Create Scanner/Camera Profile Notes
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Introduction

Using a custom profile helps ensure accurate color and tonal reproduction when you scan photographic prints or transparencies or take photographs with a digital camera.

A custom scanner profile can take the guesswork out of scanning and give you accurate results every time without having to adjust curves or make color corrections.

Custom profiles for digital cameras can help you reproduce color accurately, but to make this work you must use the same lighting and camera settings (exposure, saturation, contrast, white balance, color space etc.) when photographing the test target as when photographing the subjects for which you want to use your profile. This makes digital camera profiles most useful for studio work, duping transparencies, photographing objects or artwork using a copy stand, table top or catalog photography, or other situations where lighting and exposure are carefully controlled.

Profiles are created by scanning or photographing a test target which has a number of color and gray patches each of which has been accurately measured with a spectrophotometer. The RGB values produced by the scanner or digital camera are then combined with reference values for the test target to produce a profile that a color management system can use to convert digital images from your input device to a standard color space.

For a variety of reasons, no test targets are available for color negative film and it is not practical to use color negative film in a color managed environment.

Test Targets

The test target is key to making a scanner or digital camera profile. Picture Window Pro currently supports six types of test targets as described below.

Test targets are fragile and should be handled with care and kept clean. Avoid touching the color patches, keep your target it in its sleeve when not in use, and store it in a safe, dry dust-free location. Do not leave a transparency test target on a light table for any length of time as it may fade.

IT8
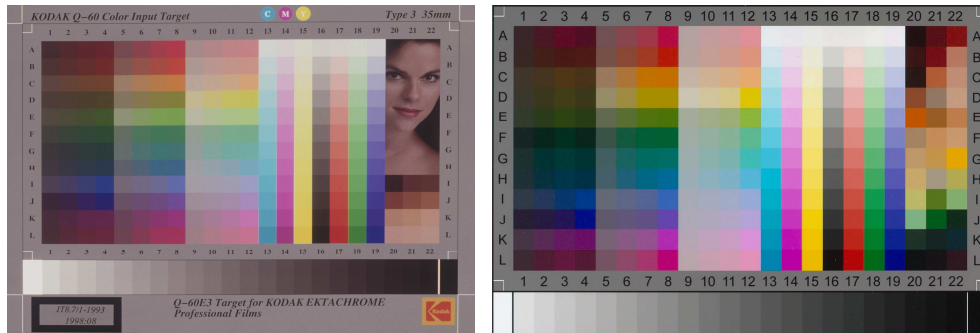
Kodak Q-60   Wolf Faust IT8

IT8 (also called Q-60 by Kodak) test targets have been an industry standard for quite a few years, and are manufactured by several sources including the major film suppliers: Kodak, Agfa and Fuji. They contain a large number of gray and color patches, are reasonably priced, and readily available in both print and transparency film versions from a number of suppliers. IT8 targets generally come with a reference file that contains precise measurements of each color patch made with a spectrophotometer—you will need this reference file to create your profile. IT8 targets are a good choice for profiling transparency and flatbed scanners.

The rightmost three columns of the IT8 target are manufacturer-dependent and are not used in the profiling process.

Original ColorChecker
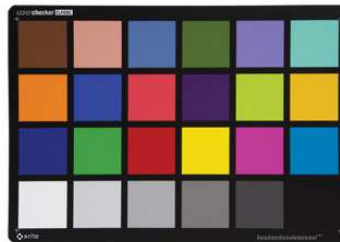
The original ColorChecker has been around for many years. While you can make a scanner or camera profile using it, a target with more color patches will produce better results. ColorCheckers are available in a large 9"x12" version and in a handy miniature version which is very convenient for field work.

ColorChecker SG and ColorChecker DC

ColorChecker SG   ColorChecker DC

The ColorChecker SG (SG stands for semi-gloss) is a target designed especially for profiling digital cameras. One nice feature of this target is that there are redundant white patches around the edges and in the center that can be used to check for non-uniform lighting. The SG replaces the now discontinued DC. The SG also contains an approximate copy of the original ColorChecker color patches embedded just above and to the right of the center.

