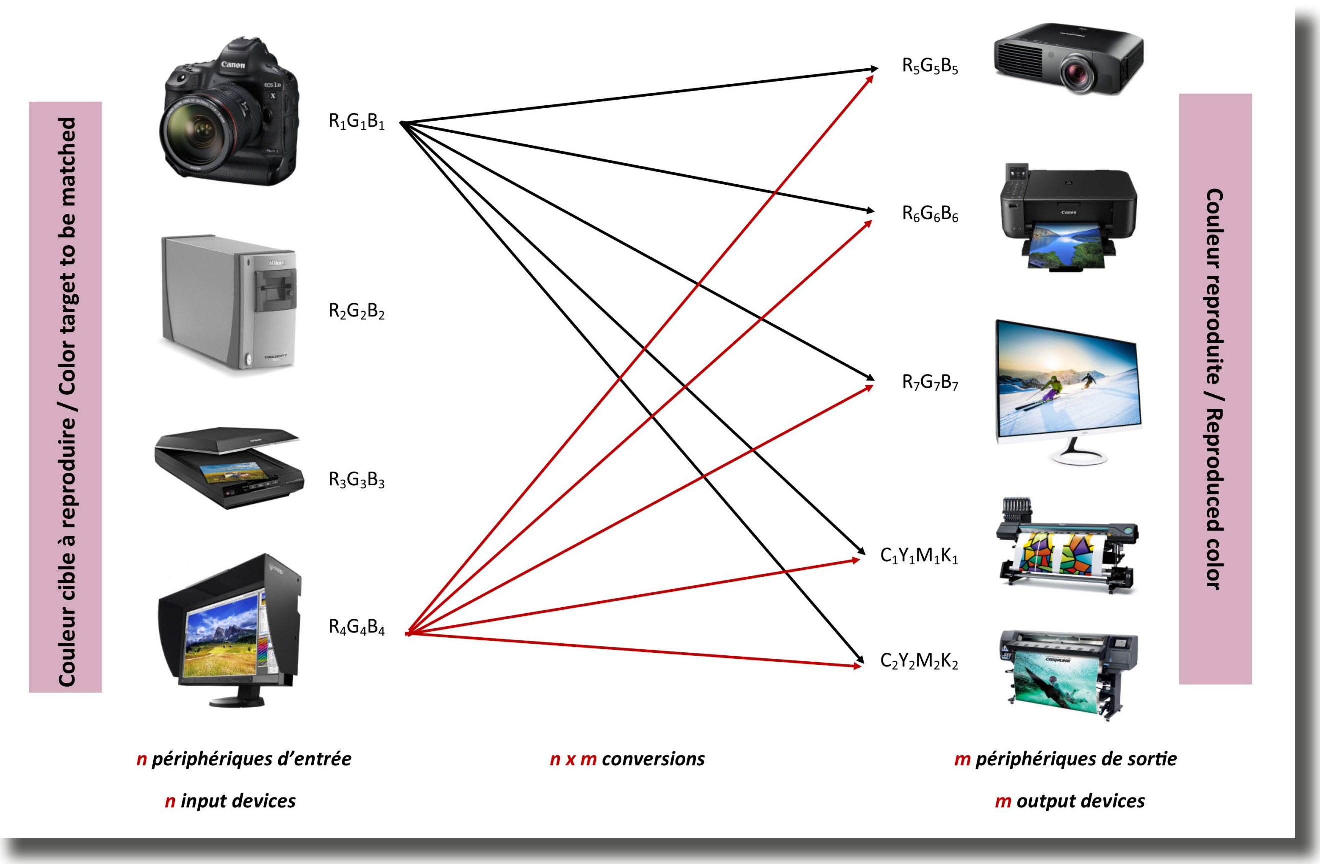


Fig. 8: Digital flow without colour management

5.2. Colorimetric connection space or PCS (Profile Connection Space)

The basic principle of colour management depends on **an intermediate representation of the desired colour in a colorimetric space** like CIELAB.

