PressCal Software

OPTIMAL ⌘ METHOD

USER MANUAL – Version 17U

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A Universal Calibration Tool

PressCal is a powerful tool for analyzing and calibrating a color printing process. PressCal uses standard mathematical techniques employed by scientists and engineers, to make perfect calibration curves by any method – **Optimal, TVI, G7** or **SCTV,** for any printing process. It's the best print calibration tool available, and it's free.

We (the authors) are practicing print consultants. We developed PressCal based on our real world experience. We like our consulting work, and don't want to be in the software business. Our business model is very straightforward. Our software tools are free. If you want our help using them, we charge for that.

Version **17U** adds many new features and refinements.

Change List

- recompiled Perl XS modules as **universal bundles** (x86_64 and arm64e) for Perl versions 5.30 and 5.34.
- modified PressCal's TextMate commands to run PressCal (versions **17UV** and **17US**) in the native machine mode (arm64e on Macs with Apple Silicon).
- added the **Optimal+** basic setting.
- added the **`blend_sctv:`** setting, enabling the **Optimal+** calibration technique.
- improved application of curves to ICC profiles, now controlled by the **`adjust_profile_path:`** setting.
- added identification and removal of bad samples for ramp-based curves using the **`minus`** selection token.
- added the **`natural:`** setting, which adds optimization constraints to keep curves straight in the shadow region.
- added the **`udf:`** setting which enables a user-defined function to compute color differences.
- added **`onyx`** output method to write Onyx linearization files.
- improved the automatic determination of curve degree for ramp-based curves.
- improved the naming of output files and folders, and made the hash keys consistent for all output settings.
- modified the **`plate_curve_path:`** setting to support hash parameter, and mapping of plate curves.
- added Onyx support for **`plate_curve_path:`** setting.
- plate curves, which previously modified the press measurements, are now combined with normally generated curves, improving accuracy.
- added graphs for the combined tone and plate curves.
- fixed an obscure bug in the graphing of optimization errors.
- added many data checks and messages to help identify and fix settings errors.

We're now developing ideas for the next version of PressCal. If you have suggestions or requests, please contact us.

Bill & Chuck

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Quick Start (Mac OS)

PressCal Software
PressCal is an open-source software program. It is written in the Perl programming language, and utilizes the Color Tool Kit. The Color Tool Kit is a set of object-oriented modules that extend the Perl language to include color management capabilities.

TextMate Editor
PressCal is a command-line program and, as such, has no GUI (graphical user interface). The user interface is a text editor called TextMate, which provides a convenient way to install and run the software. PressCal is supplied as a TextMate bundle, which contains a compiled version of the Color Tool Kit, and other required components. The bundle also contains software to run PressCal from within TextMate.

Web Browser
Graphs are displayed as tabs in your default web browser. We suggest using Firefox because it will create new tabs each time you run PressCal. This allows you to compare the results from different program settings by selecting tabs.

System Requirements
A Macintosh computer running macOS 14 (Sonoma) through 26 (Tahoe). (A version is available for maOS 11 (Big Sur) through 13 (Ventura)). Apple and Intel processors are supported natively.

Installing PressCal
You may need admin privileges to install the TextMate app. The PressCal bundle doesn't require admin privileges. *Skip to the section below if you're* ***updating.***

1. Download, install, and run the TextMate 2.0 editor.
2. Download and mount (double-click) the PressCal_17US (.dmg) disk image.
3. Double-click the **PressCal.tmbundle** file to install the software.
4. Copy the **PressCal_Basic_Settings** folder to a convenient location.
5. Eject the **PressCal_17US** disk image.
6. Open the copied **PressCal_Basic_Settings** folder in TextMate.
7. Select the **PressCal_Default.yml** file in the TextMate file browser.
8. You will be asked to allow the YAML bundle to be installed. Do this.

Updating PressCal
If you installed an earlier version of PressCal, you must remove that version before installing the updated version. We've provided a shell script to do this.

1. Download and mount (double-click) the PressCal_17US (.dmg) disk image.
2. Run the **Uninstall_PressCal.sh** shell script to remove the current software. Open the script in TextMate and enter the command ⌘**R** to run it.
3. Double-click the **PressCal.tmbundle** file to install the updated software.

Preliminaries

Basic Settings

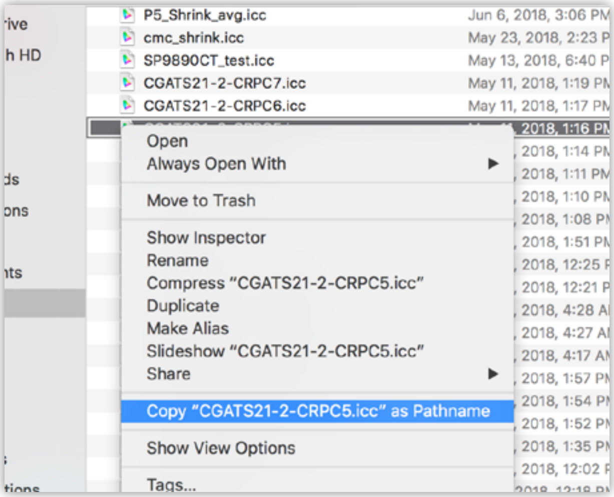
PressCal includes a collection of Basic Settings files, which you copied during installation. These files are opened in TextMate and modified with your data and preferences. The PressCal software is then run using the command keys **⌘I** (grade), **⌘B** (ink balance), or **⌘R** (curves).

Comments

A **#** character is the start of a comment, which is ignored by the software. In TextMate, comments are colored blue, while active lines are colored green. Inserting a **#** at the start of a setting line disables it. We say these settings are "commented out." The software will use its default value for a disabled setting. Deleting the leading **#** will enable a setting that was commented out.

File Paths

Files and folders are selected by their path. A path is a text string composed of the item name and the folders containing it. For instance, the path to your Desktop folder looks like this **`/Users/myusername/Desktop`**. You may drag files and folders into the settings file when opened in TextMate. This inserts the file path into the settings at the location of the cursor, which follows the dragged item.



Alternately, you can copy the path to a file or folder by right-clicking on it, then pressing the option key. This will open the contextual menu. Choose the menu item, **Copy "xxx.yyy" as Pathname**. Then paste the path into the PressCal document.

Note: If your path contains any **#** characters, they will be interpreted as comments, and your path will be truncated, causing an error. To fix this, insert a **** character before each **#** in the path.

Shortcut Paths

A file path may begin with a **~** which is a shortcut for the user's home folder. For example, the path to your desktop is **`~/Desktop`**.

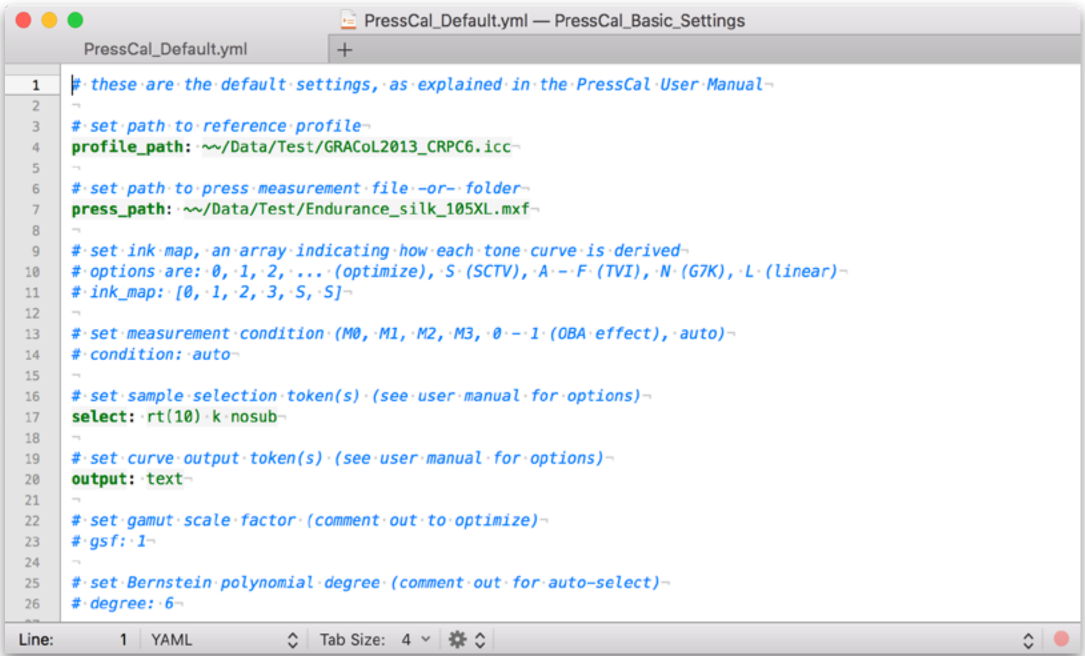
PressCal includes a large assortment of [built-in data], for your convenience. This data is located in the PressCal bundle, buried deep within the user's Library folder. You may use the shortcut **~~** to access this built-in data. For example, the path to a commonly used profile is **`~~/Data/Test/GRACoL2013_CRPC6.icc`**.

Running the Software

PressCal is run from within the TextMate editor using the command keys ⌘**I**, ⌘**B**, and ⌘**R**. These keys are active when viewing a YAML file. PressCal settings are saved as YAML files, which you may edit to suit your requirements. We've provided a set of generic settings files in the **PressCal_Basic_Settings** folder, which you copied during installation. These files reference built-in test data, and are ready to run.

Settings File

Open the file **PressCal_Default.yml**, located in the **PressCal_Basic Settings** folder. At the bottom of the TextMate window you should see a pull-down menu with YAML selected. If not, make that selection manually. The screen should look like this, with the type colored in blue and green. If not, you may need to install the YAML bundle.



Grade Tool

Run the grade tool with the ⌘**I** key (hit the **I** key with the ⌘-command key pressed). A new TextMate window will open to display the program output. Then, several graphs will be displayed in your web browser. Take a quick look at the output. The grading tool provides a comparison of the press sheet measurements against the reference profile.

Run the grade tool using measurements of your initial press sheets to identify any problems with the platemaking or press work. If you intend to have your final press sheets certified, the grade tool will tell you whether you've passed or failed, according to the standard/guidelines you select.