ColorCheckers are made by applying specially prepared relatively permanent pigments to a rigid cardboard backing. For this reason custom reference files are not required as there is relatively little variation among targets. The rigid backing makes ColorCheckers easier to handle and lets them stand up by themselves. In addition, the pigmented surfaces are less shiny than printed IT8 targets and thus photograph with fewer reflections.

For these reasons, ColorCheckers are a good choice for camera profiling. Wolf Faust also makes a letter-size IT8 target printed on matte paper with a rigid backing that is considerably less expensive than the ColorChecker SG.

ColorCheckers - originally produced by Macbeth - are now made by X-Rite (www.xrite.com) which purchased Gretag after they purchased Macbeth. They are commonly available from suppliers of photographic or prepress equipment.

HCT

The HCT from Hutcheson Consulting (www.hutchcolor.com) is the ultimate test target for high end scanners. It has more than twice the number of patches as an IT8 and comes in a variety of formats and media. Like the ColorChecker SG, it has redundant white patches around the edges and in the center to check for uneven lighting.

Because it has so many patches, even tiny variations in lighting or errors in the reference file can create artifacts in profiles created using this target. For this reason it is only recommended for use with high end scanners, and you will likely get better results profiling digital cameras or consumer/prosumer scanners with an IT8 target.

Digitizing Your Test Target

Before you can create a scanner or digital camera profile, you need to scan or photograph your target. Careful workflow when capturing this reference target image is critical and is a little different for scanners and digital cameras.

Scanners have the advantage that their light source is built in. The light source, in addition to having a carefully selected color spectrum, is generally very uniform across the scanning area. For this reason, you should not need more than one scanner profile. On the other hand, the improvement in color accuracy from a custom scanner profile will in most cases be subtle.

For cameras, there are many possible sources of illumination, each with its own spectral characteristics. A single scene may easily include several light sources such as sunlight, blue skylight, overcast skylight, as well as different kinds of artificial illumination. Adding to differences in illumination are various camera settings which affect the color and contrast of the image, such as the white balance setting. Finally, post-processing such as raw file conversion can greatly affect the way images look.

There are two basic approaches to camera profiling - creating a generic camera profile or creating a special purpose profile tailored to specific conditions.

The idea behind a generic profile is create a single camera profile that provides consistent color from the camera. Using such a profile, images will still look different under different lighting conditions or camera settings. For example a photograph taken under

tungsten lighting or at sunset will look orange compared to the same scene photographed in daylight. Although tricky, creating generic camera profiles is possible, but they have limited utility.

The goal of special purpose profiles is to compensate for the varied effects of illumination, camera settings and post-processing, and to render a scene as it would appear under standard viewing conditions. Applications for this kind of custom profile might be studio portrait or catalog photography, photographing artwork for reproduction, documenting archaeological objects for a museum, medical/dental photography, or forensic photography.

Scanners

Before you start, make sure your test target is clean.

If you are using a flatbed scanner, first clean the scanner glass; if you are using a film scanner, give it a blast of compressed air—this will save time later retouching the image. It is also a good idea to let your scanner warm up as the lighting may change color slightly right after you turn it on.

Set your scanner software to make no automatic adjustments to the color, contrast or brightness of the image. Also, make sure any scanner color management and autoexposure settings are turned off. Scan using the maximum bit depth your scanner supports. Some scanners can produce 48-bit color scans (16 bits per channel) while others, even if they internally scan at more than 8 bits per channel can only save 24-bit color images (8 bits per channel). You will get better results profiling with 16 bits per channel than with 8. Select a scanner resolution that yields at least 1000-pixels across the longer dimension of the part of the image covered by the target. The profile generated from the scan will only be valid for subsequent scans made using the same identical bit depth, color, contrast and brightness settings you use to scan the target, so make sure you record this information for future reference. If you are profiling a transparency scanner, you will get slightly more accurate results if you use a test target made from the same film type you will be scanning. The differences are subtle, but worth taking into account if you want the most accurate possible results.

If you are profiling a flatbed scanner, if you can, place a sheet of black paper, cardboard or velvet behind your test target covering the entire scanner bed. This helps reduce brightness variations resulting from flare light reflected from the white underside of the scanner lid.

