Application Note #6

Evaluating an ICC profile coverage of the Pantone® and IDEAlliance data sets

1. Introduction

This application note provides a method to evaluate, using PatchTool, how well an ICC profile covers the gamut of a standard data set. This is important when evaluating if a press or printer will accurately reproduce colors and, if not, by how much they will be clipped.

1.1. The Pantone and IDEAlliance data sets

For the purpose of this document, we have selected the Pantone Coated and the SWOP Coated-3 data sets. The Pantone colorant system is a mainstay of the print industry, particularly for printing spot colors. The SWOP Coated-3 data set was defined by IDEAlliance for printer proofing certification purposes when using high-end publication type papers (Grade 3, such as Fortune Gloss); it assign reference device-independent color values to the color patches of the standard IT8.7/4 target. You could also select any other standard data set, such as the GRACoL Coated-1 or SWOP Coated-5 data sets of IDEAlliance, or even define your own.

The Pantone data sets are often bundled with purchased products; they can also be purchased individually. You may already have them if you purchased an Eye-One Pro (the data sets can be installed from the CD provided with the packages), or a ColorMunki (ColorMunki users, upon product registration, can download the Pantone libraries from the Internet). Please consult the ColorMunki and X-Rite Web sites for more information.

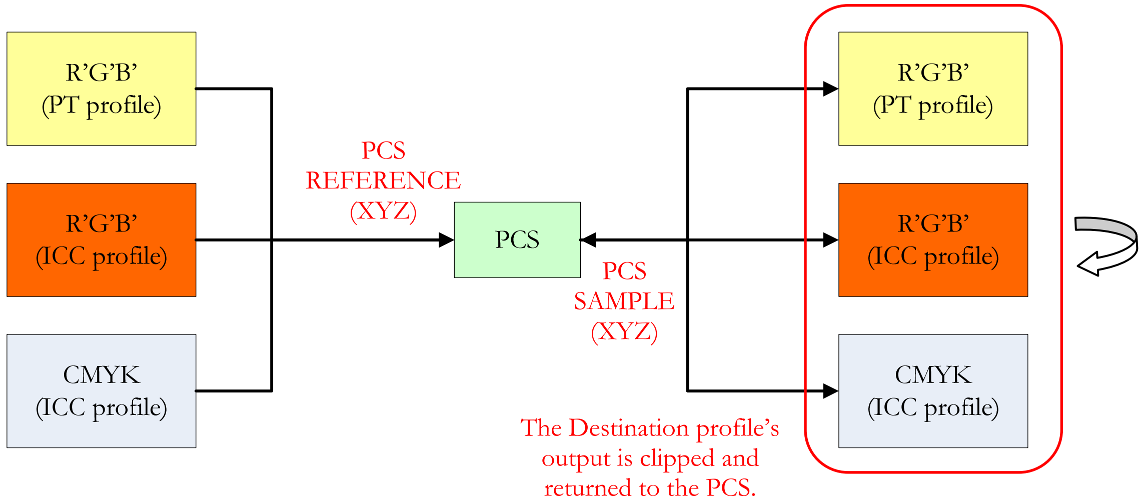
The IDEAlliance data sets are available from the IDEAlliance Web site (http://www.idealliance.org); you can also find them in the IDEAlliance folder located in PatchTool's application folder.

1.2. The evaluation procedure: PatchTool's Gamut Tools / Clip Check

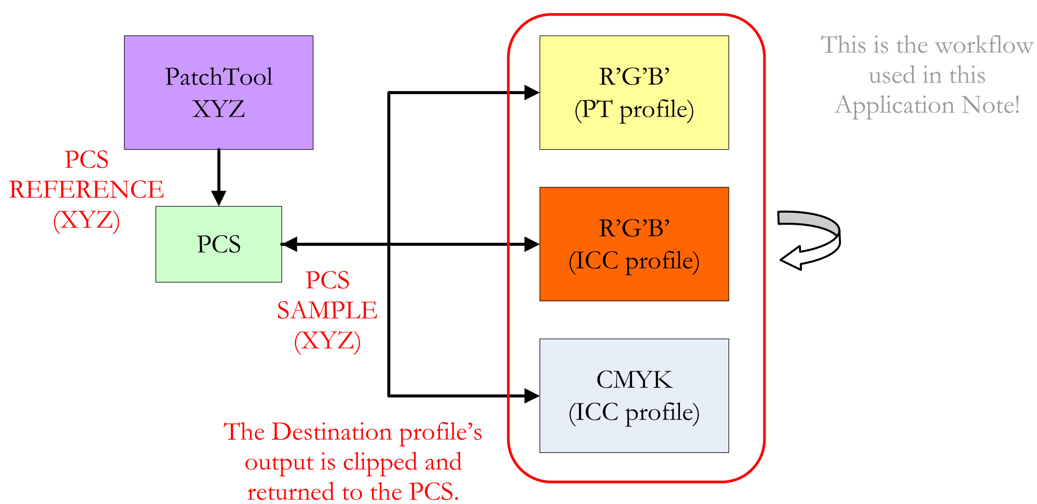
There are two methods to perform a Clip Check in PatchTool; they are illustrated on the next page. The first method starts with RGB or CMYK data and converts it to the Profile Connection Space (PCS, i.e. L*a*b* or XYZ in D50) where it becomes the reference. The PCS data is further converted through the Destination profile, where it may or may not be clipped, and sent back to the PCS through the Destination profile. The returned values are compared with the reference values previously mentioned and both data sets are shown in a PatchTool Compare window, with a statistical analysis of the data sets differences.

The second method, the method retained for this Application Note, "injects" XYZ data directly at the PCS level, without a conversion through a Source profile. This method is useful when the reference data is already defined in a device independent color space, such as spectral data, XYZ, or L*a*b*, as it is the case with the Pantone and IDEAlliance data sets. Like in the first method, the data is converted through the Destination profile, where it may or may not be clipped, and sent back to the PCS through the Destination profile, where it is compared with the initial values.

Clip Check - Method 1
(for RGB or CMYK data files)



Clip Check - Method 2
(for spectral, XYZ, or L*a*b* data files)



Note: As with all procedures involving a roundtrip through a profile, there is a small error due to the imperfect profile conversion tables in each direction (PCS-to-Output, the B2A table, and Output-to-PCS, the A2B table). These Look-Up-Tables (LUT) are not exactly the inverse of each other and even a color which is in-gamut will come back with a small error; this can be noticed in the statistical error distribution, as we will see in the examples.

2. Evaluating the ICC profile coverage

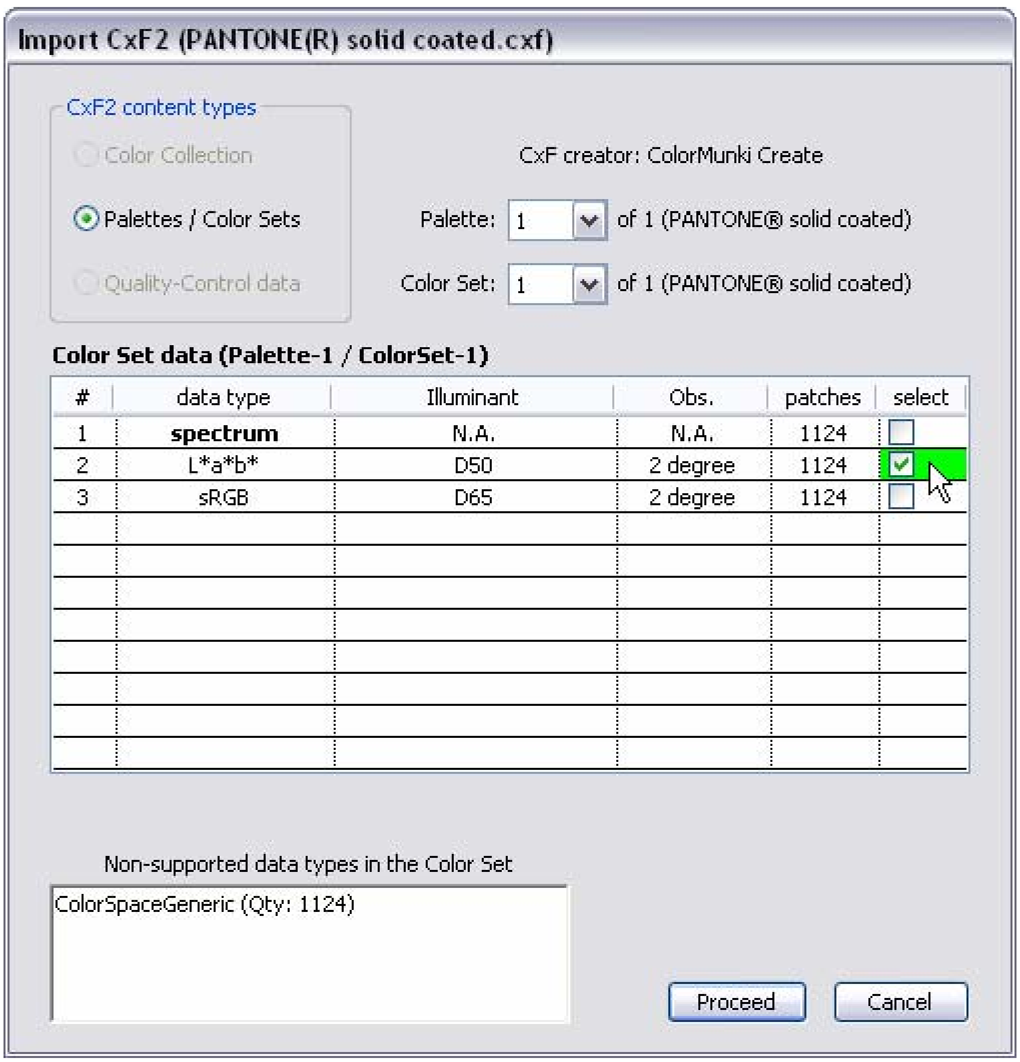
2.1. Example-1: Pantone Coated data set vs SWOP Coated-3 ICC profile

The Pantone data sets are often contained in CxF files, a file format developed and promoted by GretagMacbeth/X-Rite. Two examples for the Pantone Coated data set are:

i- "**PANTONE Coated.cxf**", a CxF Version-1 file which is installed from the Eye-One Application CD provided in some Eye-One packages; look for a "Pantone" installer application.

ii- "**PANTONE(R) solid coated.cxf**", a CxF Version-2 file (CxF2) which can be downloaded from the X-Rite Web site when you purchase any ColorMunki package. This is the file used in the first two examples.