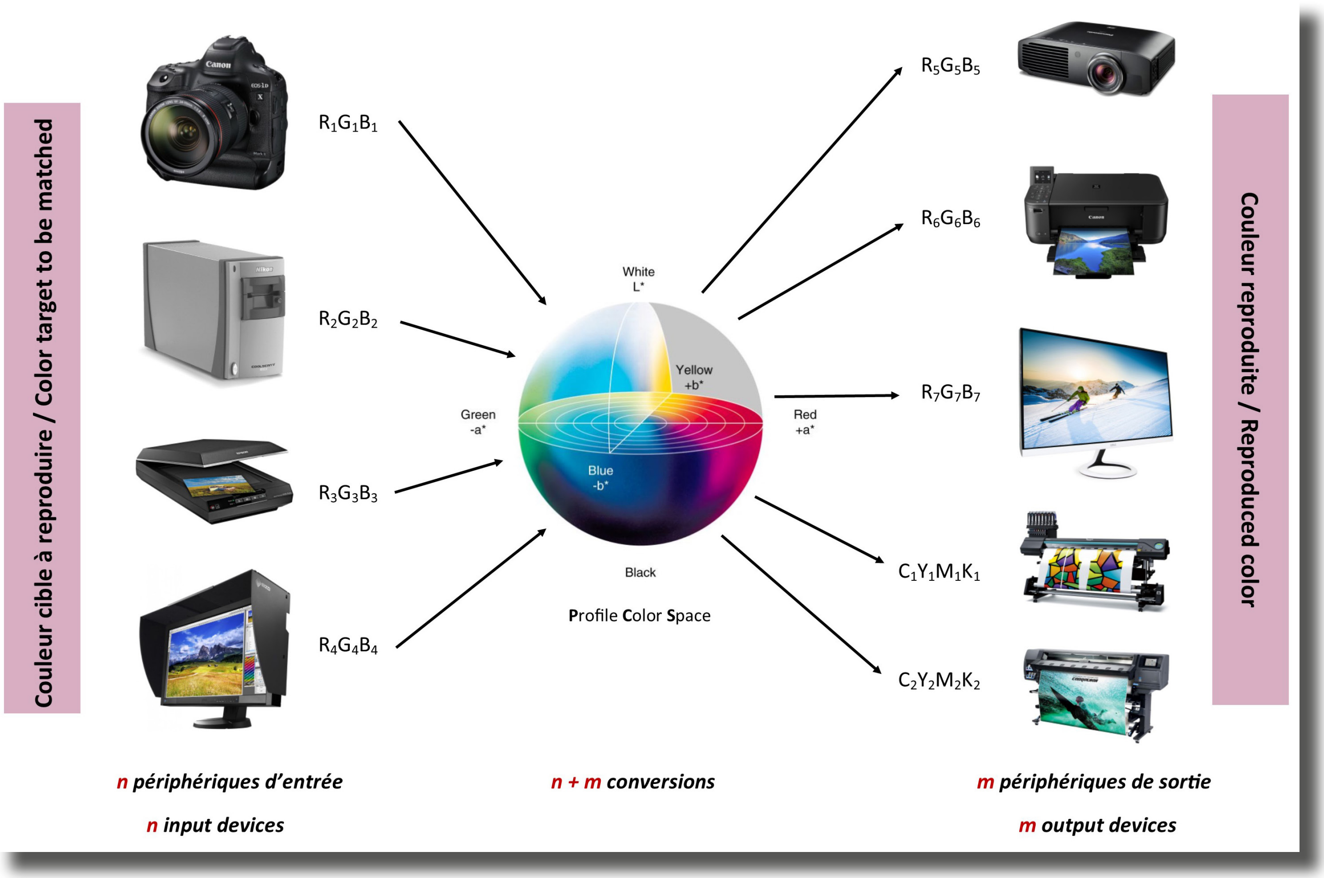


Fig.9: Digital flow with colour management

5.3. ICC profile

To do this, we need to know the **colorimetric response of different devices**, that means the relationship between RGB or CMYB values and the corresponding true colour, captured or reproduced.

This relationship is described in **a file specific to each device**, called ICC profile.