Once you have captured a good image of your test target, retouch it as necessary using the speck removal or cloning tools to clean up any dirt or scratches as non-uniformity in the color patches can lead to errors.

Finally save the file in TIFF format with a name that includes the type of scanner or camera, any custom settings, and the date.

Make sure you record any scanner settings that affect the color or tonality of images since you will need to use the exact same settings for subsequent scans if you want the profile to remain valid.

Digital Cameras

Before you start, make sure your test target is clean.

The profile you create will only be valid for the exact lighting conditions and camera settings in effect when you photographed the target. A camera profile created with the correct white balance setting for the light illuminating the test target will however be more or less generic for the camera. Getting a good image from a test target is a lot harder with a digital camera than with a scanner.

When creating special purpose profiles, first set up your lighting and, at the beginning of a session, photograph the target placed where the subject will be located. Then, using the same camera settings photographs your subject. When you are done you will be able to create a profile from the target image to correct the rest of the images.

Here are some of the variables that can affect a camera profile:

Uniform Lighting

The entire target must be evenly lit. Photographing the target under sunlight or an overcast sky is a good way to get uniform lighting. It is harder to get uniform lighting indoors or with a flash. Try to avoid placing the target near bright objects that may be reflecting light onto the target. Due to their spectral qualities, using fluorescent lighting should be avoided if at all possible.

White Balance

When creating a generic profile, the color temperature of the light illuminating the target should be consistent with the white balance setting of your camera. If you use a copy stand with tungsten lights, make sure you use the corresponding white balance setting on your camera. If you shoot outdoors, it makes a big difference if the target it is in the sun or in the shade, if it is overcast, or if it is near sunrise or sunset. Generally raw files are unaffected by a camera's white balance setting so you will need to set the white balance in the raw converter.

Reflections

Avoid reflections from the target. In particular, do not use an on-camera flash as it will produce a hot spot in the center of the image. Also try to place the target where colored light will not reflect onto it from nearby objects.

Distortion

If the image of the target is too distorted, there will be problems reading some of the color patches. A little care when photographing the target will save a lot of trouble later. If necessary, keep the target flat by taping its corners to a flat surface, but be careful not to get tape near any of the color patches. Line up the camera with the target so the image is rectangular, and center the target in the viewfinder. Avoid using wide angle zoom settings as they are prone to barrel distortion unless you are prepared to remove it in subsequent processing. Don't try to fill the frame with the target as this will produce more distortion than using just the central area. This will also minimize any light falloff in the corners of the frame.

Try to get around 1000-2000 pixels across the target. Don't save the image as a JPEG unless this is the only available option. If possible save as a raw file

Exposure

The image of the test target needs to have suitable values for the darkest and lightest patches. The lightest patch should come out slightly darker than pure white and the dark patch a little lighter than pure black. Try bracketing your exposures and select the one that keeps the gray patches centered in the tonal range.

RAW file processing

If you are using raw files, then make sure all the settings in your raw converter are set so as to make as few changes as possible to the image.

Clean-up

Once you have captured a good image of your test target, use the speck removal or cloning tools to clean up any specks in the patches.

Save the TIFF file

Finally save the file in TIFF format (preferably 48-bit color) with a name that includes the type of scanner or camera, any custom settings, and the date.