Open the file with PatchTool. A specific dialog will be shown depending on CxF version. The CxF2 dialog shows us all the CxF2 content types and data types found in the file. We see that this file has only one Palette which itself contains one Color Set, and that this Color Set has four data types (spectrum, L*a*b*, sRGB, and data in a generic color space not supported by the program). Since we use XYZ in D50 data for our tests, there is no advantage in importing spectral data; this is why we selected L*a*b* D50 in the screenshot. We could import sRGB but this would not be a good idea because many Pantone colors are outside of the sRGB gamut (this would also impose an unnecessary conversion between D65 and D50). The opened file is shown on the next page.

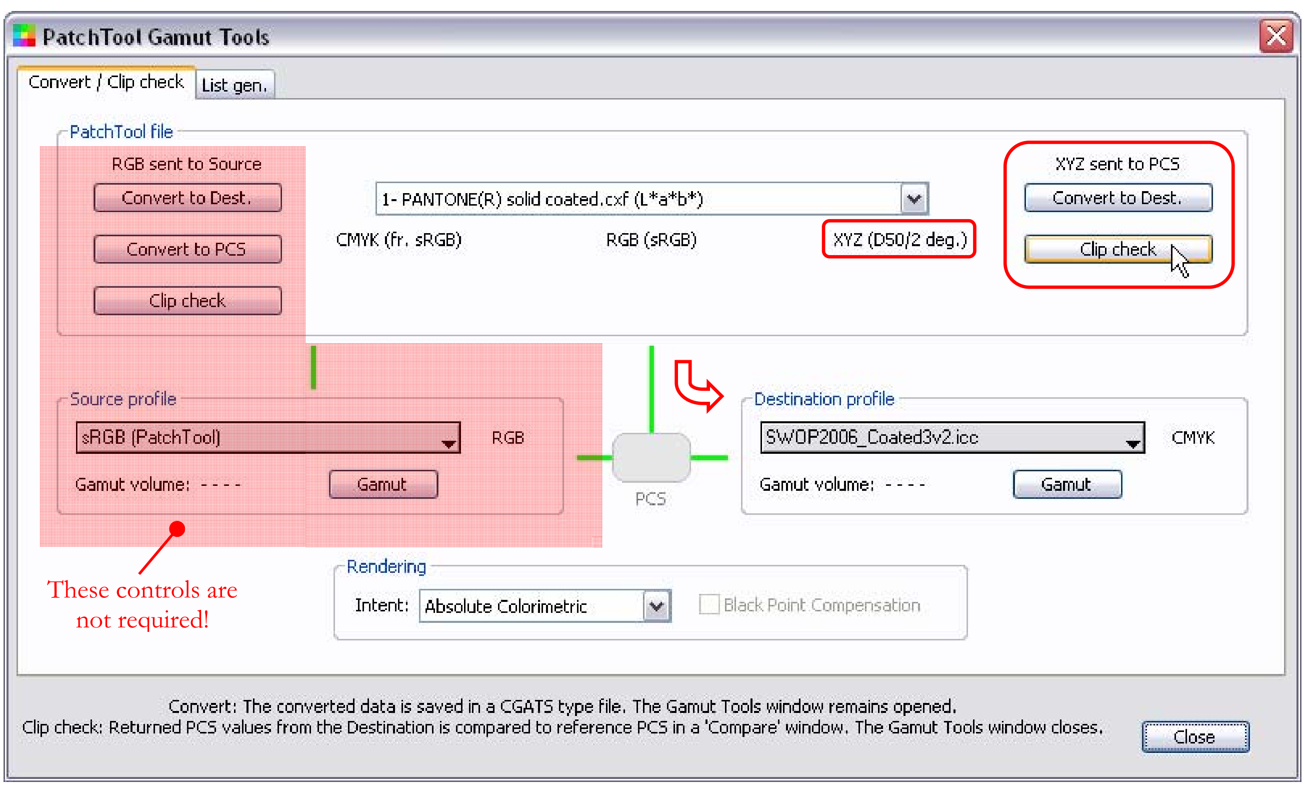


Once this file is opened in PatchTool, we can easily export it in a CGATS compatible text file, or in a text file with minimal overhead that can be opened in a spreadsheet, or even make an image out of it. Here we will go directly to the Gamut Tools and use it as a reference for a Clip Check against an ICC profile.

To open PatchTool's Gamut Tools. Select the "**Tools/Gamut Tools…**" menu or type the keyboard shortcut (**Ctrl + Shift + G** on Windows; **⌘ + shift + G** on a Mac). The tools dialog is shown on the bottom of this page, in reduced size.

For the purpose of this test, we do not use the Source profile which is required in the other Clip Check method discussed in Section 1.2. Thus, we do not need the controls and buttons on the left side of the dialog; this is why they are masked in red.

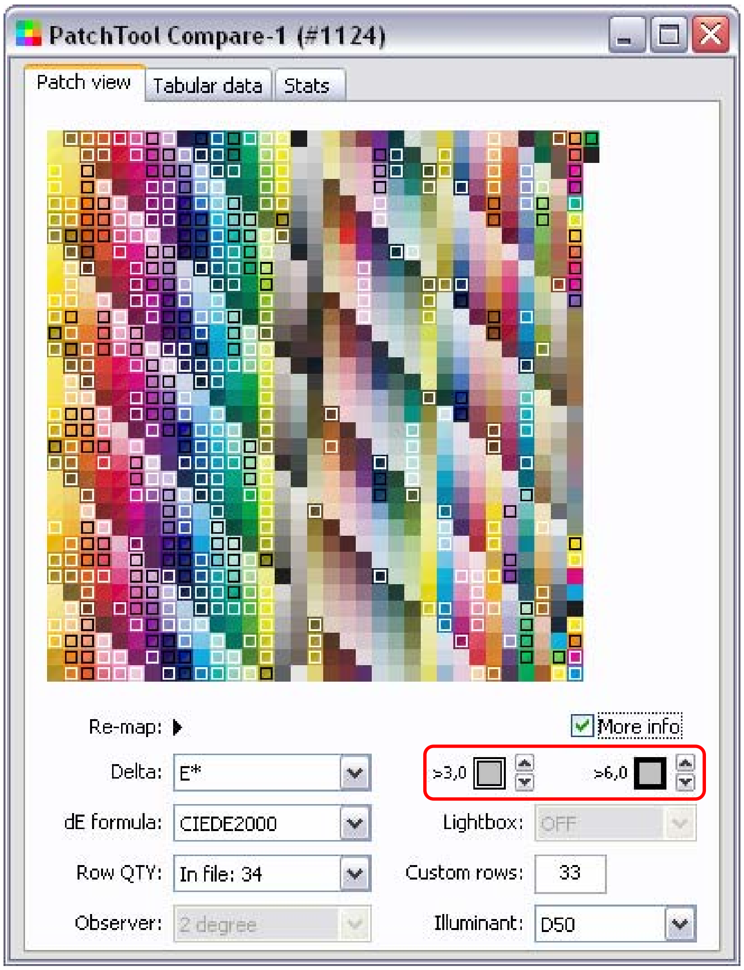
Drag and drop the destination profile, in this case the **SWOP2006_Coated3v2.icc** file, onto the Destination profile popup menu, or browse to the file by selecting "browse…" in the menu.



The profile we selected is the one defined for the **SWOP Coated-3** workflow, typical of standard press work; it can be downloaded from the IDEAlliance Web site. However, you could use the same procedure for any profile.

Select the "Absolute Colorimetric" intent, as we want to see clipping, and not distort the relative position of all colors so that they fit in the destination gamut. You should check that the Illuminant and Observer appearing between parentheses besides the XYZ label correspond to what you want as reference data. If not, you should close the dialog, go back to the file, and change the parameters to **D50** and **2 degree**.

When you are ready, click on the "Clip check" button located on the right, below the "XYZ to PCS" label. Once the check is finished, a Compare window opens.



In the "Patch view" tab of the screenshot above, the thresholds are adjusted so that patches with an error higher than 3,0 DeltaE* (CIEDE2000) but smaller than 6,0 are surrounded by a white border, while patches with an error higher than 6,0 are shown with a black border. We can see that there are quite a lot of patches with large errors, and particularly those with saturated colors. We can select the "Stats" tab to have a numerical assessment of the differences.

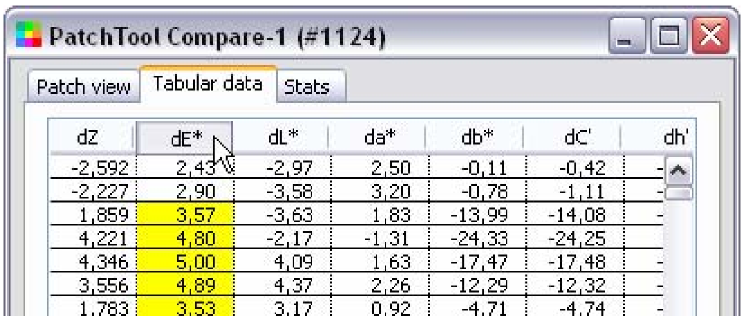
The "Stats" tab shows a histogram where the horizontal axis is separated in "bins" of fixed sizes which are used to categorize the differences; the vertical axis represents the number of patches which fall in each bin. A green line joins the bin values at the bin center, giving an idea of the histogram "envelope" shape. The "CRF" checkbox adds a graph with the *Cumulative Relative Frequency*, which is simply the sum of all the bin values, normalized to 100% for all patches. The CRF graph also corresponds to the "Max error" values shown in the bottom-right of the Stats tab.