Ink Balance Tool

Next, run the ink balance tool with the ⌘**B** key. A new TextMate window will open to display the program output. Several graphs will be displayed in your web browser. This tool will help you adjust ink densities to match the reference profile. The ink balance tool will also identify any trapping issues, and predict your success in matching the reference profile.

Curve Building Tool

Finally, run the curve building tool with the ⌘**R** key. Again, a new TextMate window will open to display the program output. There will be a short delay while the curves are calculated. This operation is very computer intensive. Once completed, additional text will be output. Then, graphs of the curves will be displayed in your web browser. A file named **tab_delim.txt** will be saved to your desktop. This file contains the computed tone curves as a step table.

Utilities

PressCal installs a folder of built-in example data used by the basic settings. With a basic setting file (**YAML**) opened in TextMate, you may open this folder with the command key ⌘**D**. You may add or delete files in this folder, but keep in mind a basic setting may fail if you delete files it uses. Also, be aware this folder is replaced when you update PressCal.

PressCal installs a grade database, which is useful when constructing your own custom grading function. With a basic setting file (**YAML**) opened in TextMate, you may dump this database with the command key ⌘**K**.

Basic Settings

The **PressCal_Basic Settings** folder contains many settings files. The file names give you some idea of their purpose. For instance, **PressCal_TVI.yml** will make TVI curves for a CMYK process. These files use built-in data, and will run without any changes. Each basic settings file has a corresponding section in this manual.

Besides demonstrating how PressCal works, the basic settings are a template for your own work. You may add or remove individual settings, as you see fit. The basic setting files are locked. Use TextMate's **Save As...** command to save your versions wherever is convenient.

Next Steps

At this point, you've installed the PressCal software and run its tools. The next three sections (**Grade Tool**, **Ink Balance Tool**, and **Curve Building Tool**) explain these tools in detail. The **PressCal_Optimal.yml** basic setting is used as an example in these sections.

Grade Tool

The grade tool compares your press measurements against target values calculated from the reference profile. The press sheet is graded according to the chosen grading standard, which defines limits for the color differences.

Open the **PressCal_Optimal.yml** basic setting in TextMate and press the **⌘I** key combination. A log window will appear with the grading results, and graphs will display in your default web browser.

Grade Log

The grade log begins with a summary of the main settings. You should verify these setting values are correct. Here is the beginning of a typical grade log.

```
Running "PressCal_Optimal.yml"...

Running "PressCal_Optimal.yml"...
Perl v5.34, arm64e

PressCal version 17U modified 2025-04-20

reference profile: ~/Data/Test/GRACoL2013_CRPC6.icc

press: ~/Data/Test/PressCalC6TS_test_data.mxf

file contains M0 M1 M2 measurement condition(s)

OBA effect: 0.661 (auto)

chart type: PressCalC6, nominal samples: 500, colorspace: CMYK, types: PPPP, created: 2020-06-28, 11:46
PM GMT

solid ink cluster size: 2.1
```

Solid Ink Comparison

Next, the log shows a comparison of the paper and solid ink colors.

```
solid ink colors and errors:

           abs L*a*b* values    ->    ref L*a*b* values      press L*a*b* values      ΔEab      ΔE00
   paper   95.0    1.0   -4.0        94.8    1.3   -3.9      94.8    1.3   -3.9       0.02      0.02
    cyan   56.0  -37.0  -50.0        55.9  -36.7  -49.9      56.0  -31.5  -49.8       5.28      2.02
 magenta   48.0   75.0   -4.0        47.9   75.1   -4.0      50.4   72.0   -2.9       4.15      2.66
  yellow   89.0   -4.0   93.0        88.8   -3.7   92.8      89.6   -6.4   87.9       5.69      1.93
     red   47.0   68.0   48.0        46.9   68.1   47.9      49.0   66.6   42.9       5.64      2.85
   green   50.0  -66.0   26.0        49.9  -65.7   26.0      50.9  -63.8   25.1       2.39      1.19
    blue   25.0   20.0  -46.0        24.9   20.1  -45.9      26.3   21.0  -44.5       2.16      1.63
     iso   23.0    0.0   -0.0        22.9    0.1    0.0      24.2    0.3   -4.2       4.40      3.97
   black   16.0    0.0   -0.0        15.9    0.1    0.0      21.0    1.0    1.7       5.43      4.03
    cmyk    9.0    0.2    0.4         9.0    0.3    0.4      12.1    0.8   -0.4       3.22      2.22
```

Notice there are three groups of L*a*b* values. The first group (**abs L*a*b* values**), are the values calculated from the reference profile. These values are transformed to the second group (**ref L*a*b* values**) according to the **`rendering:`** setting. The third group (**press L*a*b* values**) are the press measurements. The columns on the right (**ΔEab** and **ΔE_{00}**) are color differences between the ref L*a*b* values and press L*a*b* values. These color differences should be small, indicating a good match between the color gamuts of the printing process and the reference profile.

In this example, the **`rendering:`** setting is not used, so it defaults to **`[0, 0]`** or media relative. This means the ICC profile white point is mapped to that of the press sheet. We have **M1** and **M2** press measurements and the **`condition:`** setting is **`auto`**. These measurements (M1/M2) are mixed in a 66%/34% ratio, to best match the reference profile white point.

Grading Tests

Next, the log shows the grading test results for the standard you've selected.

```
standard: optimal, version: 2020, level: offset

process solids color error

      cyan ΔE00: 2.02 ✔ [3.00]
   magenta ΔE00: 2.66 ✔ [3.00]
    yellow ΔE00: 1.93 ✔ [3.00]
     black ΔE00: 4.03 ✔ [5.00]

RGB solids color error

       red ΔE00: 2.85 ✔ [3.00]
     green ΔE00: 1.19 ✔ [3.00]
      blue ΔE00: 1.63 ✔ [3.00]

gray axis color errors

     average ΔL: 1.86 ✘ [1.50]
     maximum ΔL: 3.97 ✔ [4.00]
    average ΔCh: 2.93 ✘ [1.50]
    maximum ΔCh: 5.80 ✘ [4.00]

realistic samples (375)

    median ΔE00: 2.31 ✔ [2.50]
  95th pct ΔE00: 4.43 ✔ [5.00]
   maximum ΔE00: 5.99 ✔ [10.00]

failed 3 tests
```

Program exited with code #2 after 1.24 seconds. copy output

In this example, the standard is **Optimal Offset**. This press sheet failed gray axis tests. Failed tests are an indication of how the press sheet needs to be improved. In this case, the gray balance and tonality are off. Tone curves will fix this problem.

Solid Ink A-B Plot

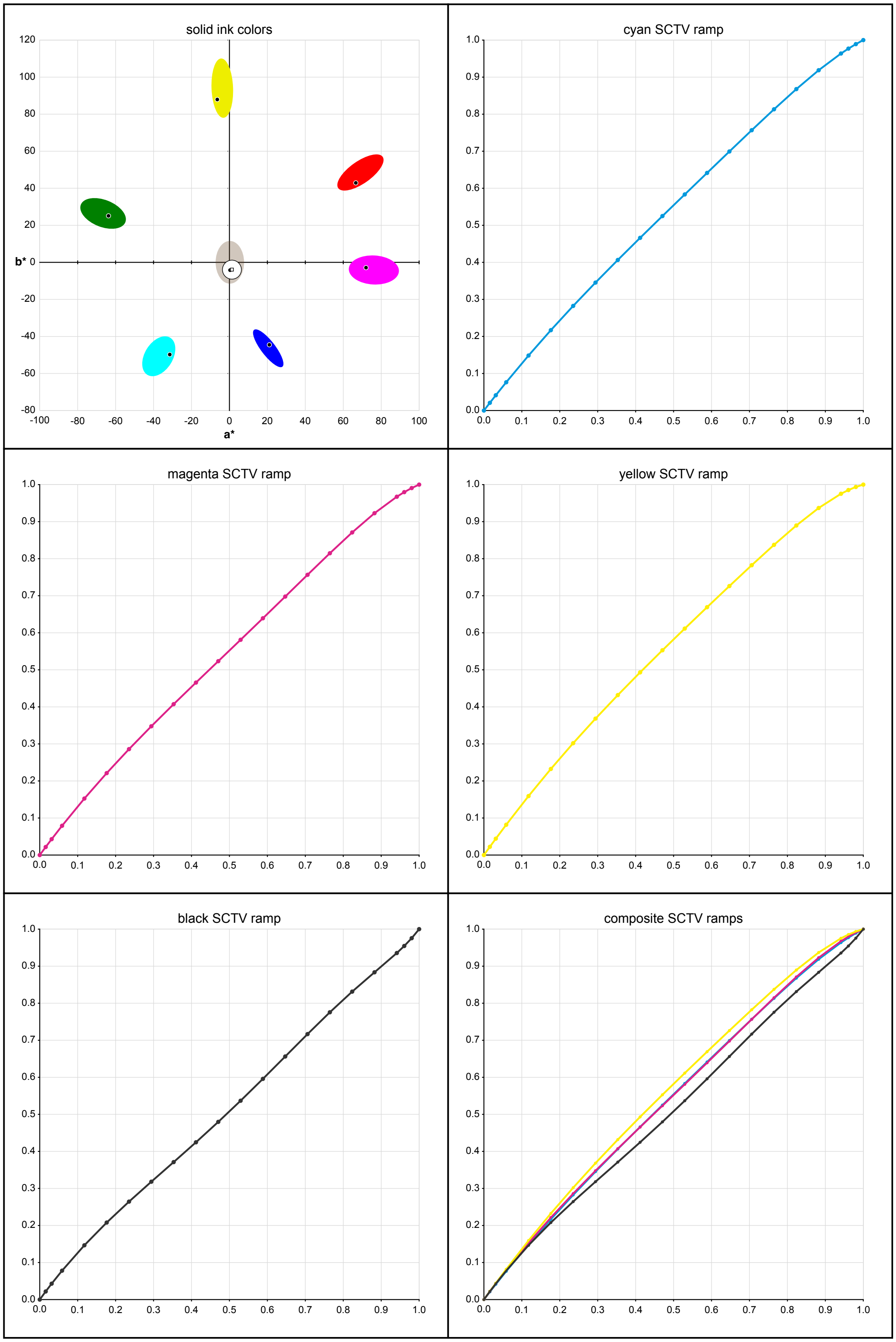
The solid-ink comparison is also plotted in your web browser (see graphs on the next page). The plot coordinates are **a*** and **b***. The large colored ovals represent the permissible values of each solid color. The black dot within or near each oval is the measured solid color. The size and shape of the colored ovals depend on the target color, the error metric, and the error tolerance. The A-B plot doesn't show the **L*** values, so it's possible for a measurement to fall within the colored oval, but still fail its test. If you move your cursor over the black dot, the L*a*b* and error values will be displayed.