Creating a Profile

Armed with your target image file, you are ready to create a profile, so start up Picture Window Pro, open the target image, and select *Create Scanner/Camera Profile* from the *File* menu.
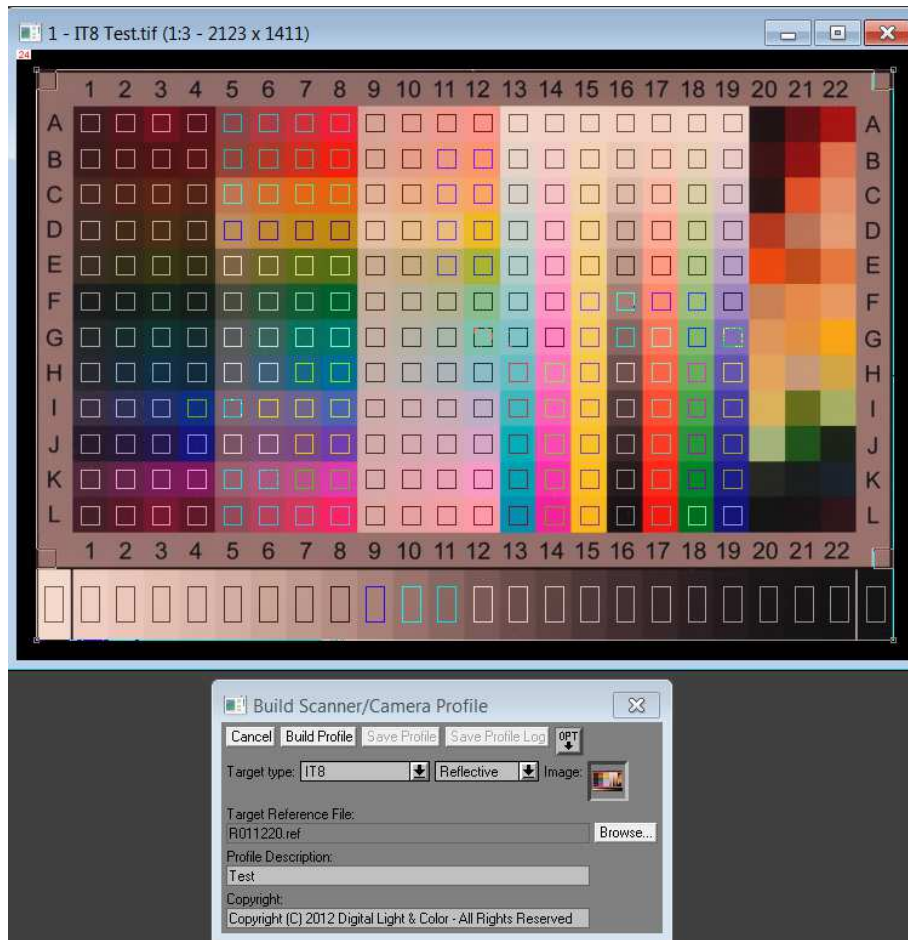
Example with an IT8 target image

Target Type

The Target Type control lets you select the type of target you are using (IT8, ColorChecker SG, ColorChecker DC, ColorChecker or HCT). If you select one of the ColorCheckers, the *Target Reference File* control is automatically filled in as reference files for these targets are built into Picture Window Pro.

Reflective/Transmissive

While this setting does not affect computation of profile data, it does set a flag in the saved profile that indicates if the profile was made from a reflective (paper) or transmissive (film) target.

Advanced Options

Clicking on the *Opt* button displays the options menu. The available options are described in Appendix C. In most cases the best results will be obtained with default settings.

Target Image File

This control selects the image of the target which you captured with your scanner or camera. If a color image was selected when you started the command from the File menu, the image will already be selected. Or you can select it later or change images.

Once you select a target image, an overlay is displayed superimposed on its image window indicating the locations of the gray and color patches. It is important that you select the correct Target Type (see above) so the overlay matches the target image.

Before proceeding, align the overlay with the patches in the target image. You can adjust the overlay by dragging its corners, edges, or its interior.

A target image file must be selected before you can build a profile.

Reference File

If you are using an IT8 or HCT target, click the *Browse...* button and select the reference file for your target. It is important to use the correct reference file. The target should be labeled with a batch or serial number that identifies the corresponding reference file. Picture Window Pro comes with a collection of reference files that were available at the time the software was released, but if you have a more recent target, its reference file will probably not be included. In this case there should either be a reference file that came with the target or you should be able to download one. The following are locations on the internet from which you can download reference files for certain test targets:

Kodak	ftp://ftp.kodak.com/gastds/q60data
Wolf Faust	http://www.targets.coloraid.de
HCT	http://www.hutchcolor.com/HCT_data.htm

By default Picture Window Pro looks for reference files in the following folder:

C:\Users\username\AppData\Roaming\Digital Light and Color\Picture Window\Reference Files

If you copy your reference file to one of the subfolders of the above folder, the *Browse* button will take you to the right place. Otherwise you can simply navigate to the folder where the reference file is located.