The histogram has a sharp peek near zero, corresponding to the patches which are in-gamut, but has a very long and constant tail for patches progressively more out-of-gamut. The CRF curve tells us that about 50% of all

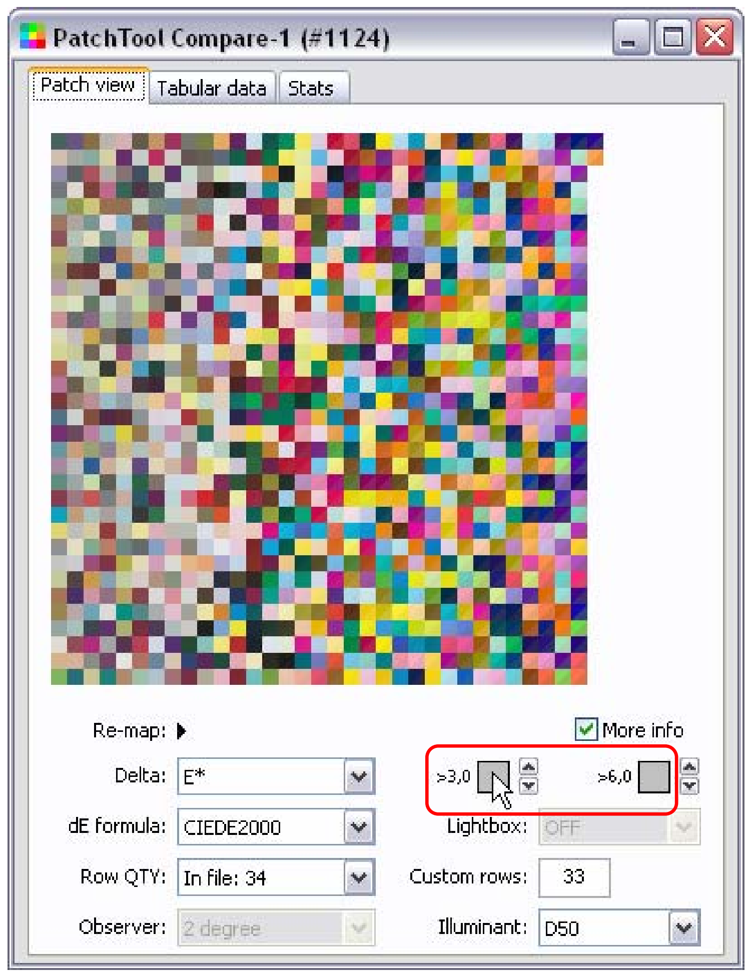
patches have an error of 2,1 DeltaE* or less, which leaves us with 50% of the patches with an error higher than 2,1. This would not be too bad if the CRF curve would go to 100% rapidly, but it ramps up slowly to an error of about 8 DeltaE* at 95% (7,92 to be more precise, if we look at the 95th percentile in the Max error data group), and even more slowly to 13,3 at 100%.

Now, how would you define the Pantone coverage? It depends on your tolerance and sensitivity to errors! There is no magic answer here. You could say for instance that anything higher than a CIEDE2000 error of 2,0 is not acceptable. This corresponds to a CRF of about 50% or, in other words, a Pantone coverage of 50%. This means that half of all Pantone Coated patches cannot be accurately reproduced with the selected profile.

If you want to have a better idea of the actual colors that cannot be printed, you can re-order the patches in ascending order of error; to do this, select the "Tabular data" tab and click on the header of the "dE*" column.



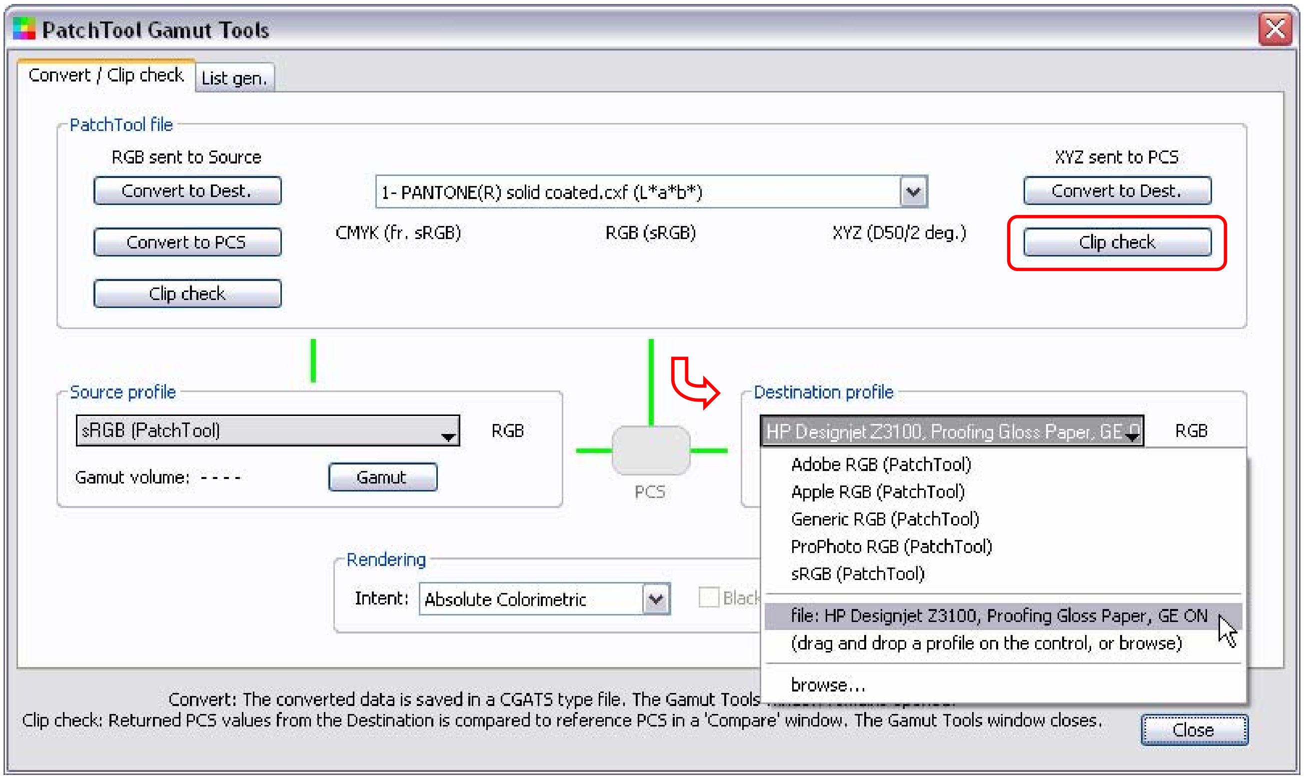
When you go back in the Patch view, you see the patches re-ordered as per the table. To have an even better view of the colors, you can temporarily remove the threshold borders; simply click twice within the small square where the colored border is defined. You will then have the view shown on the right. We see that the problem is particularly acute in the deep blues, light purples, and light greens, and somewhat less important, but still non-negligible, in the oranges and yellows.



2.2. Example-2: Pantone Coated data set vs HP Z3100 Proofing Gloss Paper profile

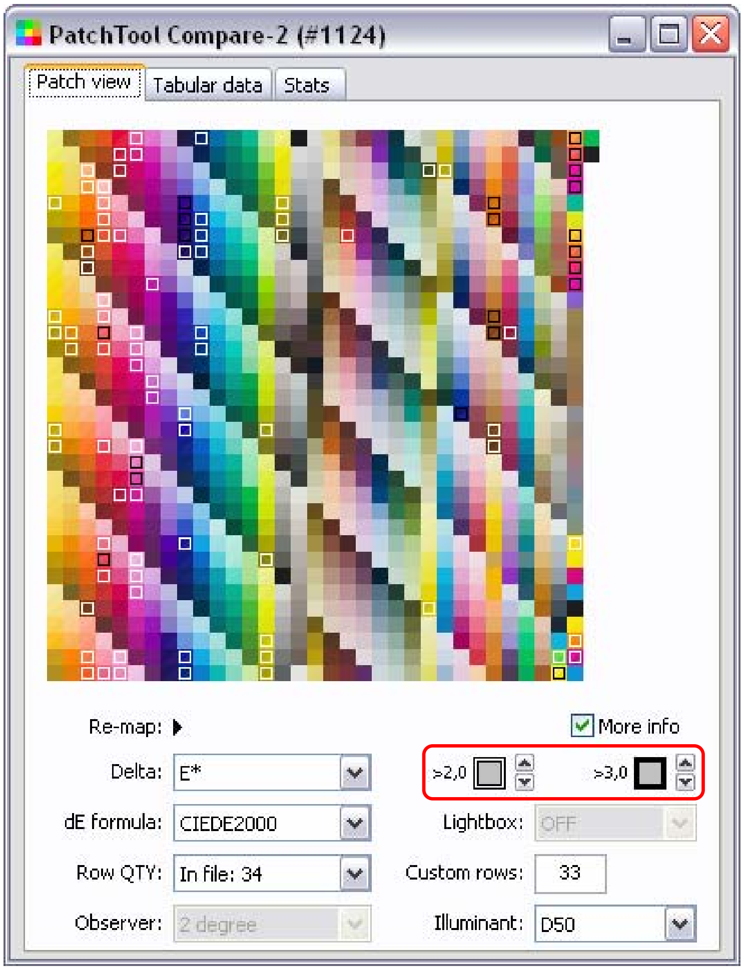
In this second example, we use the same Pantone data set file opened in the first example, but we select a different Destination profile. This profile is for the **HP Proofing Gloss Paper** profiled for the HP Z3100 printer, with Gloss Enhancer. The Z3100 printer is advertised as being able to cover 80% of Pantone colors [1-2]. While no specific paper and profile are provided with the claim, we have selected this paper because it is designed for proofing, where such a specification is important.