Example: Large format inkjet printer

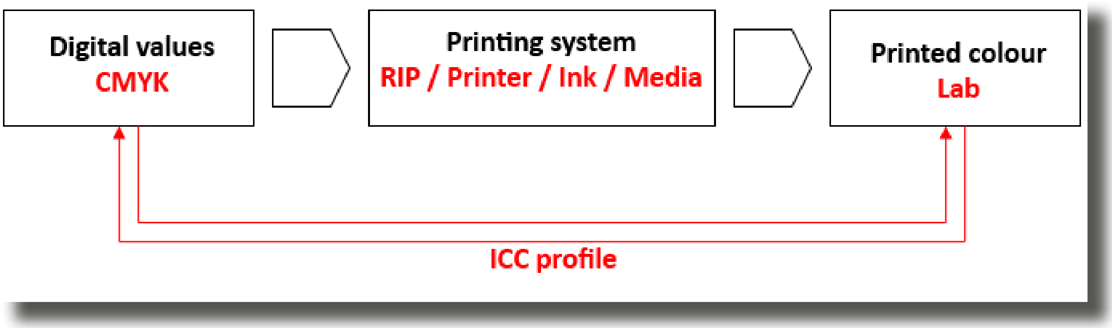


Fig. 10: ICC profile operating principle diagram

The ICC profile contains matching «tables» between the digital values and the corresponding true colours measured in Lab.

This «conversion table» is used in both directions:

- It indicates **the colour obtained on my output device according to the initial digital values**.
- It indicates which **digital value must be sent according to the colour that we want to obtain from the output**.