Profile Description

The description you enter will be embedded in the profile you create. Most color management applications - including Picture Window Pro - identify profiles by their description and not by their filename, so be sure to enter enough information in the description so you can recognize your profile later. At a minimum you should include the make and model number of your scanner or camera. You might also want to include the date and any special conditions under which the target image was created or the image was processed.

While technically legal within a profile description, using the characters "/", "\" and ":" is not recommended as they are illegal within a filename. When you eventually go to save your profile or profile log, the default filename is derived from the profile description.

You must specify a profile description before you can build a profile.

Copyright Notice

A copyright notice is optional. You may choose to include a copyright notice if you need to establish legal ownership of the profile you are creating or to limit its distribution rights. A standard copyright notice looks like this:

Copyright © YEAR NAME - All Rights Reserved

where *YEAR* is the year the profile was created and *NAME* is the name of the entity claiming ownership of the profile.

Building the Profile

Once you have entered all the necessary information, click the *Build Profile* button at the top of the dialog box to compute the profile and display the results.

If everything is OK, the profile is computed and a summary of the results is displayed on the right hand side of the dialog box.

If errors were detected while computing your profile, Picture Window Pro displays an error message (see Appendix B for a list). The most common problem is misalignment of the overlay or some other problem that makes one or more of the color or gray patches non-uniform. If this occurs, problem patches will be identified with an X on the overlay when you click OK to dismiss the message.

Initially, the results displayed consist of a standard CIE diagram illustrating the approximate color gamut of your scanner or camera as a white triangle. For reference purposes, the sRGB color gamut is also displayed as a dark gray triangle. A small circle is also displayed corresponding to each color patch in the target.

Using the tabs below the diagram, you can switch the display from the scanner gamut to the gamma curves that linearize the scanned data (see below) or to the profile log. It is a good idea to check the gamma curves to make sure they are smooth since kinks in the curves indicate problems with the gray patches in the target. If this occurs, you may want to check one of the Smooth Gamma Curves menu items in the options menu and rebuild the profile. If the target image is clipped, there will usually be some kind of glitch at one end of the curves or the other.

To save your profile, click the *Save Profile* button and select a pathname for your profile. By default, the profile is saved in your system profile folder so it can be used by other programs.

Clicking the *Profile Log* tab displays various useful details about the profile. To save this information as a text file, click the *Save Profile Log* button and select a pathname for your report. For information on profile logs, see Appendix A.

Using Custom Profiles

Once your profile has been created and saved in the system profile folder, it is ready to use. There are two ways to use a profile to color correct images:

The Change Color Profile transformation

The most straightforward way to apply a scanner or camera profile to an image that has been captured under the same conditions and workflow as the target image is to use the *Change Color Profile* transformation. First select the image you want to correct, then select *Change Color Profile* from the *Transformation/Color* menu. Next specify the scanner or camera profile as the *Input image color profile*.

If you are going to process the image further, it is important to convert it to the working color space so its RGB data will be converted to standard values that can be combined consistently with other images. In this case, set *Change* to *Image Data and Profile Setting.* Then select the desired output color space - generally this will be the current working color space as the *Output image color profile*. Click *Preview* to preview the results and click *OK* to complete the operation.

If you are just going to store the file for later use and want to defer the decision about what color space to convert the image to, you can just set the profile without converting to another color space by leaving the *Input image color profile* setting alone and setting *Output image color profile* to the scanner or camera profile. Then set *Change* to *Profile Setting Only* and click *Preview* or *OK.*

Whichever option you choose, you should see a color shift between the input and output images reflecting the corrections made by the profile. The example below shows a photograph of an IT8 target taken on a copy stand with halogen lights (thus the orange cast). On the right is the same image corrected using a custom profile created from the target image.
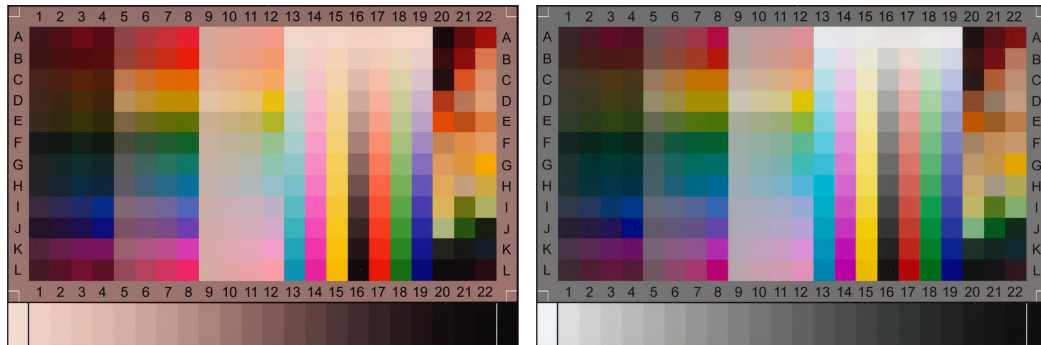
Original IT8 Target Image   Corrected Target Image