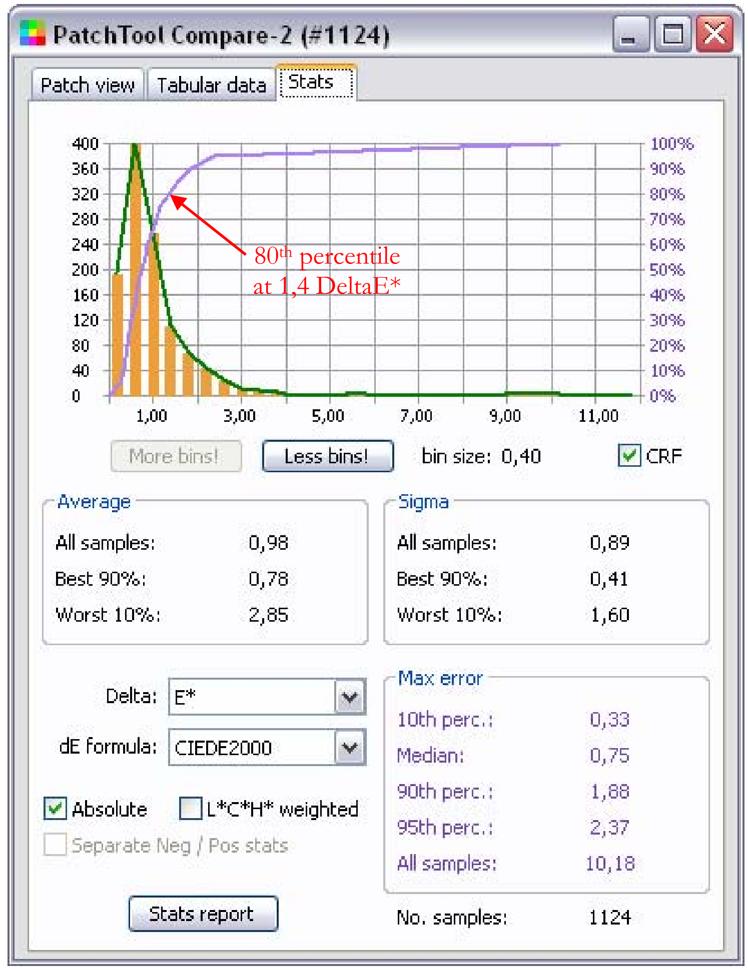
Assuming your Pantone reference file is still opened, you can go back in the Gamut Tools dialog. If required, select the Pantone file in the PatchTool file menu. Drag and drop the new profile you want to test on the Destination profile popup menu. If you do not have the profile used in this example, you should select the profile of another proofing paper you regularly use. When done, click on the "Clip check" button located on the right of the dialog.



The Compare window from this Clip Check is shown on the next page, with screenshots of the "Patch view" and "Stats" tabs.

[1] HP Designjet Z3100 Photo Printer series specification; Ref.: 4AA0-6248ENW Rev. 1, August 2007.
[2] HP brochure of the HP Designjet Z3100 Photo Printer series; Ref.: 4AA0-6247ENW.





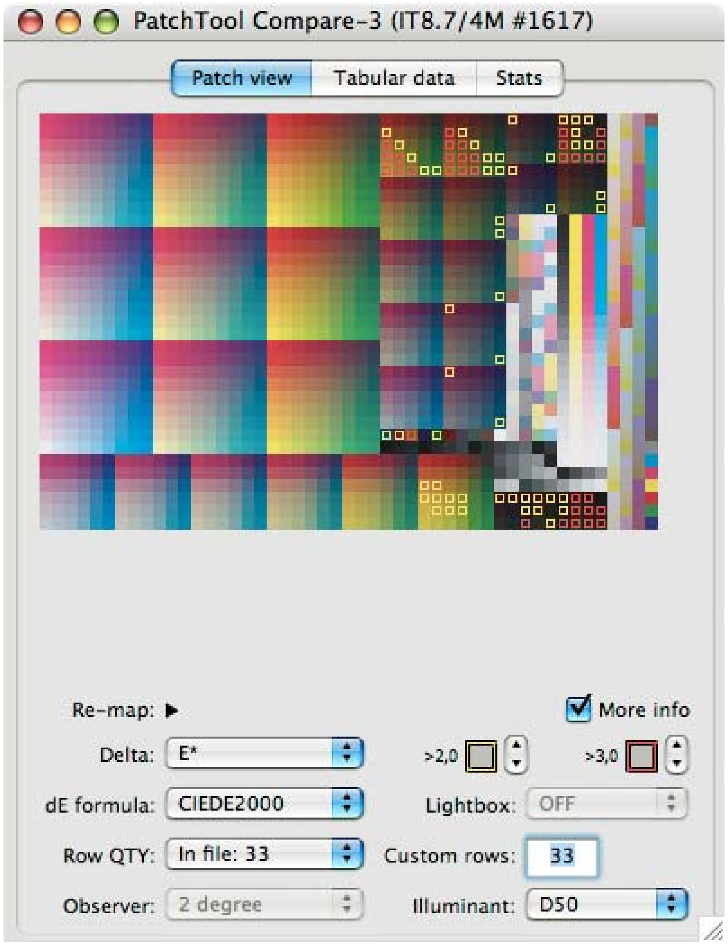
You will note that we have changed the thresholds for the error borders, in order to reflect the better results we obtained. This time, there are only a handful of patches with errors higher than 3 DeltaE* (CIEDE2000). We notice that the errors are located mainly in the saturated blues, light purples, and red-oranges, but that most of these errors are between 2,0 and 3,0 DeltaE*, errors which are much lower than what we saw in Example-1.

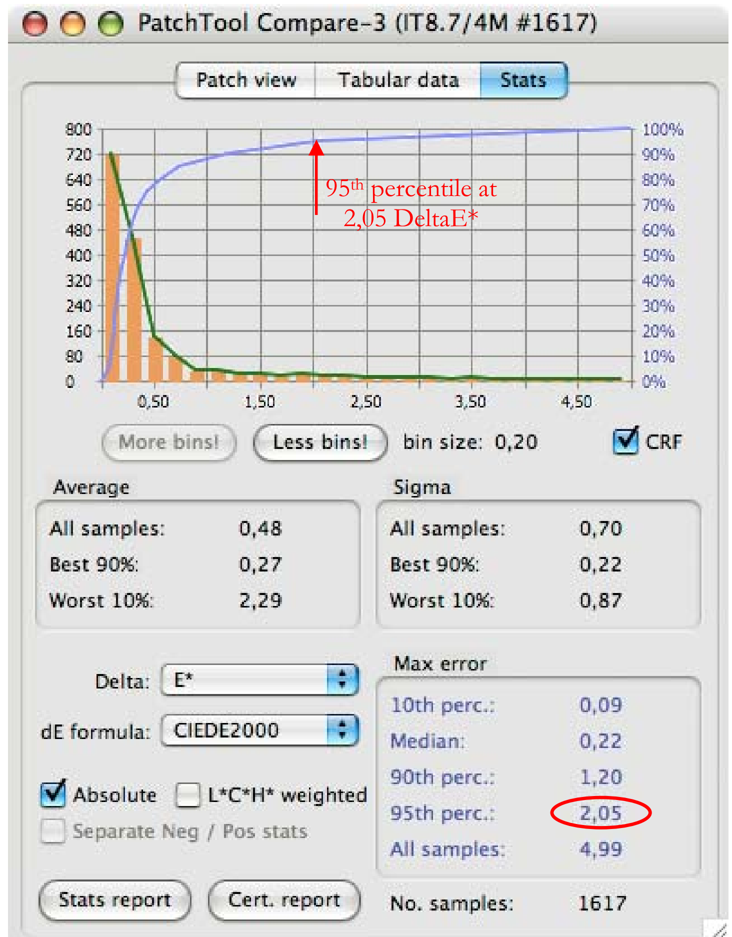
The CRF curve in the Stats tab shows that 80% of the patches have errors smaller than or equal to about 1,4 DeltaE*. This is quite in line with HP's claim of 80% Pantone coverage for this printer! From the CRF curve, we can infer that 90% of the Pantone color set is covered if we tolerate a DeltaE* of 1,88 and 95% are covered for a DeltaE* of 2,37.

2.3. Example-3: IDEAlliance SWOP Coated-3 data set vs SWOP Coated-3 ICC profile

This example uses the "**SWOP2006_Coated3.txt**" reference file that can be found in the "IDEAlliance_files" folder located in the PatchTool application folder. Use the "**File/Open Sample Files/IDEAlliance Files…**" PatchTool menu to get to this folder directly.

Once the reference file is opened, go to the Gamut Tools dialog. Drag and drop the **SWOP2006_Coated3v2.icc** file onto the Destination profile popup menu, or browse to the file by selecting "browse…" in the menu. Here we have a reference file which should, in principle, be perfectly matched to the output profile. The resulting Compare file is shown below.