5.4. ICC flow

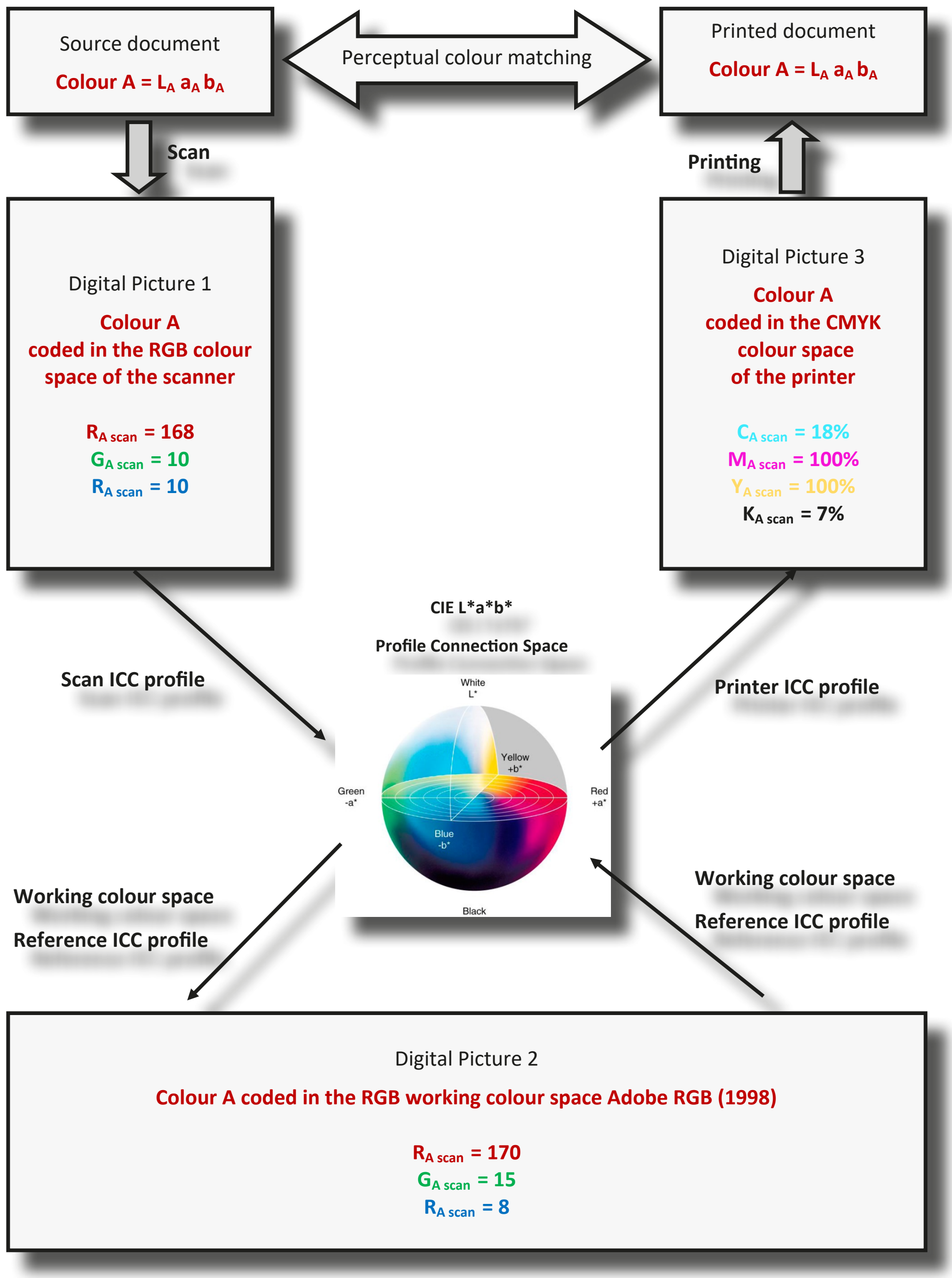


Fig. 11: Representative diagram of an ICC flow

In a digital printing flow, we usually have an image file to be printed whose colours are coded by **digital RGB or CMYB values**.

In fact, these values alone are not enough to accurately describe the colours to be printed if we do not know the reference device to which they are linked to.

To accurately interpret these values in terms of colour (in Lab), we need **the ICC profile of this reference device**.

During the profile to profile conversion, this ICC profile that interprets the file colours from digital values is called **the input or source profile**.

Once the colour to be printed has been expressed in Lab (regardless of the reference device), the printer's ICC profile will tell us which digital values must be sent to output in order to obtain it.

In this conversion, the printer's ICC profile is called **the output or destination ICC profile**.

Often, we avoid processing the images in chromatic spaces linked to true devices; we prefer to work in **colorimetric spaces related to standards** (virtual devices used as standard).

Example:

In RGB, the most common colorimetric spaces are: **sRGB** and **Adobe RGB (1998)**.
In CMYB, **Coated FOGRA39** is currently the most common.

5.5. ICC profile and printable colour range

A printing system's ICC profile gives us information about its colorimetric response and thus about the colours it can print or not. This is called a printable colour range or «gamut» (2D representation/projection).

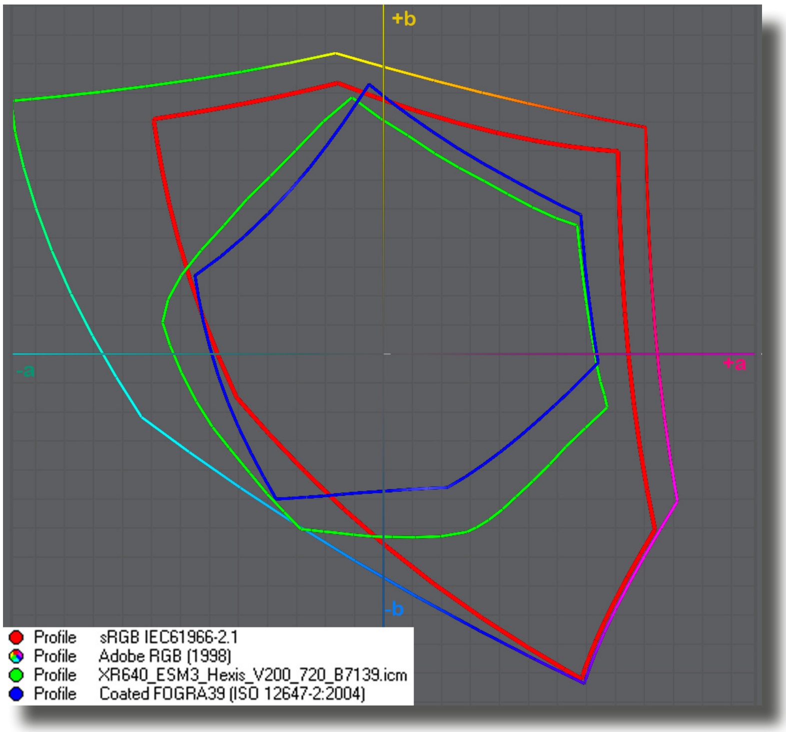


Fig. 12: Comparison of gamuts corresponding to several ICC profiles

The colours inside the gamut of a printer are printable, those outside are not printable.

We notice in the attached diagram that the CMYB systems (Fogra39 and Roland XR) feature a smaller gamut surface than sRGB (traditional screen, amateur camera) or Adobe RGB devices (1998) (graphic arts screen, professional camera).

That means that **in CMYB, I cannot print all the colours perceived by my camera or displayed on my screen**.