Opening raw files

To set a camera profile for opening raw files, first open a raw file from the camera for which the profile was created. In the open raw file dialog box, click on the down arrow button (in the top row of controls) to bring up the raw options menu and select *Advanced Settings* from the drop down menu. Finally, select the camera profile as the *Camera Color Profile*.

Appendix A - How to Read the Profile Log

The profile log is a text file containing detailed information about the profile you just created. The information in the log is organized as follows:

Date -- the date the log was created.

Target Type -- the type of target used to create the profile.

Description -- the profile description.

Copyright -- the profile copyright notice.

Red, Green and Blue Primaries

Estimated CIE XYZ and CIE xy values for the red, green and blue primaries are given. The CIE xy values define the vertices of the gamut triangle displayed in the chromaticity diagram. The white point for scanner profiles is always specified as D50.

The reported primary values are estimates and not direct measurements as there is no way to create a test target with pure red, green and blue color patches—consequently the values may not be accurate and should only be used for making relative comparisons between different scanners. While scanner primaries are included in the scanner profile, they do not affect conversions from the scanner color space to the working color space as this is done using lookup tables.

Dmin and Dmax RGB values

These are the measured RGB values of the darkest and lightest gray patches in the target on a scale from 0.00% (black) to 100.00% (white).

For scanners, the Dmax value should be a little above 0.00% and the Dmin should be a little below 100.00%, indicating that none of the gray patches has been clipped. Since the darkest patch generally reflects (for flatbed scanner) or transmits (for a film scanner) some light, its measured value will usually not be 0%. Similarly, the lightest patch will absorb some light and its measured value will not be 100%. This is perfectly normal and not a cause for concern. If you are seeing values of 0% or 100%, this means that you are losing some shadow or highlight detail and need to rescan.

For digital cameras, the situation is more complicated since an outdoor scene may include deep shadows that are darker than the darkest target patch or highlights lighter than the lightest patch. For studio photography, this should be less of a problem as the range of densities of the target should be representative of subject brightness values.

White, Gray and Black RMS Non-uniformity.

These are measures of the variability of the redundant white, gray and black patches scattered around the target (ColorChecker SG, ColorChecker DC and HCT only). Values greater than 5% to10% indicate uneven target illumination.

Gray and Color Uniformity, and Delta E

These tables list the RMS uniformity, and Delta E for each gray and color patch in the target.

If the uniformity error for a given patch is large (> 5%), this indicates that the image of that patch may be noisy, stained, include specks or be uneven for some reason.

The regression error indicates how far the measurement of a given patch differs from the predicted value based on the regression model. A large number (> 5) may indicate some nonlinearity in the scanner, a problem reading the patch, uneven target lighting, problems with the spectral properties of the scanner light source, or simply an inconsistency between the target and the reference file. These inconsistencies can arise from variations among individual targets in a batch, aging of the target, dirt on the target, or abrasion of its surface. In some cases, regression errors are reduced considerably when creating a custom reference file by measuring all the patches with a spectrophotometer, or by using a different target with a more accurate reference file. This means that errors may be a result of target inconsistency and not scanner nonlinearity. For this reason, *Eliminate All Residuals* (see Appendix C) is turned off by default since there is no point in modeling errors in the reference file. If you are using a custom measured reference file, you may want to select *Eliminate All Residuals* to increase the accuracy of the profile. In this case, Picture Window Pro still reports the regression errors from the regression model even though these are all reduced to zero in the final profile.