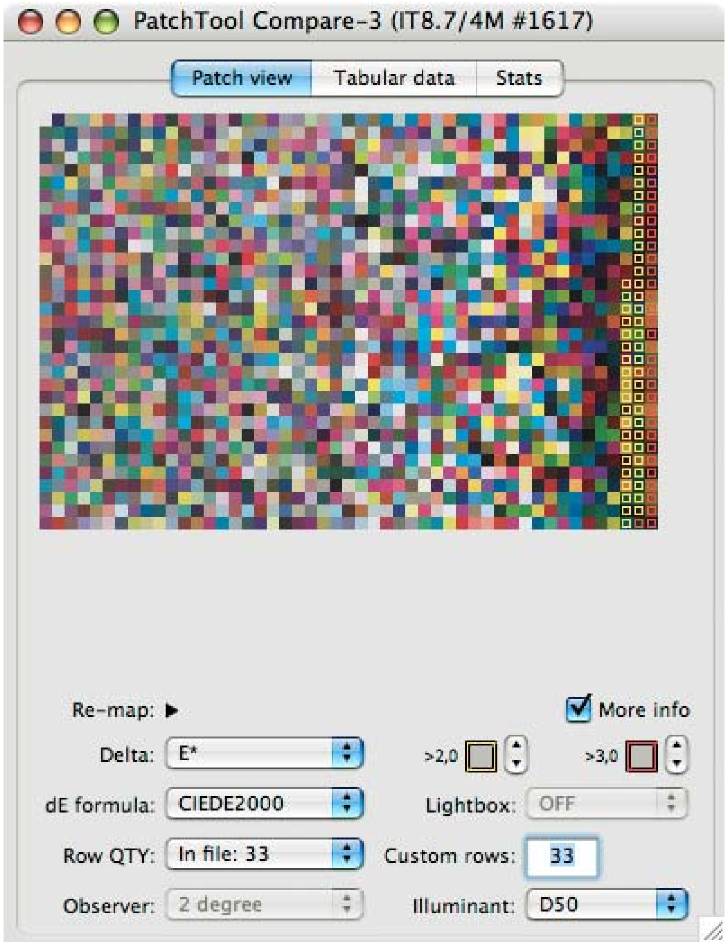


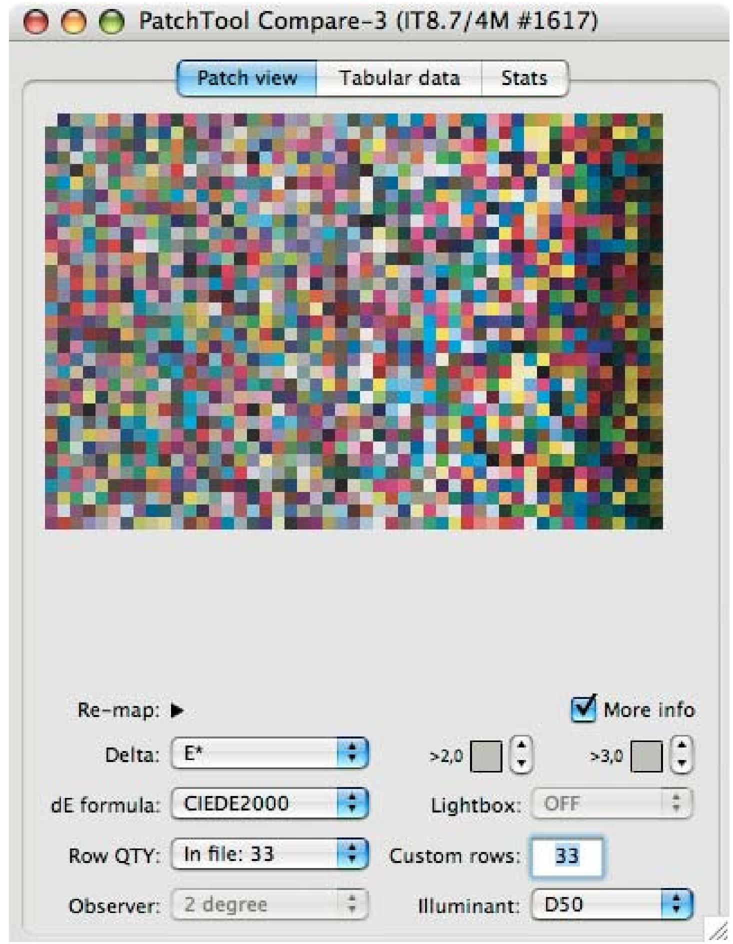


While not perfect as we first expected, the Clip Check is excellent. 95% of the patches show a round-trip error of 2,05 DeltaE* or less, with an average of 0,48 for all patches (with 50% of the patches below 0,22!). Compared to the Pantone data set of Example-1, many errors are found in the darker patches. This is something we have noticed in almost all CMYK profiles, where the PCS-to-Output conversion tables do not match the Output-to-PCS tables for the darker patches as well as they do for lighter colors. In other words, the LUTs correspondence is worse when we have combinations of the four inks. The patches, sorted by increasing error, are shown on the next page.

Does this result indicate that the SWOP Coated-3 reference data cannot be perfectly printed by the SWOP Coated-3 profile? No, it simply points out to a limitation of the profiling technology, which is always a mix of compromises.

Note: From experience, and by observing that a higher error is present in dark patches, we can put more weight in LUT asymmetry than in clipping as the cause of the roundtrip error. However, with a Clip Check, we cannot say if the error is greater going TO or going FROM the PCS; such an analysis is presented in Appendix-A.


PatchTool Compare-3 (IT8.7/4M #1617)
Patch view
Tabular data
Stats
Re-map:
More info
Delta:
E*
>2,0
>3,0
dE formula:
CIEDE2000
Lightbox:
OFF
Row QTY:
In file: 33
Custom rows:
33
Observer:
2 degree
Illuminant:
D50

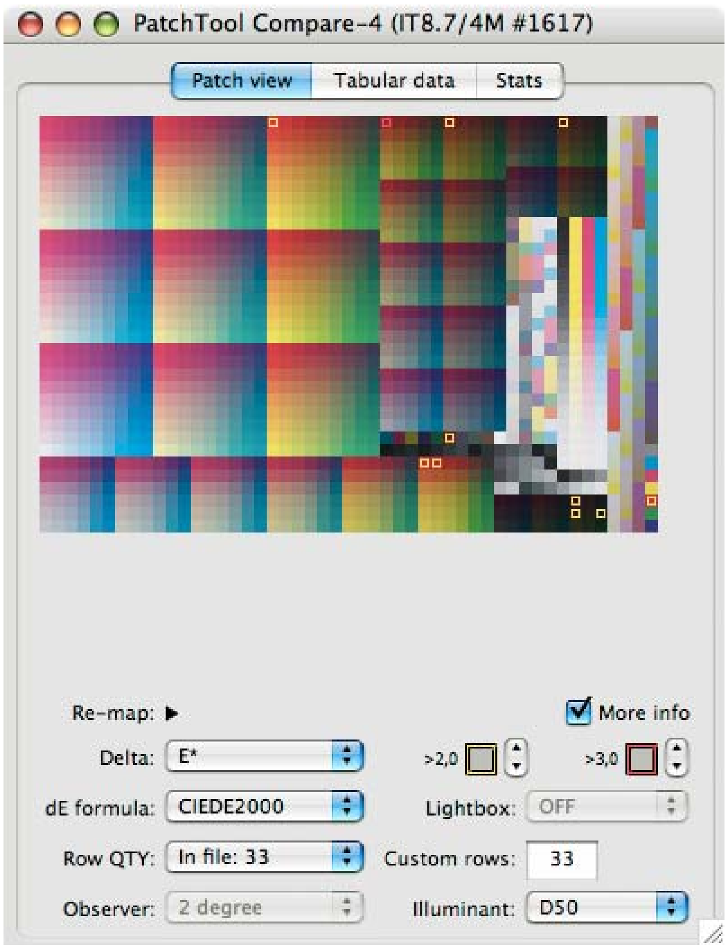

PatchTool Compare-3 (IT8.7/4M #1617)
Patch view
Tabular data
Stats
Re-map:
More info
Delta:
E*
>2,0
>3,0
dE formula:
CIEDE2000
Lightbox:
OFF
Row QTY:
In file: 33
Custom rows:
33
Observer:
2 degree
Illuminant:
D50

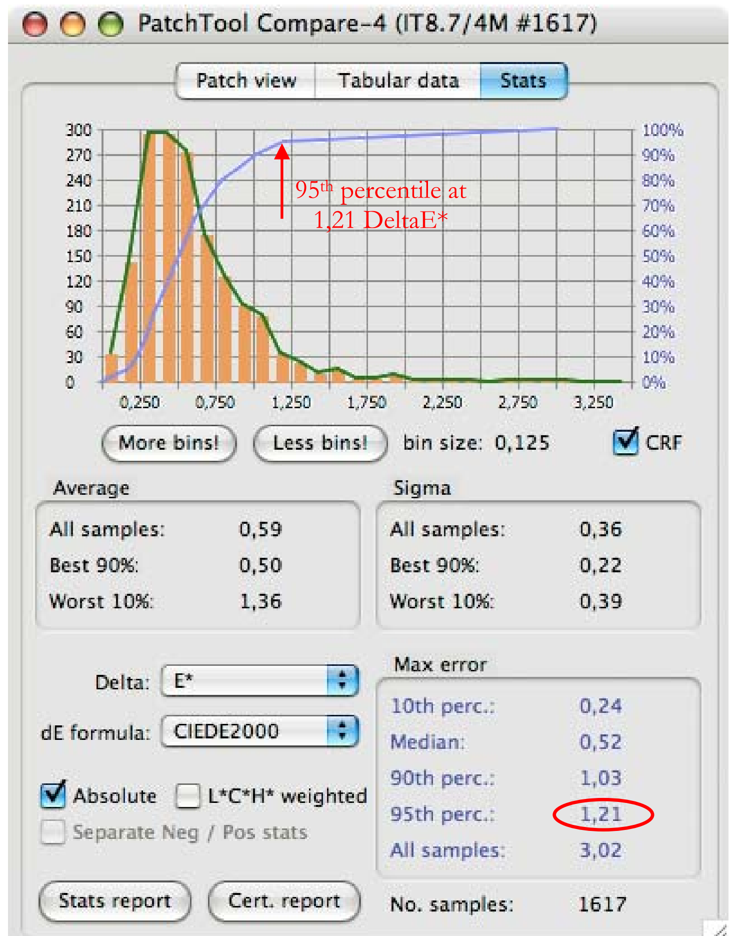
2.4. Example-4: IDEAlliance SWOP Coated-3 data set vs HP Z3100 Proofing Gloss Paper profile

According to the specifications of the HP Z3100 printer (the references are provided in Example-2, Section 2.2), this printer fully covers the SWOP, ISO, GRACoL, Euroscale, Toyo, FOGRA and 3DAP prepress standards. Here we will check how the SWOP Coated-3 reference data is handled by one of this printer's proofing profile.