This plot is used to visualize the gamut of the press, in relation to the target color-space. This is especially helpful for adjusting ink densities on an offset press. The density of each ink affects three colors, e.g., yellow affects red and green. The A-B plot allows you to visualize the direction and magnitude of color errors.

SCTV Curves

The SCTV curves show measurements of your uncalibrated printing BEFORE any curves are applied (see previous page). The purpose of these curves is to help you spot tonal irregularities. The curves should be smooth and monotonic. Abrupt slope changes, discontinuities or clipping should be viewed as potential problems, and investigated.

SOLID INK
A-B PLOT
SCTV PLOTS

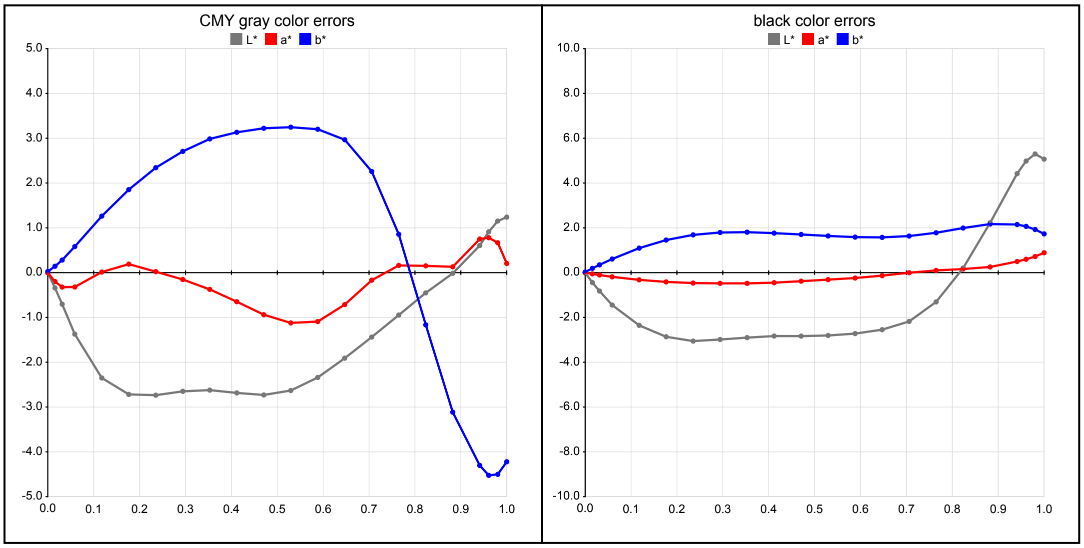


CMY Gray Color Error Curves

The **CMY** gray ramp color error is plotted in your web browser (see below). The purpose of this plot is to show deviations in gray balance and tone. IDEAlliance gray **CMY** samples are used, if present in the test chart. Otherwise, isometric (**C=M=Y**) samples are used. The x-axis is the cyan value. Ideally, the curves will be zero everywhere, indicating no error. The a* (red) and b* (blue) curves indicate gray balance, while the L* (black) curve indicates tone. The error values at x = 0.0 are the color difference between the paper, and the reference profile. These values will be zero for relative rendering. The error values at x = 1.0 are the color difference between the **CMY** solid overprint and the reference profile.

Black Color Error Curves

The black ramp color error is plotted in your web browser (see below). The purpose of this plot is primarily to show tone deviations. The x-axis is the black value. Ideally, the curves will be zero everywhere, indicating no error. The L* (black) curve is the tonal error. The error values at x = 0.0 are the color difference between the paper, and the reference profile. These values will be zero for relative rendering. The error values at x = 1.0 are the color difference between the black solid and the reference profile.



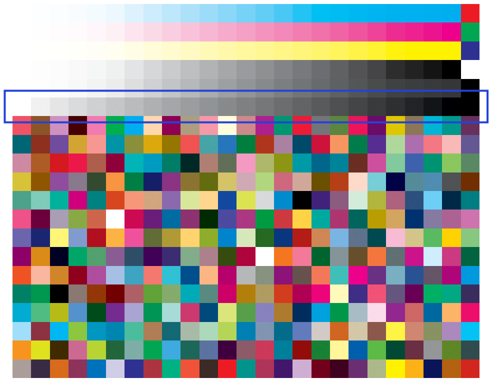
Gray Axis Color Error Curves

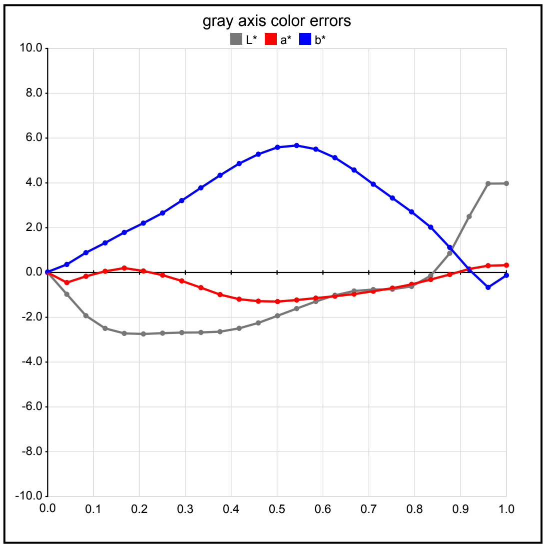
The gray axis ramp consists of 25 gray samples computed from the reference profile. These samples may contain any or all of the printing inks, as determined by the software that made the reference profile. The steps vary from paper white to the darkest possible black, equally spaced by their SCTV value. This ramp is the true gray axis of the printing process, and should measure neutral (a* and b* values = 0) using media relative rendering intent.

The difference between the **CMY** gray ramp and the gray axis ramp is illustrated by this table. The **CMY** gray samples (on the left) contain arbitrary combinations of **CMY**, defined by Idealliance to be gray. The gray axis samples (on the right) contain black ink, and are gray as defined by the reference profile, regardless of its origin.

PressCal Charts

Because the gray axis samples are computed from the reference profile, a custom test chart is needed. PressCal charts are available for two commonly used reference profiles, GRACoL2013_CRPC6.icc and PSOcoated_v3.icc. The PressCalC6TS chart is shown below, on the left. The gray axis samples are in row 6, within the blue frame. The gray axis color errors are shown in the graph, on the right. The horizontal axis of this graph is the SCTV value of the samples. There are 25 steps, equally spaced from paper white to the darkest black tone. If the test chart is missing these gray axis samples, the errors cannot be computed or displayed. If you need a PressCal test chart for another reference profile, contact the authors.





Ink Balance Tool

The ink balance tool guides the setting of solid ink densities for conventional printing processes such as offset, flexo, etc. It tries to minimize the color errors of the **CMYK** and **RGB** solids, as compared to the reference profile. This is a complex task because each of the **CMY** densities affects three colors – itself plus two overprints.

Open the **PressCal_Optimal.yml** basic setting in TextMate and press the **⌘B** key combination. A log window will appear with the ink balance calculations, and graphs will display in your default web browser.

How It Works

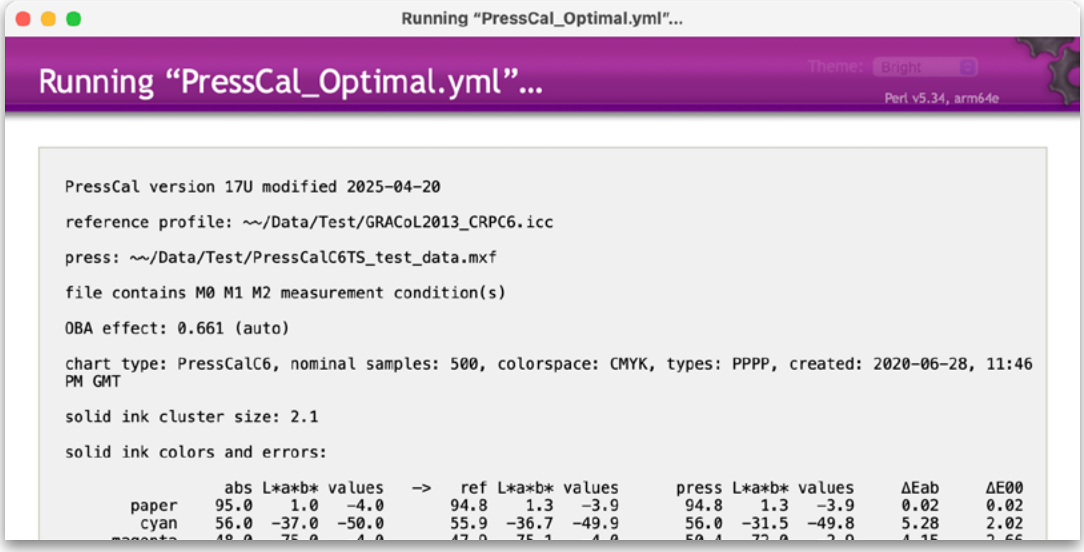
The ink balance tool requires spectral measurements of the paper, the **CMYK** solids, the **RGB** solids, and the isometric (**CMY**) solid. These measurements are used to build a mathematical model of the printing process. This model predicts the color of each sample as a function of the **CMYK** ink film thicknesses. These values are optimized to produce the minimum overall color error in the solid samples. The new ink densities are computed, and presented as density changes.

RGB Solid Colors

On an offset press, the ink keys directly control the density of the **CMYK** solids. The **RGB** solids are each controlled by two of the **CMY** ink keys. For instance, the red solid is controlled by the magenta and yellow ink keys. The hues of the **RGB** colors depend on the balance of the two inks that comprise them. We believe it is important for the **RGB** solids to be correct, which is why they are part of the mathematical model, and why we use "ink balance" to describe this tool. The default settings give equal weight to each of the **CMYRGB** solids.