In the attached diagram, we can also notice that the SRGB gamut does not fully cover the gamut of the CMYB systems. This means that **some printable colours cannot be displayed on the screen**.

5.6. Converting source profile to destination profile

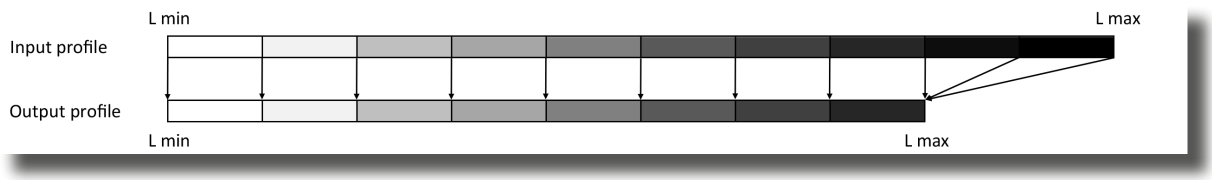
We have seen that sometimes certain colours of the file to be printed are not printable, they are out of the printer's gamut.
How best to treat the replacement of these colours out of gamut between a source and destination space?

If, for example, the photographic print on paper corresponds to the destination profile, we know in advance that certain colours such as the electric blue tints listed in the RGB file will not be reproducible on paper. It will therefore be necessary to replace this origin blue by another blue, slightly duller. The rendering mode will determine which destination blue will replace the source blue.

The ICC specifies four different ways to match the source colours with the destination ones with each time compromises made. This is called **rendering mode or intent**.

5.6.1. «Absolute colorimetry» rendering intent

In this mode, **the colours inside the gamut are printed as accurately as possible**.
On the other hand, this mode ignores out-of-gamut colours by focusing them on the periphery of the destination gamut. If the image has a large number of colours out of gamut, **the risk of breakage in the gradations is real**.



The absolute colorimetric mode does not take into account the adaptability of the human eye to match the white colour when there is a difference in white between source and destination.

In this mode, we try to **simulate in the output the source profile white**.

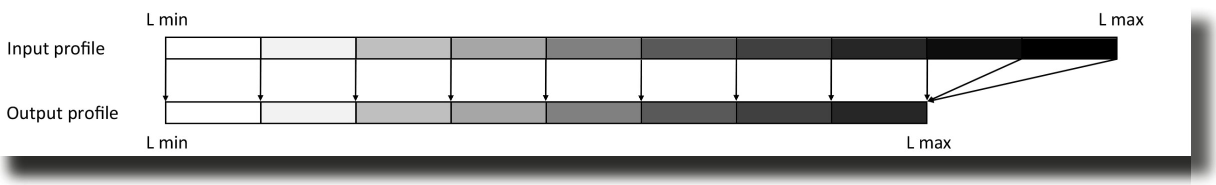
Thus on a large format plotter, the white of a CMYB Coated Fogra39 image (offset printer standard) will be printed with a little bit of yellow ink on an adhesive-coated vinyl. Indeed, the source paper's white is more yellow than the vinyl's white, and we try to compensate this discrepancy.

This conversion mode must be used for **CMYB proof simulation with simulation of the source white**, or **spot colours** (Pantone, Ral, etc.).

5.6.2. «Relative colorimetry» rendering intent

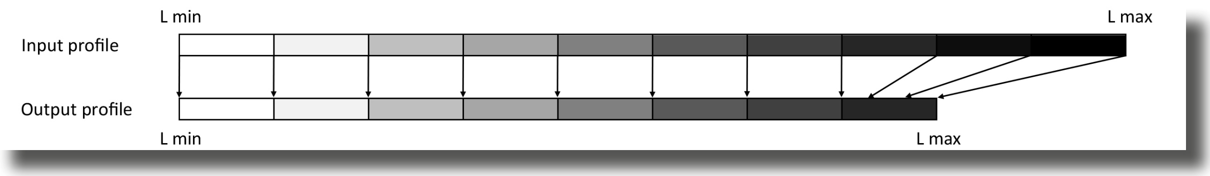
The relative colorimetric rendering (relative to the print medium) is an «enhanced» version of the absolute colorimetric rendering that takes into account the variations in white between source and destination. It allows the **conservation of colours as close as possible when they are printable while matching the source white with the destination white** (white of the printed medium).