The reference file is the "**SWOP2006_Coated3.txt**" reference file that can be found in the "IDEAlliance_files" folder located in the PatchTool application folder. Use the "**File/Open Sample Files/IDEAlliance Files…**" PatchTool menu to get to this folder directly. This is the same file used in Example-3 and it may still be opened in PatchTool if you do these tests while reading this Application Note.

The Destination profile is the one for the **HP Proofing Gloss Paper** profiled for the HP Z3100 printer, with Gloss Enhancer; this is the profile we used in Example-2; this is an RGB profile. The Compare file results are shown below.





95% of the patches have a roundtrip error of 1,21 or less, and the maximum error is 3,02. As in Example-3, the patches with the largest errors have darker shades. The average roundtrip error is 0,59, a typical value. From this analysis, one can be confident that the selected proofing profile can cover the selected SWOP gamut.

3. Conclusion

We evaluated how a given press or printer profile covers a reference data set. In the first example where we looked at how well the Pantone Coated data set is covered by the SWOP Coated 3 profile, the results showed us that we can easily detect clipped colors by the shape of the Cumulative Relative Frequency (CRF) graph. In another example, we saw an excellent match between HP's claims for its Z3100 printer Pantone printing capabilities and the Clip Check errors obtained with the Pantone Coated data set against a typical proofing paper profile.

We also saw that the Look-Up-Tables within a profile are not perfectly symmetrical, and that a certain error is associated with a profile conversion. It is important to remember that a profile conversion error does not always happen on the profile edge, but can also be present well within the profile's gamut; this is particularly common for the darker shades within a CMYK profile. It is thus important to make a judgment based not only on a few numbers, but also in the shape of the error statistics, and by a global look on the color of the patches for which we obtained a larger error.

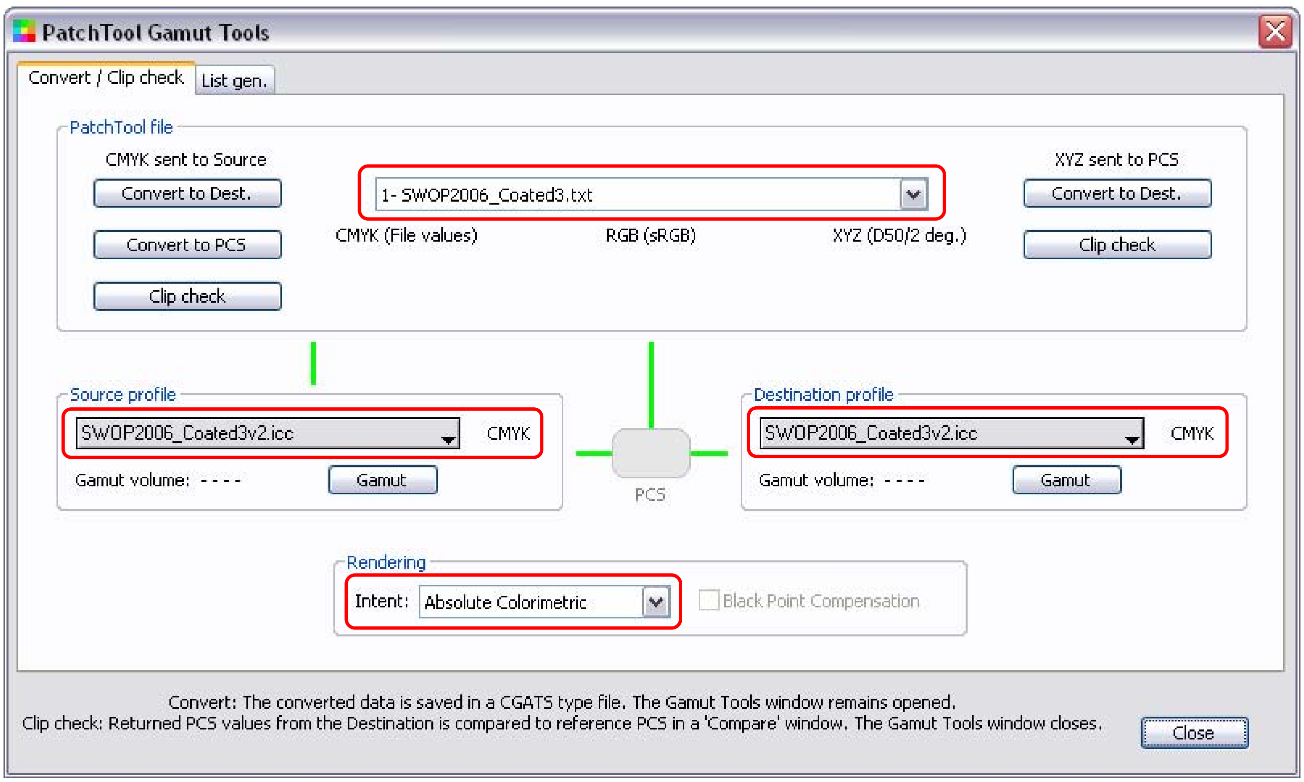
Appendix A

A step-by-step analysis of the Example-3 Clip Check
(SWOP Coated-3 reference data set vs SWOP Coated-3 ICC profile)

In this appendix, we will go through each step behind the Clip Check performed in Example-3. We will also show that profile conversion is not a perfect process and that a profile conversion may be better in one direction than in the other.

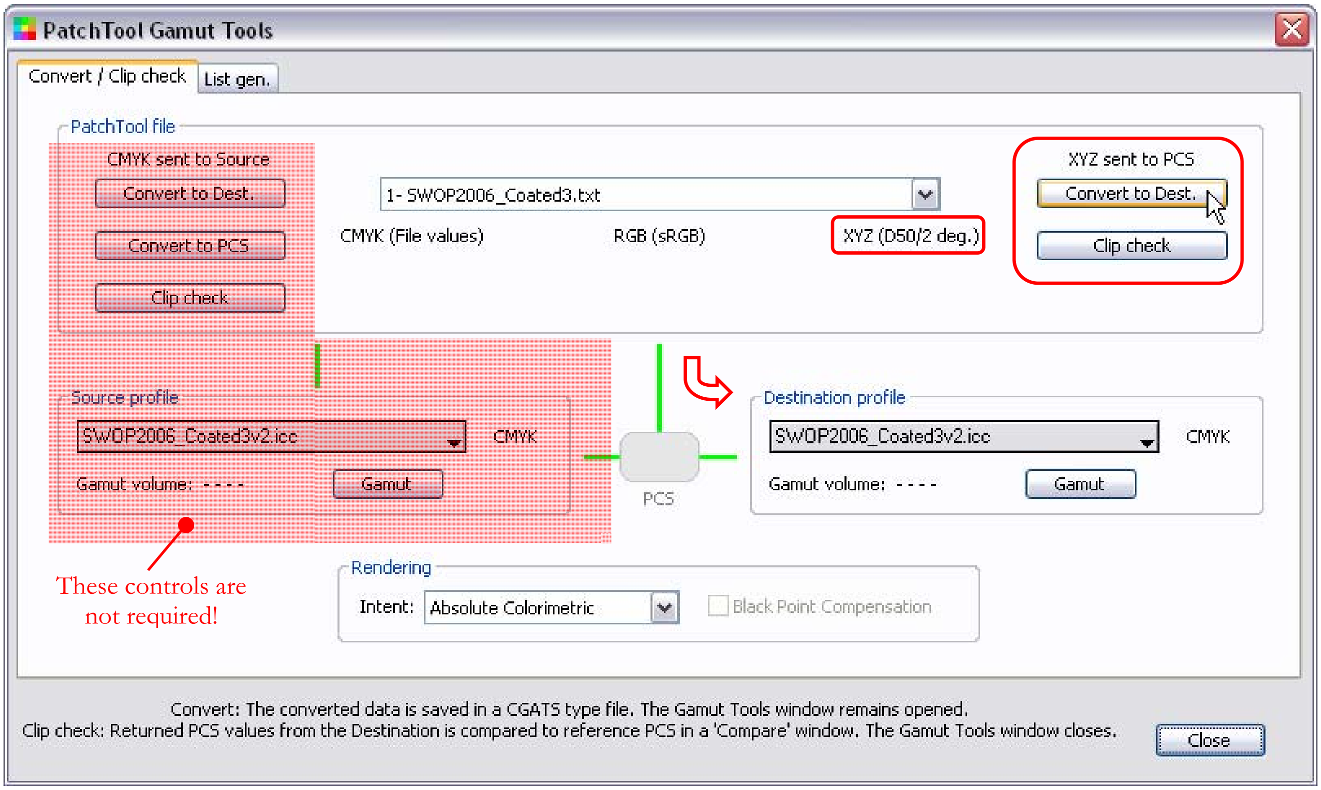
As in Example-3, open the "**SWOP2006_Coated3.txt**" reference file that can be found in the "IDEAlliance_files" folder located in the PatchTool application folder. Use the "**File/Open Sample Files/IDEAlliance Files…**" PatchTool menu to get to this folder directly. Now open PatchTool's Gamut Tools by selecting the "**Tools/Gamut Tools…**" menu or typing the keyboard shortcut (**Ctrl + Shift + G** on Windows; **⌘ + shift + G** on a Mac).

Drag and drop the destination profile, in this case the **SWOP2006_Coated3v2.icc** file onto the Source and Destination profiles popup menus, or browse to the file by selecting "browse…" in each menu. Select "Absolute Colorimetric" as the Rendering intent. The tools dialog should appear as shown below.