Ink Balance Log

The ink balance log begins with a summary of the main settings. You should verify these setting values are correct. Here is the beginning of a typical ink balance log.



Solid Ink Comparison

Next, the log shows a comparison of the paper and solid ink colors.

```
solid ink colors and errors:

             abs L*a*b* values   ->   ref L*a*b* values      press L*a*b* values     ΔEab     ΔE00
     paper   95.0    1.0   -4.0       94.8    1.3   -3.9      94.8    1.3   -3.9     0.02     0.02
      cyan   56.0  -37.0  -50.0       55.9  -36.7  -49.9      56.0  -31.5  -49.8     5.28     2.02
   magenta   48.0   75.0   -4.0       47.9   75.1   -4.0      50.4   72.0   -2.9     4.15     2.66
    yellow   89.0   -4.0   93.0       88.8   -3.7   92.8      89.6   -6.4   87.9     5.69     1.93
       red   47.0   68.0   48.0       46.9   68.1   47.9      49.0   66.6   42.9     5.64     2.85
     green   50.0  -66.0   26.0       49.9  -65.7   26.0      50.9  -63.8   25.1     2.39     1.19
      blue   25.0   20.0  -46.0       24.9   20.1  -45.9      26.3   21.0  -44.5     2.16     1.63
       iso   23.0    0.0   -0.0       22.9    0.1    0.0      24.2    0.3   -4.2     4.40     3.97
     black   16.0    0.0   -0.0       15.9    0.1    0.0      21.0    1.0    1.7     5.43     4.03
      cmyk    9.0    0.2    0.4        9.0    0.3    0.4      12.1    0.8   -0.4     3.22     2.22
```

Notice there are three groups of L*a*b* values. The first group (**abs L*a*b* values**), are the absolute values calculated from the reference profile. These values are transformed to the second group (**ref L*a*b* values**) according to the **`rendering:`** setting. In this example, that setting is absolute rendering (**`[1, 1]`**), so the values in the first and second groups are identical. The third group (**press L*a*b* values**) are the press measurements. The columns on the right (**ΔEab** and **ΔE_{00}**) are color differences between the ref L*a*b* values and press L*a*b* values.

Solid Ink Model

Next the log shows fitting the solid ink model. The model uses your ink sequence,

```
fitting solid ink model

ink sequence: KCMY

L-M optimization completed at 459 iterations

offsets:

      cyan   0.005   0.037
   magenta   0.003   0.026
    yellow   0.013   0.021
       iso   0.010

trap values:

       red   1.007   0.718
     green   0.931   0.887
      blue   0.843   0.815
       iso   0.804   0.729   0.638
```

which is displayed in the log. The default value is **KCMY**. If your ink sequence is different, you should use the **`ink_sequence:`** setting. The ISO 12647-2 standard, and most standard data sets use the **KCMY** ink sequence. *Generally, it is a bad idea to use an ink sequence that differs from your reference profile.*

The solid ink model has 16 parameters, which are determined from the initial press measurements. **M2 spectral measurements** are required.

Trap Values

The trap values are shown in the log. Ideally, these values would all be 1, indicating perfect ink trapping. The values apply to the ink layers that make up each color, in the order of the ink sequence. For instance, in this example (above), the first red value applies to the magenta ink, and the second value to the yellow ink. These values are not the same as trap values computed from density, but their meaning is similar.

Ink Balance Optimization

Next, the log shows the calculation of optimal ink densities.

```
optimizing ink balance

error metric: dE00

error weights: [1, 1, 1, 1, 1, 1, 0]

L-M optimization completed at 288 iterations

optimized ink film thicknesses:

       cyan   1.047
    magenta   1.052
     yellow   1.128
      black   1.237
```

There are two settings controlling these calculations. The **`ink_deltaE:`** setting selects the metric used to compute color errors. You may choose from an assortment of popular color error formulas. This is distinct from the **`deltaE:`** setting used for curve optimization.

The **`ink_weight:`** setting controls the weight given each of the **CMYRGB/ISO** color errors, when computing the optimal ink densities. These weights are entered as an anonymous array of values between 0 and 1. The default value is [1, 1, 1, 1, 1, 1, 0], which indicates equal weight (1) to the **CMYRGB** colors, and no weight (0) to the isometric (C+M+Y) solid. If you were only concerned with the **CMY** solids, you would set the weight array to [1, 1, 1, 0, 0, 0, 0]. For G7 calibrations, you might want to include the isometric (C+M+Y) solid by using this weight array [1, 1, 1, 1, 1, 1, 1].

Ink Film Thickness

The initial **CMYK** ink film thicknesses all have a value of 1. These values will change after optimization. If the value is greater than 1, the suggested ink film is thicker. If the value is less than 1, the suggested ink film is thinner. In the example above, the cyan ink film is 1.068, which means the suggested value is 6.8% thicker. The magenta ink film is 0.916, which means it is 8.4% thinner.

Spectral reflectance values are computed using these ink film thicknesses. From the spectral values, we can determine both color and density. The optimized color values are displayed in the log, in the same format we used initially.

```
solid ink colors and errors (optimized):

              abs L*a*b* values   ->   ref L*a*b* values      press L*a*b* values     ΔEab     ΔE00
      paper   95.0    1.0   -4.0       94.8    1.3   -3.9      94.8    1.3   -3.9    0.02     0.02
       cyan   56.0  -37.0  -50.0       55.9  -36.7  -49.9      55.1  -31.0  -50.6    5.82     2.42
    magenta   48.0   75.0   -4.0       47.9   75.1   -4.0      49.6   72.7   -1.5    3.82     2.03
     yellow   89.0   -4.0   93.0       88.8   -3.7   92.8      89.2   -5.8   92.4    2.22     1.17
        red   47.0   68.0   48.0       46.9   68.1   47.9      48.3   67.5   45.7    2.73     1.63
      green   50.0  -66.0   26.0       49.9  -65.7   26.0      49.5  -64.3   28.1    2.56     1.12
       blue   25.0   20.0  -46.0       24.9   20.1  -45.9      24.9   21.2  -44.0    2.13     1.59
        iso   23.0    0.0   -0.0       22.9    0.1    0.0      22.4   -0.0   -2.0    2.09     1.98
      black   16.0    0.0   -0.0       15.9    0.1    0.0      15.9    1.0    0.8    1.18     1.49
       cmyk    9.0    0.2    0.4        9.0    0.3    0.4        sample missing      ----     ----
```

The color errors are reduced overall, and hopefully fall within the grading limits. In this example, the **blue ΔE_{00} error** was reduced from **5.93** to **3.64**, which is now less than the G7 limit of **4.2**. Keep in mind these optimized values come from a math model, so your actual colors will be somewhat different.

Density Changes

The next step is to adjust the ink densities to the suggested values. The density values computed by PressCal probably won't agree exactly with those measured in the pressroom. So, we prefer to suggest density changes instead of literal values. Based on the precision of your inking control, ink balance may require multiple iterations.

```
status T densities:

                  nom     opt    change
     cyan (R)   1.265   1.299    +0.03
  magenta (G)   1.278   1.326    +0.05
   yellow (B)   0.933   1.008    +0.07
    black (V)   1.484   1.677    +0.19
```

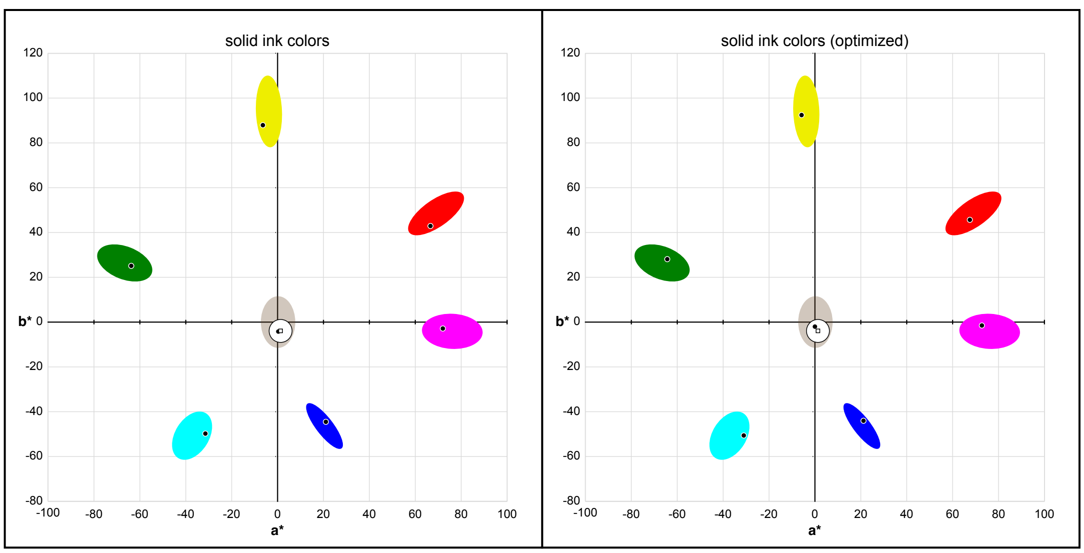
Program exited with code #1 after 1.45 seconds. copy output

PressCal will compute densities using your preferred density status. This is generally **status T** in the US, and **status E** elsewhere. The **`ink_status:`** setting allows you to override the default value, which comes from your grade settings.

Solid Ink A-B Plots

The solid-ink comparison is also plotted in your web browser (see below). The plot coordinates are **a*** and **b***. The large colored ovals represent the permissible values of each solid color. The color is the black dot within or near each oval. The size and shape of the colored ovals depend on the target color, the error metric, and the error tolerance. The A-B plot doesn't show the **L*** values, so it's possible for a measurement to fall within the colored oval, but still fail its test. If you move your cursor over the black dot, the L*a*b* and error values will be displayed.

This plot labeled **solid ink colors** shows the initial values. The plot labeled **solid ink colors (optimized)** shows the optimized result. In this case the **RGB** solids were improved, while maintaining compliance in the **CMY** solids.