Even if your target has a few regression errors in the 5-10 Delta E range, this does not mean there is anything significantly wrong with the profile your created as the regression process averages the response over all the patches and normally still produces very accurate results even if a few errors are large.

Errors larger than 10-20 Delta E may indicate a some kind of problem with the input image, reference file, target or scanner.

The Delta E values represent the color differences between the values predicted by the regression model and the reference values expressed in standard CIE Lab ΔE units.

Appendix B - Error Messages

This section lists error messages listed alphabetically and explains what they mean and what you can do about them.

Cannot profile negative images

If the brightness of the gray patches is reversed, then likely you are attempting to create a profile using a negative image which is not supported.

Illegal reference file: <pathname>

Before reading a reference file, Picture Window Pro does a few tests to see if it is a valid file and that it was made for the type of target you have specified.

Non-uniform target illumination detected

Some targets include redundant white, gray and black patches in various locations intended to be used as a check for non-uniform target lighting. Picture Window Pro examines these patches and issues this warning if it finds significant variation among these extra patches. If you are profiling a digital camera, this may indicate that the target was unevenly lit when you photographed it. If you are profiling a scanner, it may indicate that the scanner light source is not uniform over the scanning area.

One of more gray patches not in increasing brightness order. Target lighting may be uneven.

Picture Window Pro examines the gray patches in the target to make sure the measured brightness of each progressively lighter patch is higher than the previous patch. If any of the values is out of sequence, this may indicate that the target was unevenly illuminated or the target image is noisy. For targets such as the HCT which has many very closely spaced gray patches, this is not uncommon. If you are getting this warning, try selecting one of the Smooth Gamma Curves options in Advanced Options (see Appendix C) to reduce noise in the gray measurements.

Regression error

The regression process performed to model the scanner's response has failed. Normally this means there is a serious problem with the target image file or the reference file. If both files are OK, you can try changing to a different regression model (see Appendix C).

Some gray or color patches are non-uniform. Bad patches will be identified with an X when you click OK.

Picture Window Pro samples the central part of each color patch at 441 different points and averages the results. It also computes the standard deviation of the measurements and displays this error when that values exceeds a preset threshold. Generally patches may be non-uniform if the target image has dust specks or if the image is unusually noisy. If the image is basically OK, you can increase its uniformity by applying a median blur to it or by using retouching tools to clean up the image.

Appendix C - Advanced Options

This section describes the options available in the options menu.

Regression Type (Linear / Quadratic / Cubic)

Picture Window Pro can perform linear, quadratic or cubic regression to model the behavior of the input device. If the test target has a sufficient number of color patches and the reference file is accurate, cubic regression will produce the most accurate results. The ColorChecker target has too few patches to perform cubic regression. When this target is selected, quadratic regression is used if you specify cubic.

Residual Handling (Eliminate All Residuals)

Normally a profile's color lookup tables are generated by using a linear, quadratic or cubic model of the response of the scanner or digital camera. In most cases, the regression model, especially cubic regression, closely approximates the measured color response. You can check how well the model fits the data by looking at the Delta-E errors in the profile log. If all or nearly all the values are small (mostly less than 2.0-3.0 possibly with a few outliers less than about 5.0), the regression model is an good fit to the measured data. If some values are larger, this means that the values in the reference file are inaccurate for the target or that the scanner or digital camera has characteristics that are not accurately modeled.

When you select *Eliminate All Residuals*, Picture Window Pro applies a nonlinear model to the residual errors from the regression model when creating the profile. This distorts the color lookup tables in the profile so they precisely match all patches in the target to their corresponding reference values, but can introduce artifacts in the profile if the regression errors are due to inconsistencies between the target image and the reference file or if you are using a target with a small number of patches.

Smooth Gamma Curves

When *Smooth Gamma Curves* is selected, the sequence of measured gray patches is smoothed. This can be helpful in reducing wiggles in the gray curve that can occur if you are using a target such as the HCT that has many closely spaced gray patches. Select the smallest amount of smoothing (None, Light, Moderate, or Heavy) that produces a curve without kinks. Smoothing is not recommended for targets such as the ColorChecker that have a small number of widely spaced gray patches.