In Example-3, we obtained the Clip Check by a single push on the "Clip check" button located on the right of the dialog window; this opened a Compare file where the file XYZ data was compared to XYZ data first converted from the PCS to the CMYK output and then immediately converted back to the PCS. Here we will do it in three steps:

i- Convert the reference file from PCS to CMYK; this will give us a second file (File-2).
ii- Convert File-2 from CMYK to PCS; this will give us a third file (File-3).
iii- Do a Compare between the reference file (File-1) and the last file (File-3).



Click on the "**Convert to Dest.**" Button located on the right, below the "XYZ sent to PCS" label. This will generate the following file:

SWOP2006_Coated3-PCS_to_CMYK.txt .

Close the Gamut Tools dialog and open the file just created.

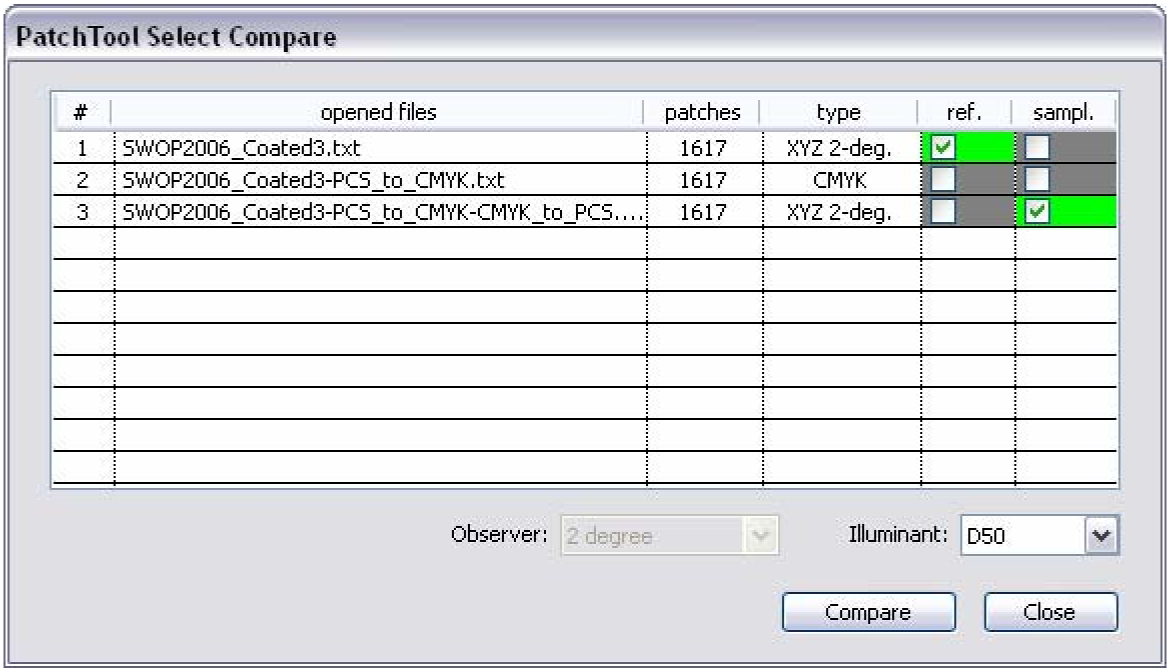
Note: If you look into the **SWOP2006_Coated3-PCS_to_CMYK.txt** file, you will see L*a*b* data presented with "IN_L, IN_A, IN_B" data tags; these are the INPUT L*a*b* values that were converted to CMYK through the profile. They are not presented with the usual CGATS tags (LAB_L, LAB_A, LAB_B) in order to prevent these values to be recognized as equivalents to the CMYK values (i.e. they should NOT be recognized and imported by a color management program).

Important: Since this file only contains recognizable CMYK values, you will be asked by PatchTool to assign an RGB space to the CMYK data when you open it. The converted CMYK to RGB data is used by PatchTool to assign XYZ and L*a*b* values to the CMYK data. This assignment results in very approximate XYZ values, but they are not used in this example. This approximate internal CMYK conversion explains the rather colored patches that you see in the opened file. You can assign any RGB space when asked.

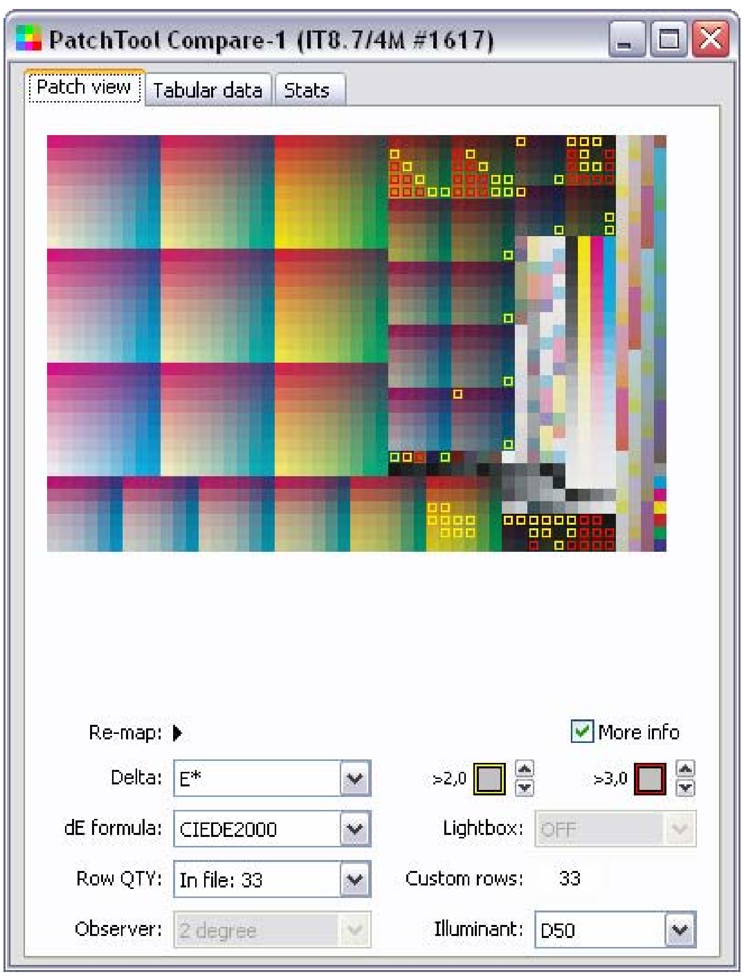
Open PatchTool's Gamut Tools; select the file you just opened, if not already selected. You should notice the "**CMYK(File values)**" label below the file name; this confirms that the CMYK values were imported from the file and not generated from other imported data. This time, click on the "**Convert to PCS**" button located on the left of the dialog. This will generate the

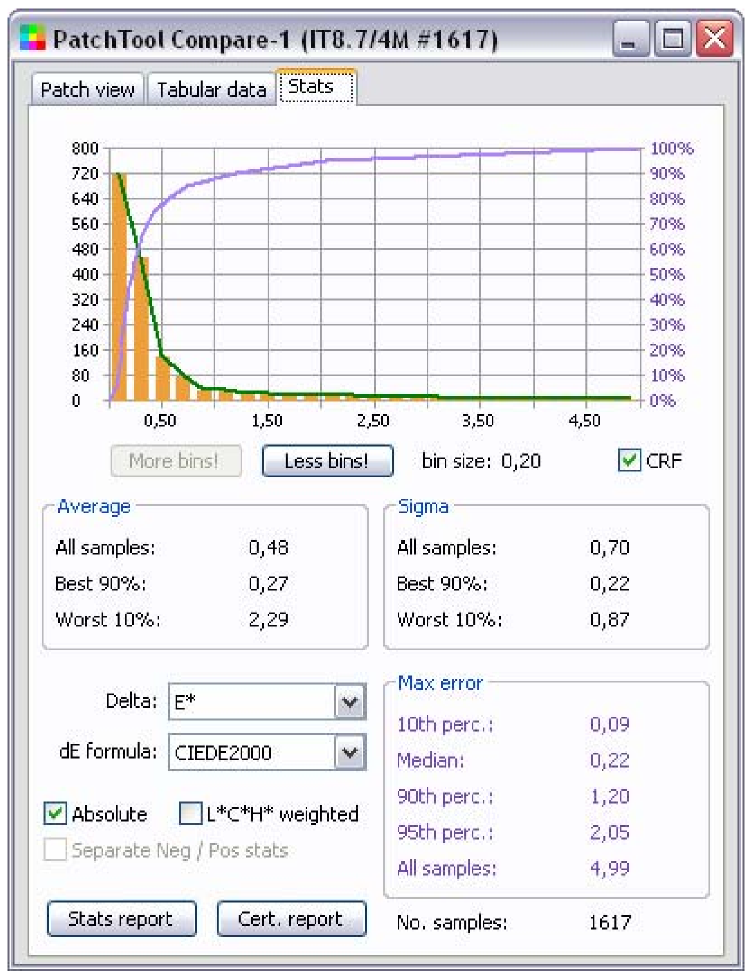
SWOP2006_Coated3-PCS_to_CMYK-CMYK_to_PCS.txt

file. Again, close the Gamut Tools dialog and open the file just created. As the final step, we will compare the reference file with this third file. Open PatchTool's Compare tool by selecting the "**Tools/Compare…**" menu or typing the keyboard shortcut (**Ctrl + Shift + C** on Windows; **⌘ + shift + C** on a Mac). Select the first and third file, as shown on the next page, and click on the "Compare" button.