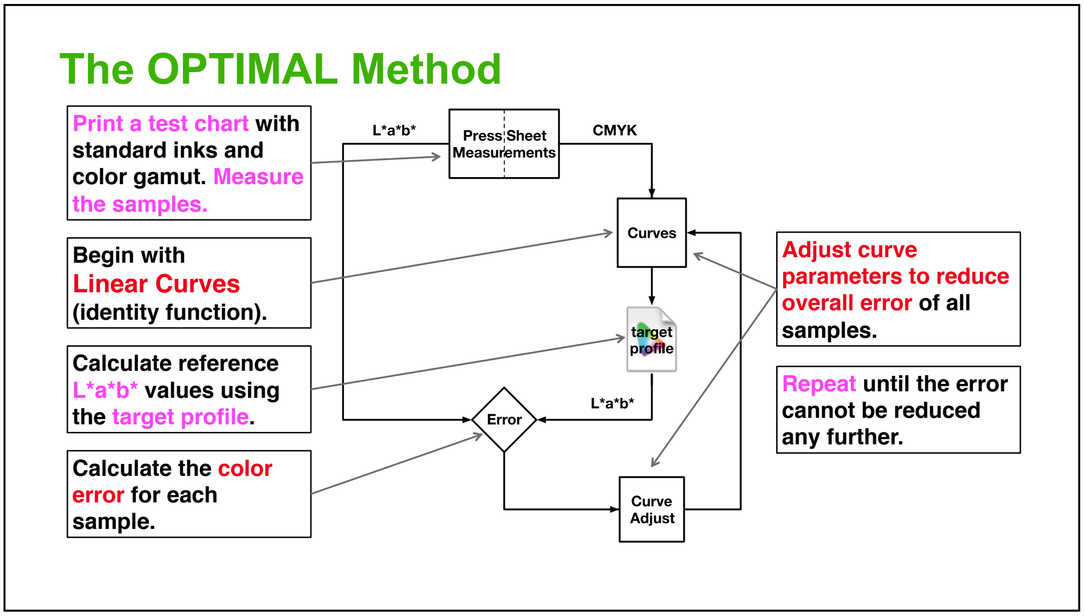
Curve Building Tool

The curve building tool is the main function of PressCal. It builds tone reproduction curves (TRCs) that minimize the color errors between a standard reference profile and your press sheet.

Open the **PressCal_Optimal.yml** basic setting in TextMate and press the **⌘R** key combination. A log window will appear with the curve calculations, and graphs will display in your default web browser.

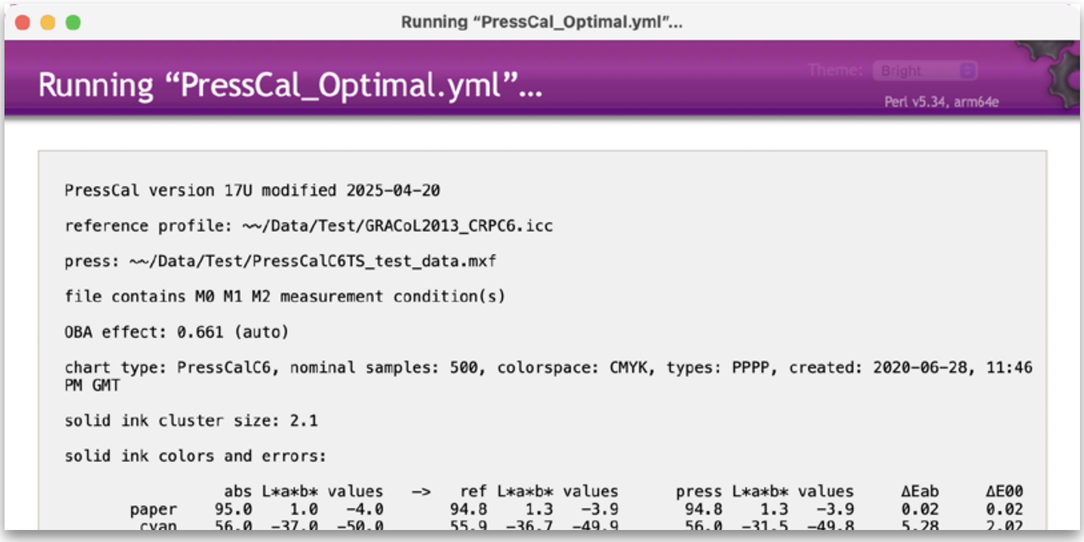
How It Works

The curve building function is illustrated by the following diagram, taken from our [2018 TAGA presentation](). Follow the text blocks starting with 'Print a test chart'.



Curve Log

The curve log begins with a summary of the main settings. You should verify these setting values are correct. Here is the beginning of a typical curve log.



Solid Ink Comparison

Next, the log shows a comparison of the paper and solid ink colors.

```
solid ink colors and errors:

           abs L*a*b* values   ->   ref L*a*b* values      press L*a*b* values      ΔEab      ΔE00
  paper    95.0    1.0   -4.0       94.8    1.3   -3.9     94.8    1.3   -3.9      0.02      0.02
   cyan    56.0  -37.0  -50.0       55.9  -36.7  -49.9     56.0  -31.5  -49.8      5.28      2.02
magenta    48.0   75.0   -4.0       47.9   75.1   -4.0     50.4   72.0   -2.9      4.15      2.66
 yellow    89.0   -4.0   93.0       88.8   -3.7   92.8     89.6   -6.4   87.9      5.69      1.93
    red    47.0   68.0   48.0       46.9   68.1   47.9     49.0   66.6   42.9      5.64      2.85
  green    50.0  -66.0   26.0       49.9  -65.7   26.0     50.9  -63.8   25.1      2.39      1.19
   blue    25.0   20.0  -46.0       24.9   20.1  -45.9     26.3   21.0  -44.5      2.16      1.63
    iso    23.0    0.0   -0.0       22.9    0.1    0.0     24.2    0.3   -4.2      4.40      3.97
  black    16.0    0.0   -0.0       15.9    0.1    0.0     21.0    1.0    1.7      5.43      4.03
   cmyk     9.0    0.2    0.4        9.0    0.3    0.4     12.1    0.8   -0.4      3.22      2.22
```

Notice there are three groups of L*a*b* values. The first group (**abs L*a*b* values**), are the values calculated from the reference profile. These values are transformed to the second group (**ref L*a*b* values**) according to the **`rendering:`** setting. The third group (**press L*a*b* values**) are the press measurements. The columns on the right (**ΔEab** and **ΔE00**) are color differences between the ref L*a*b* values and press L*a*b* values. In this example, the rendering is media relative (**`[0, 0]`**), so the paper values in the second and third groups are identical.

Ink Map

The **`ink_map:`** setting determines how curves are calculated for each ink channel. This section explains ink mapping in detail. If the ink map contains numbers, those ink channels will be computed by optimization using selected samples. Curves for non-numeric channels are computed separately, after optimization. The ink map is disabled in this basic setting, so the default value **`[0, 1, 2, 3]`** is used.

Sample Selection

The **`select:`** setting determines which samples will be used for optimization. This section explains sample selection in detail. Sample selection depends on the method used to compute curves. In this basic setting, the sample selection is **`rt(10) k nosub`**. This selects round-trip **CMY** samples and the **K** ramp, excluding substrate samples.

Color Error Metric

The **`deltaE:`** setting selects the function used to compute color errors. The deltaE setting is not used in this basic setting, so the default value **`dE00`** is used. The Optimal Method minimizes color errors during optimization. The color error of each sample is displayed, before and after optimization.

```
degree: 6, sample selection: 'rt(10) k nosub', samples: 480

sample       device values               ref L*a*b* values      press L*a*b* values      ΔE00
7        0.000  0.833  0.500  0.000       53.7   60.2   22.6     53.7   60.2   25.1      1.28
8        1.000  0.021  0.255  0.499       35.4  -30.0  -19.4     34.5  -27.3  -13.6      3.18
9        0.138  0.513  0.146  0.037       62.5   28.8   -3.8     61.6   28.1   -1.6      1.52
10       0.100  0.117  0.892  0.083       75.3   -1.4   66.3     72.8   -2.5   62.7      2.20
11       0.665  0.091  0.491  0.095       58.3  -28.1    2.2     55.9  -28.9    8.2      4.43
12       0.000  0.833  0.167  0.000       53.7   62.9    3.6     53.9   63.1    4.8      0.56
13       0.667  0.667  0.000  0.000       43.6   16.5  -34.6     42.8   18.5  -35.5      1.27
14       0.232  1.000  0.000  0.325       33.2   47.0  -11.5     32.6   43.5  -10.8      1.30
15       0.000  0.833  1.000  0.000       52.2   57.8   52.2     52.7   59.4   46.8      2.91
16       0.822  0.089  0.627  0.287       44.8  -34.1    4.0     43.4  -31.7    8.4      3.39
17       1.000  0.000  0.167  0.000       55.2  -43.6  -36.8     55.1  -42.3  -32.1      1.78
18       0.333  0.000  0.000  0.000       81.6  -10.0  -19.9     79.9  -11.9  -21.9      1.91
19       0.000  0.500  1.000  0.000       66.7   31.2   66.8     65.7   33.7   61.0      3.21
```

Optimization

All of the selected samples are displayed, followed by the average error(s). Curves are then adjusted to minimize color errors, using the **Levenberg-Marquardt** algorithm. When this completes, the samples are displayed again, this time with the reference L*a*b* values updated for the optimized curves. The average error value(s) should be reduced. For this basic setting, the average **ΔE** went from **2.35** to **1.05**, a significant improvement.

```
498     0.667  0.000  0.000  0.000      68.0  -23.4  -35.9      66.9  -22.1  -37.1      1.24
499     0.728  0.448  0.493  0.485      31.6   -7.1   -4.5      30.7   -7.1   -0.5      3.46
500     0.000  0.967  1.000  0.127      43.4   59.3   42.9      43.8   56.5   37.7      2.00

                                                        initial average error:   2.35

optimizing curves for minimum ΔE00...

L-M optimization completed at 216 iterations

error values with optimized curves are below...

sample        device values               ref L*a*b* values       press L*a*b* values      ΔE00
7       0.000  0.833  0.500  0.000      53.7   59.3   27.0      53.7   60.2   25.1      1.13
8       1.000  0.021  0.255  0.499      34.5  -27.7  -14.3      34.5  -27.3  -13.6      0.42
9       0.138  0.513  0.146  0.037      60.6   28.0   -1.8      61.6   28.1   -1.6      0.93
```

```
498     0.667  0.000  0.000  0.000      67.7  -23.6  -36.2      66.9  -22.1  -37.1      1.08
499     0.728  0.448  0.493  0.485      30.7   -6.4   -1.0      30.7   -7.1   -0.5      0.82
500     0.000  0.967  1.000  0.127      43.6   56.8   38.9      43.8   56.5   37.7      0.59

                                                      optimized average error:   1.05

final gamut scale factor = 0.993, linearity = 0

curve parameters:

           HLV    1/6    2/6    3/6    4/6    5/6    SHV
   cyan  0.000  0.229  0.342  0.571  0.679  0.804  1.000
magenta  0.000  0.222  0.382  0.484  0.715  0.832  1.000
 yellow  0.000  0.248  0.415  0.696  0.669  0.869  1.000
  black  0.000  0.185  0.427  0.440  0.868  0.742  1.000

CED sample selection same as optimization, samples: 480
```

Gamut Scale Factor

The gamut scale factor is displayed following the optimized average error (see above). This number describes the relative size of the reference profile gamut. By default, the gamut scale factor is adjusted during optimization. This is equivalent to Adobe's black point compensation. The **`gsf:`** setting allows you to fix (lock) the gamut scale factor.