Therefore, this mode must be favoured when trying **to simulate colours as close as possible while keeping the white of the finale medium**, and while starting **from a source gamut smaller than the destination one**.



5.6.3. Relative colorimetry with BPC (Black point compensation)

«Black Point Compensation» is an option of the relative colorimetric mode. The aim is **to avoid the flattening of all shades and details present in the shadows out of output gamut when converting shadows and blacks**.

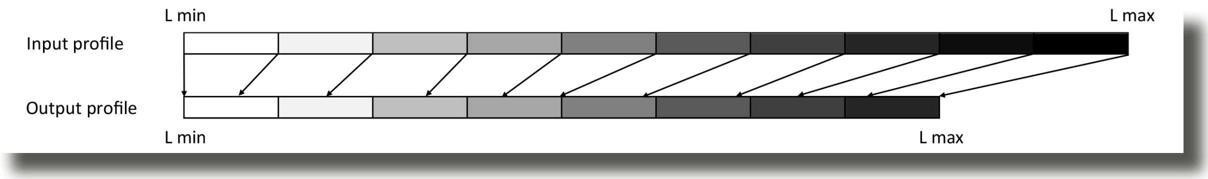


5.6.4. «Perceptual» rendering intent

The perceptual mode responds to the difficulty of reproducing colours out of gamut and, if necessary, **to preserve gradations without breakages**.

Like many perceptual phenomena, our visual system is sensitive to gaps, colour contrasts, more than to isolated colours perceived in an absolute way. It is quite similar to music. Musicians hear intervals, work in a tone, but very few have the «absolute» ear.

Therefore, the perceptual mode seeks to preserve the relative discrepancies between the colours and thus all the gradations; it consists of compressing the source gamut to make it «fit» into the output gamut.



When converting a large source gamut to a small destination gamut, all the colours will undergo modifications but the discrepancies between the colours will remain proportional to those that existed in the source space. **We do not loose neither the gradations nor the details**.

This is why this rendering is the preferred mode for conversions from a source space that is large enough to a considerably smaller destination space, such as converting a RGB space to a CMYB space.

On the other hand, we notice **a contraction of the gamut**, and therefore **a general decrease of saturation and/or density between source and destination.**
Unlike colorimetric modes, the perceptual mode is not the same regardless of the software; it is specific to each manufacturer. **The rendering will therefore differ from one software to another**.

5.6.5. «Saturation» rendering intent

Also based on the contraction of the gamut, this rendering proposes **to reproduce bright colours without taking into account the colorimetric accuracy**. This rendering mode is able to take maximum advantage of the brightest colours that a printer can produce for example. The only interest of this rendering is **the production of company graphics having bright colours and the preservation of this flashy aspect** even if there is a big colour deviation.

6. Colour management in practice, in large format digital printing

The purpose of colour management is **to control the colour's portability throughout the graphic chain**. In terms of printing, it allows **to print the colours described in the image files as accurately as possible**.

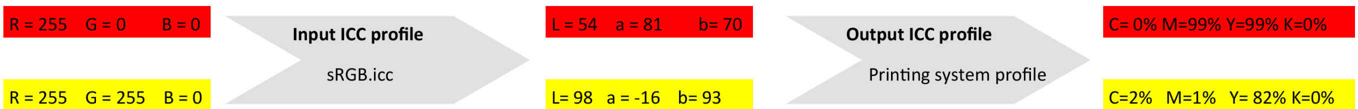
6.1. Printing by using colour management or not

Sometimes, when we do not have to print a specific colour, colour management may not be useful and may even be a source of complications.

<u>Example</u>: I want to print the following image with my printer.

My customer gave me an RGB file without an integrated profile.
The digital colour values are: Red (R = 255, G=B=0) and Yellow (R=255, G=255, B=0)
Theoretically, I do not know exactly which colours must be printed because I am not aware of the colorimetric space related to this image, namely the ICC profile that would allow me to interpret the file's RGB colours in terms of Lab colour.

My RIP is set by default with the sRGB.icc input profile for the RGB images because it is the most common (image banks, amateur cameras, web, etc.). If I print the file directly, the conversion of input profile to output profile in perceptual mode gives me the following CMYB output values.



With colour management, we try to simulate screen colours (sRGB), and yellow comes out «dirty» (presence of M and C).