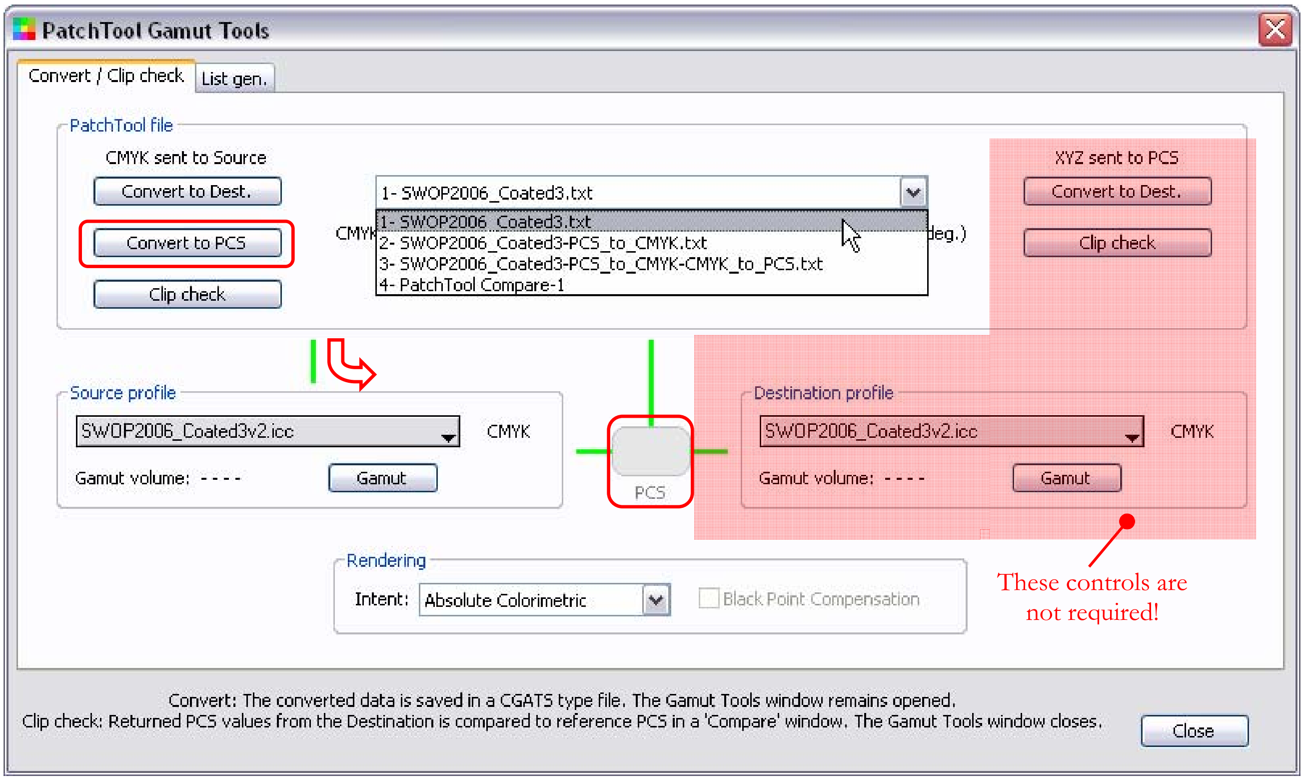
The “Patch view” and “Stats” tabs of the resulting compare window are show below. The results are identical to the ones obtained in Example-3 (You can compare these screenshots with those of Section 2.3). This confirms that a single step Clip Check is the same as doing the three steps procedure.



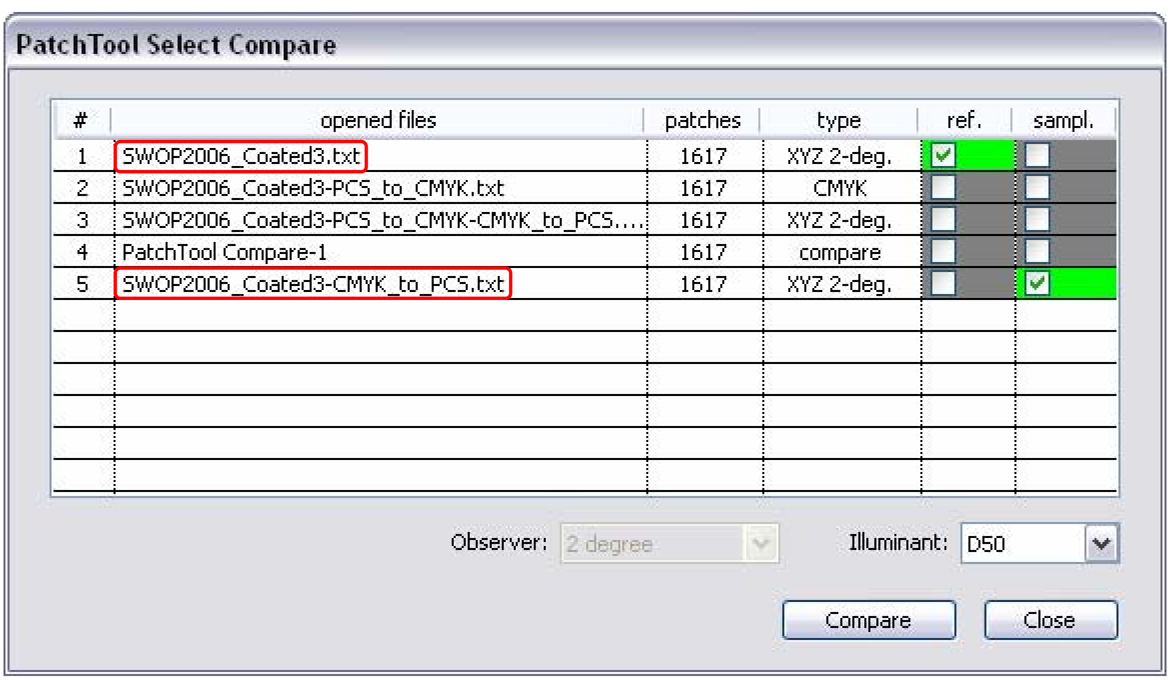


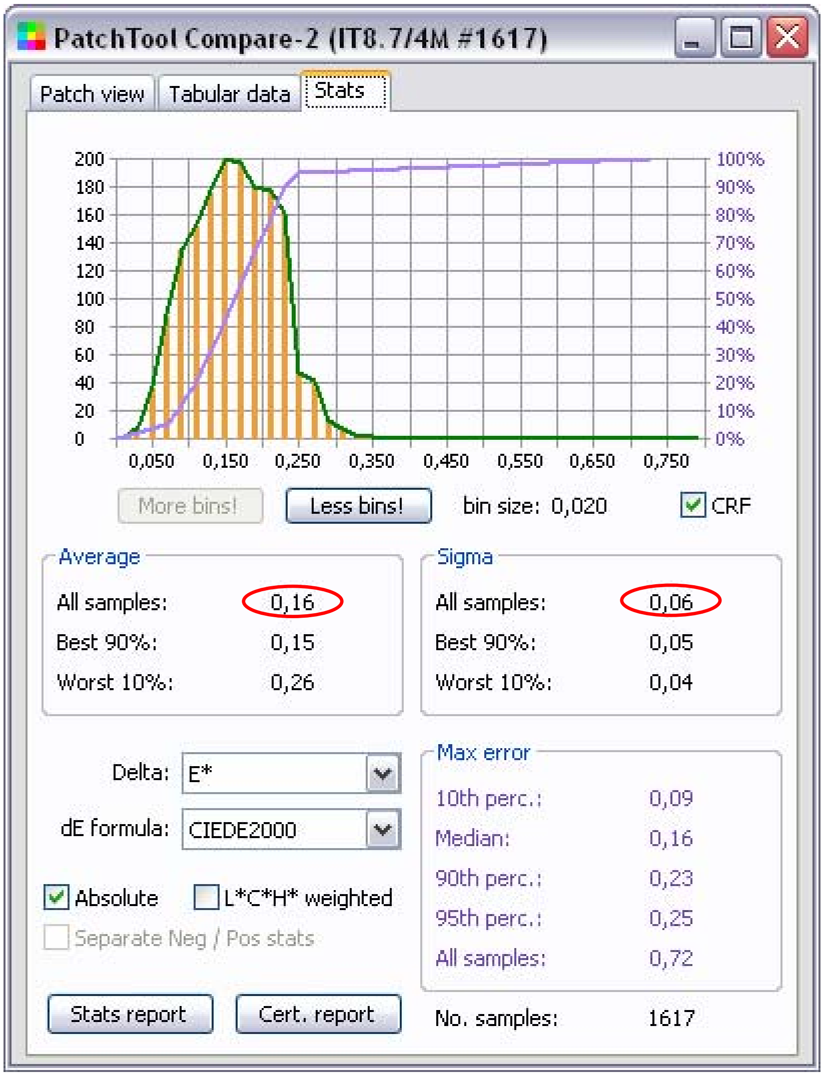
As mentioned in Example-3, the residual errors are likely due to conversions through imperfect Look-Up-Tables (LUTs) and not due to gamut clipping. To better see where the errors come from, we will do yet another file conversion. We will start with the reference file (SWOP2006_Coated3.txt), but this time we will just do a CMYK-to-PCS conversion and compare the converted XYZ values with the reference file XYZ values.

Once again, open the Gamut Tools dialog. Select the reference file, and click on the "Convert to PCS" button.



This should give you a file named **SWOP2006_Coated3-CMYK_to_PCS.txt**; close the Gamut Tools dialog and open this file. Now compare this last file with the reference file using the Compare tool.





As shown on the left, the difference between the reference file and the CMYK-to-PCS converted file is extremely small, demonstrating an excellent correspondence between the profile and the reference data.

By comparing these statistics, where the average error is 0,16 DeltaE* with a sigma (Standard Deviation[3]) of 0,06, with those from a complete roundtrip, i.e. the Clip Check of Example-3, with an average of 0,48 and a sigma of 0,70, we deduce that the PCS-to-CMYK LUT is the one which causes most of the errors we see in this example.

[3] In a random process, you should find 66% of your samples in a range equal to the average plus or minus one sigma.

The BabelColor Company

Founded in 2003, *The BabelColor Company* is dedicated to the development and sale of specialized color translation software and color tools. It also provides color consulting services for the professional and industrial markets.

info@BabelColor.com
http://www.BabelColor.com