Non-Numeric Channels

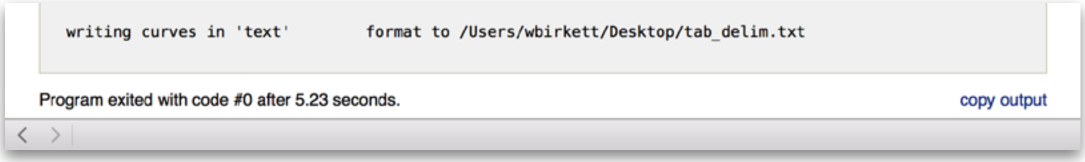
Curves for non-numeric ink map channels are computed next. This includes TVI curves, SCTV curves, and G7 black curves. These curves are built from the ink ramp samples using the same Levenberg-Marquardt algorithm as the optimized curves.

Bernstein Degree

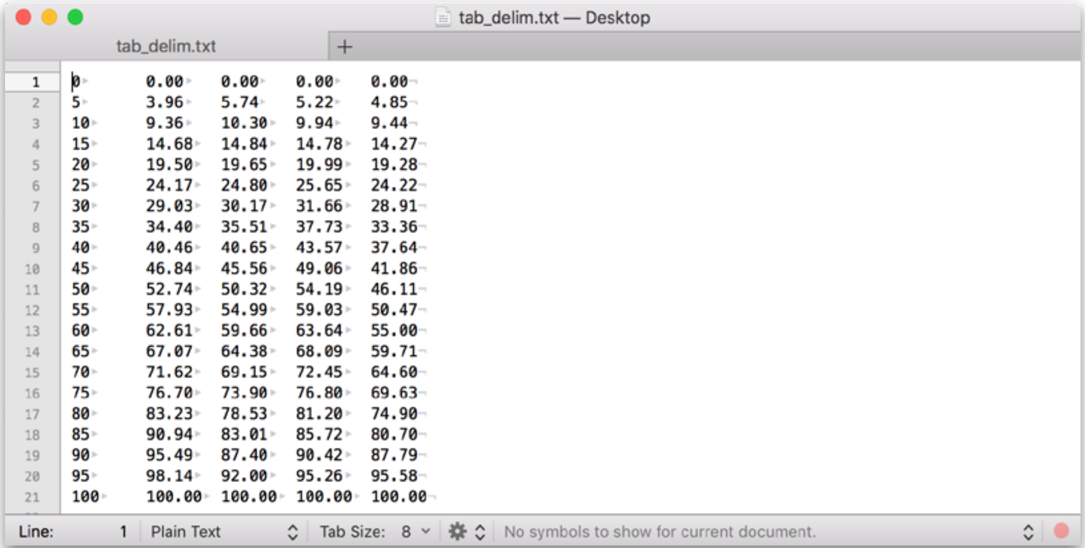
The Bernstein curve parameters are then displayed. These values control the shape of the curves, and are computed by the optimization step(s). The number of parameters is one more than the **Bernstein degree**, which controls the complexity of the curves. The **`degree:`** setting allows you to override the default value, which is the largest degree supported by the selected samples. Reducing the degree will make the curves smoother, but will increase the residual errors. Normally, the degree should not be greater than the default value. In this example, the degree is 6, and there are 7 (6+1) curve parameters.

Output Selection

The **`output:`** setting allows you to select the curve output format(s). This section explains the setting in detail. A line is displayed in the log as each curve format is output. In this example, only the **text** format is output.



The **text** format produces a 21 step table, often used to display curves. These values could be entered into your **DFE** (digital front end) to manually create a **TRC**.



0	0.00	0.00	0.00	0.00
5	3.96	5.74	5.22	4.85
10	9.36	10.30	9.94	9.44
15	14.68	14.84	14.78	14.27
20	19.50	19.65	19.99	19.28
25	24.17	24.80	25.65	24.22
30	29.03	30.17	31.66	28.91
35	34.40	35.51	37.73	33.36
40	40.46	40.65	43.57	37.64
45	46.84	45.56	49.06	41.86
50	52.74	50.32	54.19	46.11
55	57.93	54.99	59.03	50.47
60	62.61	59.66	63.64	55.00
65	67.07	64.38	68.09	59.71
70	71.62	69.15	72.45	64.60
75	76.70	73.90	76.80	69.63
80	83.23	78.53	81.20	74.90
85	90.94	83.01	85.72	80.70
90	95.49	87.40	90.42	87.79
95	98.14	92.00	95.26	95.58
100	100.00	100.00	100.00	100.00

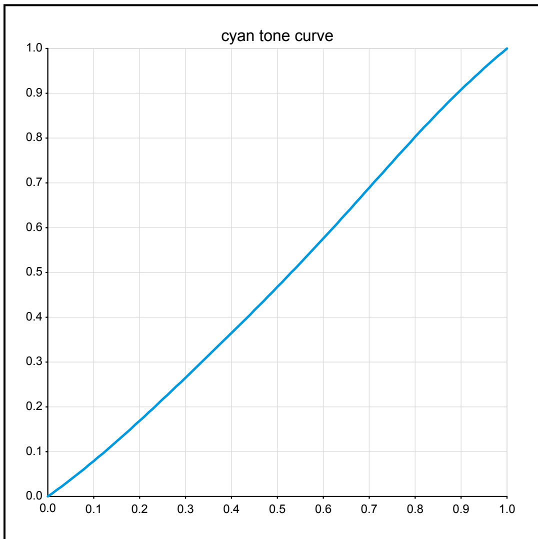
That manual entry would take some time, and be error-prone. Most DFEs allow you to load your curves from a file. PressCal supports many file formats. You should consult your DFE documentation to see what formats it supports. The **`iso_18620`** format (commonly known as **`.ted`** format) is an international standard, and your best choice, if available.

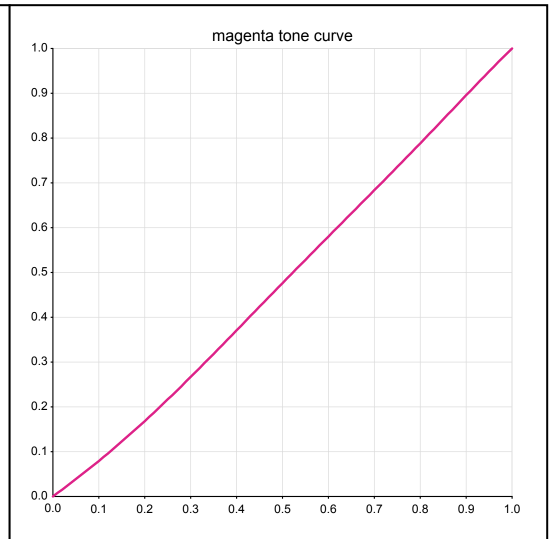
Tone Curve Graphs

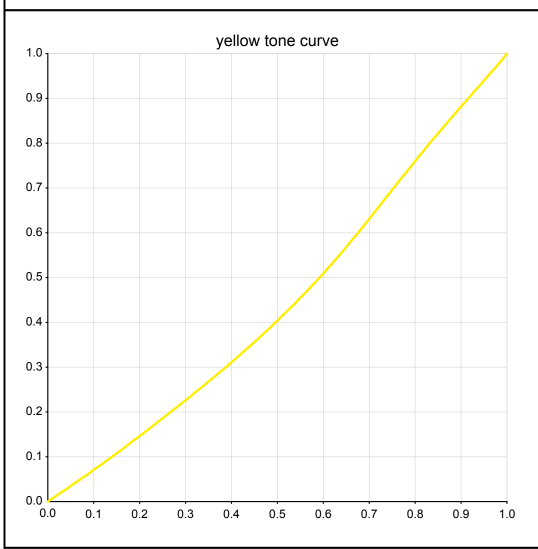
Tone curve graphs will display in your web browser (see next page). The curve for each ink color is displayed individually, followed by a composite graph of all curves. The graphs provide a quick visual assessment, helping you spot any irregularities.
If you move your cursor over one of the individual curves, values for the 21 steps will be displayed (see bottom right graph).