In fact, in this case, the objective is not necessarily to accurately simulate the starting colours, we rather seek to obtain a «beautiful» pure red and a «beautiful» pure yellow.

The solution is to express the red and yellow colour in CMYB and to print by deactivating the ICC conversion for both colours.

Therefore, the 100 % yellow will be printed with yellow ink solely and the red with magenta and yellow.

The limit of this method is that **the output colours will depend on the printer and its inks, the media profile and primary colour restrictions that it contains, printing mode, medium, etc.**

6.2. Good use of ICC profiles during printing

When working with colour management, it is important to control the important items of the method.

- How are the colours described? RGB, CMYB, spot colours, etc.
- Do I know the profiles related to the RGB and CMYB colours (incorporated profiles)?
- Do I have the right output profile corresponding to my printing system (printer, ink, colour number, mode, media, etc.)?
- Which rendering intents do I have to choose?

6.2.1. Printing RGB files

RGB images are most often in sRGB (image banks, amateur cameras, web, etc.) or Adobe RGB (1998) mode for professional photographers. The gamuts related to these ICC profiles are wider than that of printing, and the preservation of gradations for photographs is an important point.

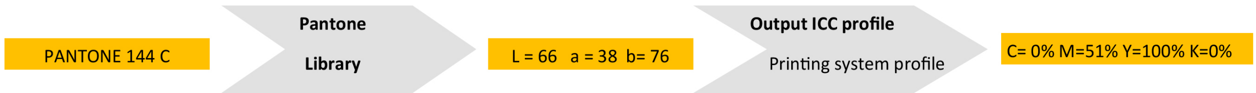
So we work in **perceptual mode**.

6.2.2. Printing CMYB files

CMYB images are most often in Coated FOGRA39 mode.
If we do proofing, we work in relative colorimetric mode, even in absolute colorimetry when we try to simulate the white of the source colorimetric space.
For the remaining (the majority), we work in **perceptual** or **relative colorimetry with black point compensation**.

6.2.3. Printing spot colours

Usually, we use spot colours when we must respect a graphic charter with logos whose colours are specified using spot colours. The image is therefore vectorial and the colours defined using a reference (RAL, Pantone, etc.).
The right method is to work with the spot colour libraries existing in the RIP that directly indicate us the colour, expressed in Lab, to be printed.



Library example:

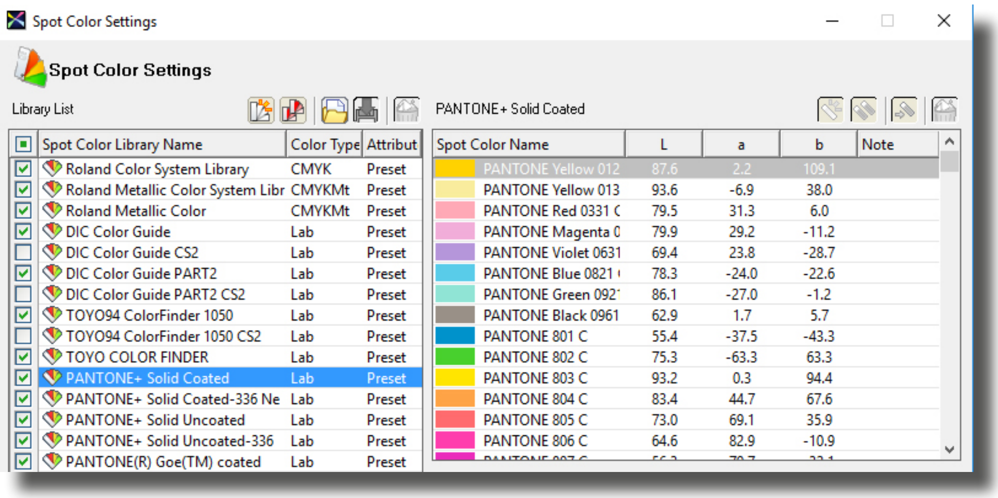


Fig. 13: Spot colour library in Roland VersaWorks

As we try to be as accurate as possible, we use **the absolute colorimetric table of the output profile**.
We absolutely must not convert spot colours into CMYB, as we hereby limit ourselves to the FOGRA39 gamut, which is smaller than those of the inkjet printing systems.
This prevents from reproducing certain spot colours that are inkjet but not offset printable.