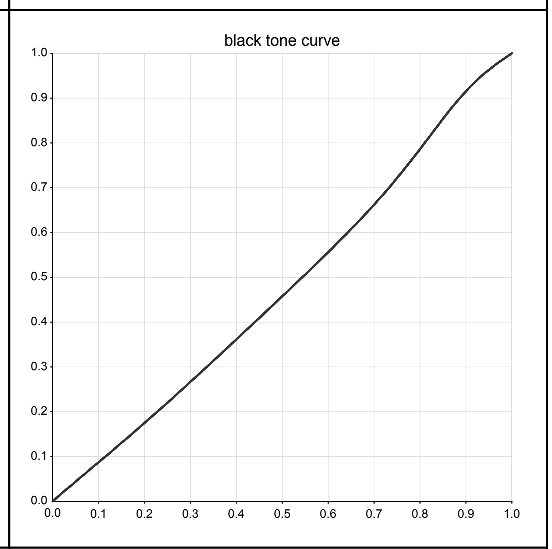
Output Folder

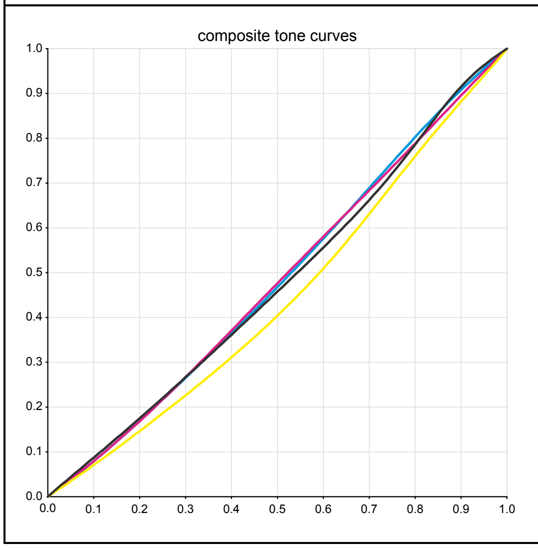
Tone curve and graphs are written to your **Desktop** by default. The graphs are in a folder named **PressCal_graphs**. These items may be renamed, moved to other locations, or deleted, as you prefer. The **`output_path:`** setting allows you to change the location where these items are written. The value for this setting is a folder path. The folder will be created if it doesn't already exist.

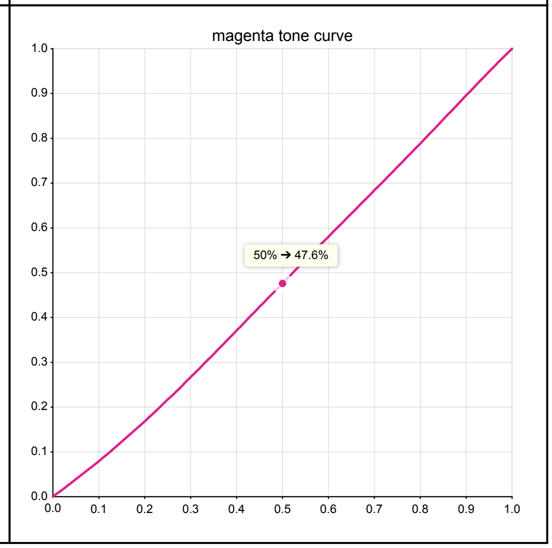

cyan tone curve
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0


magenta tone curve
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0


yellow tone curve
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0


black tone curve
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0


composite tone curves
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0


magenta tone curve
50% ➔ 47.6%
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

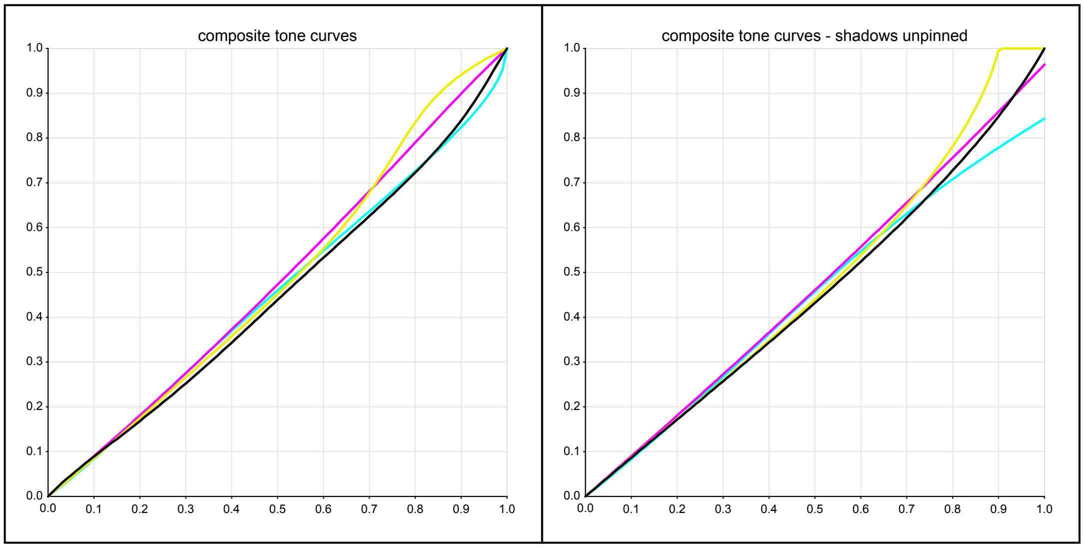
Curve Endpoints

Curves are normally "pinned" at the endpoints. An input of 0% dot produces an output of 0%, and an input of 100% dot produces an output of 100%, regardless of the curve shape. Linear curves have these properties, which are preserved during optimization by disabling changes to the first and last Bernstein parameters.

By pinning the highlights, we avoid printing a background dot on the bare media, and/or clipping highlight detail. By pinning the shadows, we avoid a halftone pattern in solids, and/or clipping shadow detail. So, it normally makes sense to pin both highlight and shadow endpoints.

Highlight and Shadow Settings

There are times when the highlight and shadow endpoints need to be handled differently. The **`highlight:`** setting and **`shadow:`** setting provide endpoint options. Below are examples of curves with pinned (left) and unpinned (right) shadow endpoints.



The shadow endpoints are unpinned by adding the optional setting, **`shadow: [undef, undef, undef, undef]`**. The last Bernstein parameters for each ink channel are then included in the optimization. Notice how the shadow curves diverge, with the cyan and magenta ending less than 100%, and the yellow being clipped. This occurred because the isometric (C+M+Y) overprint was not gray, and the black ink density was too high. These curves are not suitable for offset printing, for reasons already explained.

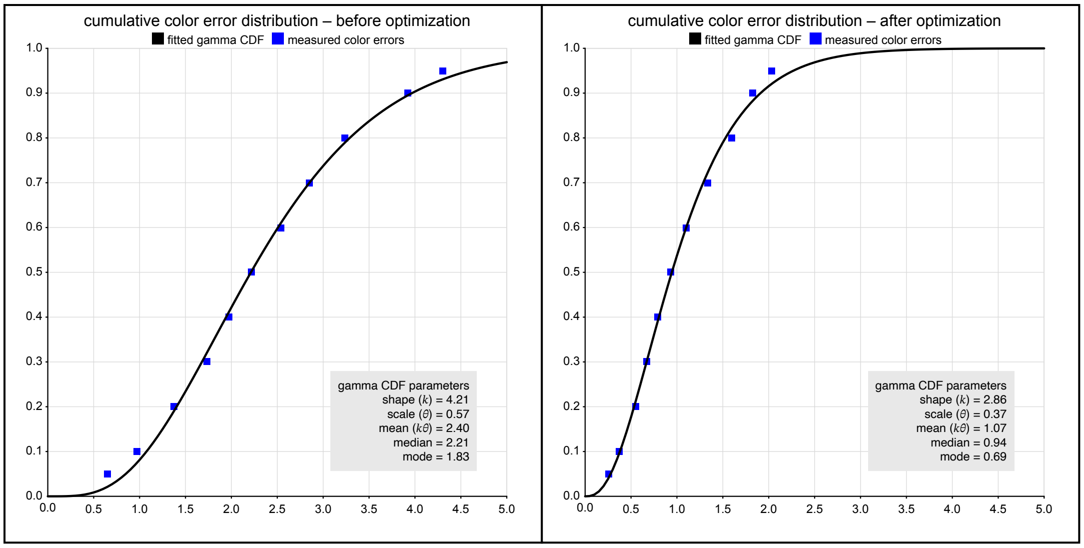
However, if this were an ink jet printer, there would be no halftone dot pattern, so you could tolerate solids less than 100%. In this case, you might use the setting, **`shadow: [undef-, undef-, undef-, undef-]`**, which prevents clipping by forcing the shadow endpoints to be 100% or less.

In flexo printing, it may be desired to set the minimum highlight values. For example, the setting **`highlight: [2.5, 2.5, 2.5, 2.5]`** fixes the highlight endpoints at 2.5%. These values may be determined by running the grade tool, which computes the highlight dot retention (minimum printable %-dot) from SCTV values.

Cumulative Error Distribution

The sample color errors, before and after optimization, are shown in the text log of the curve building function. These errors give us an indication of how well the optimized curves improved the color reproduction. This may be visualized using a statistical tool – the cumulative error distribution.

The cumulative error distribution is normally displayed as a graph with the error value on the horizontal axis, and the quantile value on the vertical axis. To make these graphs, the color errors are sorted from lowest to highest. The quantile value is a number, ranging from 0 to 1, indicating the location within that sorted list. The start of the list (smallest error) is quantile 0. The end of the list (largest error) is quantile 1. The middle of the list (or median) is quantile 0.5.



The graphs above show typical cumulative error distributions, before and after optimization. The blue squares are the actual measured data, while the black S-shaped curve is a standard statistical function (gamma function), which describes data of this type. The closer the curve is to the left-hand edge of the graph, the better the match between the reference profile and press. You can see that the optimization made a big difference (lowered the median ΔE) in the color error distribution.

Median Error

The median error value is the best single metric to describe these curves. The median error is the value at the middle of the curve, where the quantile value is 0.5. Another way to describe the median is that half of the samples have smaller errors, and half have larger errors.

Gamma Distribution

The residual errors of a calibrated press or printer will resemble the gamma distribution. This function has two parameters, shape (k) and scale (θ). The curves usually have a slight s-shape, which is more pronounced with greater values of k. The curves always start at the origin (0, 0) and their width is determined by θ.

Sample Selection

By default, the samples used for the CED graphs are the optimization samples. The **`ced_select:`** and **`ced_ink_map:`** [settings](#) allow you to make an alternate sample selection for the CED graphs. These settings use the same notation as the **`select:`** and **`ink_map:`** [settings](#), but have NO effect on the tone curves. You may wish to compare the results of different calibration methods, e.g. G7 vs. Optimal. These settings allow you to use the same CED sample set for each method, for a valid comparison.

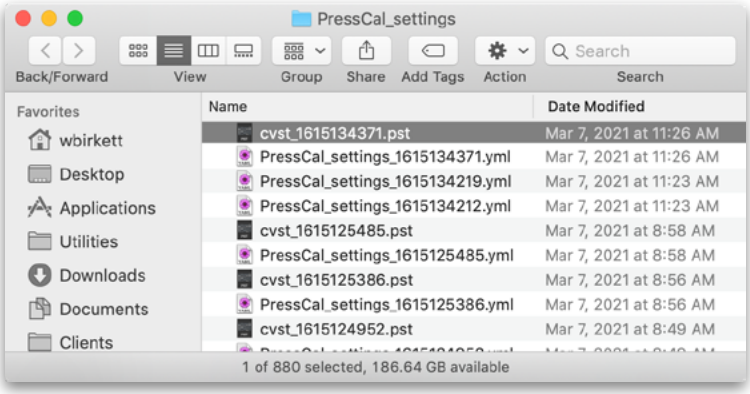
Iterative Workflow

Normally, linear plates (no tone curves applied) are used to print the test sheets. Once ink densities are set, we measure the test charts, and compute tone curves to match the reference profile. If the press characteristics are identical to the reference data set, but for tonality, PressCal will generate tone curves that cannot be improved. But, if the residual color errors are significant, this indicates differences between the press and reference data set that cannot be completely resolved with tone curves.

In this case, it may be possible to improve the color match by making new tone curves based on measurements of the verification run. We call this an iterative workflow, because it may be repeated until no further improvement is obtained.

PressCal will incorporate the initial tone curves into the calculation of the new curves. The **`plate_curve_path:`** [setting](#) identifies the tone curves that were used to make the verification plates. If the tone curves were generated by PressCal, the path would be to a curve set file (.pst suffix) in the settings folder.

Curve set files are named **cvst_xxxxxxxxxx.pst**, where **xxxxxxxxxx** is the [Unix time](#) when the file was created. You will need to identify the curve set corresponding to the test plate curves. If you're unsure, check the file creation dates.



Once you've entered the paths for the plate curves and your new press measurements, run the curve building function (⌘**R**). PressCal will combine the plate curves with those generated from the new measurements. The resulting curves will further reduce color errors. This process may be repeated until there is no further improvement.

You may find that the mean color error of your second curve set is no better than your first, yet the second optimization appeared to make some improvement. This is likely due to variation of the press between the first and second runs. Both curve sets are correct for the press conditions that created them.

Tone Curve Limitations

You may be aware that software used to make ink jet proofs (e.g. GMG, Oris, EFI) uses a similar iterative process. These systems fine-tune multi-dimensional look-up tables (LUTs), which makes it theoretically possible to match the reference profile perfectly. Tone curves, on the other hand, cannot generally eliminate all color errors. There will aways be some residual errors, which we try to minimize.

Variation

Because we use color management tools to create press curves, it is tempting to think of an offset press as a large ink jet printer. An experienced pressman will tell you why that is mistaken.

An offset press is subject to many variations, and requires considerable skill to operate. Press characteristics are dynamic. It takes some time for the ink-water balance to stabilize, and color may drift throughout a run. Ink keys allow density adjustments side-to-side, but not around the cylinder. There are myriad factors that may affect color.

Pressman's Skill

It is the pressman's job to obtain good color reproduction everywhere on the sheet, by reproducing the press conditions measured by the test chart(s). A well made set of curves enables the pressman to achieve good color matching. But curves are not a substitute for the pressman's skill.

Basic Settings Files

The **PressCal_Basic_Settings** folder contains generic settings files for the most common calibration scenarios. You may edit these files by changing the setting values, or by adding or deleting individual settings.

Here are links to user manual sections explaining these basic settings files:

PressCal_Default.yml – Make curves to match a color reference.

PressCal_TVI.yml – Make curves based on the tone value increase (TVI) of the process ramps (ISO 12647-2).

PressCal_G7.yml – Make curves based on the color of a CMY gray ramp and a black ramp, for submission to IDEAlliance (G7*, CGATS TR 015).

PressCal_G7_Plus.yml - Make curves using the G7+* concept to fix erratic shadow behavior.

PressCal_Optimal.yml – Make curves that minimize the color error of realistic test chart samples (Optimal Method).

PressCal_Optimal_Plus.yml – Make Optimal curves blended with SCTV curves to improve shadow rendition.

PressCal_SCTV.yml – Make curves that linearize the spot color tone value (SCTV) of the tone ramps (ISO 20654).

PressCal_Proof.yml – Make curves that minimize the color error of a control strip or profiling test chart (ISO 12647-7).

PressCal_G7_Proof.yml – Make curves that minimize the color error of test chart samples, for submission to IDEAlliance (G7*, CGATS TR 015).

PressCal_Flexo.yml – Make curves for flexo printing with spot colors and CxF/X-4 files (Optimal Method).

PressCal_Extended_Gamut.yml – Make curves for a CMYKOGV process (Optimal Method).

PressCal_Multi.yml – Make curves for a CMYKOGV process using mapped multiple reference profiles and measurement files (Optimal Method).

PressCal_PSD.yml – Make curves that minimize the color error of realistic test chart samples (ISO/TS 15311-2).

PressCal_Media_Profile.yml – Calibrate a media profile to minimize the color error of a control strip.

PressCal_RGB.yml – Make curves for an RGB process (Optimal Method).

PressCal_Normalize.yml – Make a custom reference data set.

PressCal_Dissimilar.yml – Make curves for a very dissimilar process.

PressCal_Bernstein.yml – Experiment with the curve optimization settings.

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* G7 and G7+ are registered trademarks of IDEAlliance

Locked Files

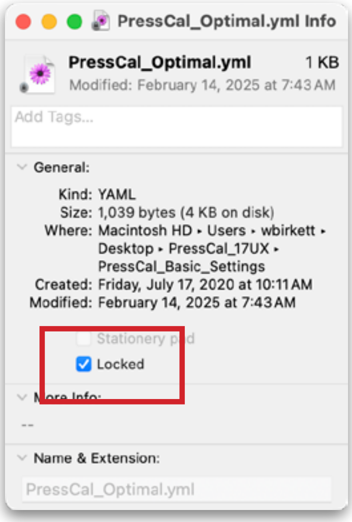
The basic settings provided with PressCal are locked files. You can edit them in TextMate, but you cannot write over them. File locking is enabled or disabled by a check box in the file's **Get Info** pane (see below).

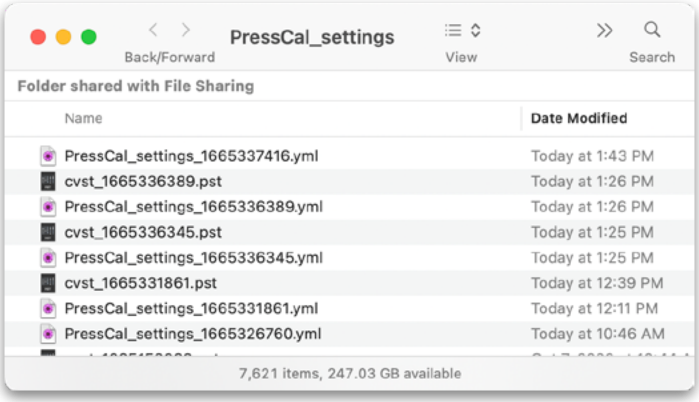
Custom Templates

Basic settings include some relevant settings as comments, which you may activate to create a custom template. Once you have the settings you like, save the file with another name (and .yml extension), and lock it. This file is then a template for future work. When you use the template, you will change some of the settings. Each time you run PressCal, the modified settings are saved in the **PressCal_settings** folder as a .yml file (see below). If curves were built, they are saved as a .pst file. You may wish to archive these files for future reference.

Line Order

If there are duplicate settings in a .yml file, only the last one is active. Other than that, settings may be arranged in any order. Also, each setting is limited to one line, ending with a return. TextMate has a "soft wrap" item in the "View" menu. With this option enabled, long lines will wrap around, giving the appearance of multi-line settings.





Default Basic Settings

The **Optimal Method** is a unique calibration technique for *matching color printing to an ICC profile using tone curves*. A color test chart is printed and measured with a spectrophotometer. The **`press_path:`** setting is the path to these measurements. The ICC profile is typically a standard reference profile such as **GRACoL2013_CRPC6** or **FOGRA51**. The **`profile_path:`** setting is the path to this profile.

The matching algorithm is explained graphically by this flow chart. It is simple in concept, but requires special software. **PressCal** is an open-source software tool that implements the Optimal Method and other common calibration techniques.

The desired print characteristics are represented by an ICC profile, rather than traditional print metrics like density, TVI, and print contrast. The same is true for color-managed ink jet proofs, and for digital print, both cut sheet and wide format. So, the Optimal Method is the ideal calibration tool for a modern print shop.

Properties

The Optimal Method works with any colorspace. This includes, RGB, CMYK, CMYK + spots, or ECG, e.g., CMYKOGV. The **`ink_map:`** setting, allows you to choose the curve building technique for each print channel.

The Optimal Method works with any sample set, unlike other techniques that require specific targets and/or samples. PressCal uses all measurement samples by default. A sample subset may be chosen with the **`select:`** setting. This permits using samples most likely to appear in jobs, and avoiding samples that cause problems.

Vector curves are computed to minimize the overall color errors of the sample set. These curves are perfectly smooth, and may be output in a variety of curve formats, according to the **`output:`** setting. The "complexity" of the curves is controlled by the **`degree:`** setting. These curves are **Bernstein polynomials** – elegant mathematical functions ideally suited for this purpose. If you are math-averse, don't worry. PressCal handles the scary details.

PressCal supports **CIE 015:2018** colorimetry, including all standard observers and illuminants. This is important when your printed materials are being used in non-D50 conditions, e.g., store lighting. It also supports measurement conditions (M0, M1, M2) and M1/M2 blending with the **`condition:`** setting. This is important when your media contains optical brighteners (OBAs). The reference profile colors are mapped to your press measurements with variable rendering intent, according to the **`rendering:`** setting.

Run The Tools

PressCal provides three tools – grade, ink balance, and curves.

Run the grade tool with the ⌘**I** key combination. This tool compares your measured printing to the reference profile, and will grade it according to the rules you select. This is useful if you plan to submit your press sheets for certification.

It is also useful to identify problems with the presswork. Graphs of the individual tone ramps are plotted using SCTV. These curves should be smooth. Graphs of CMY and K gray balance errors are also plotted, when the press measurements contain G7 gray samples.

Run the ink balance tool with the ⌘**B** key combination. This tool helps set solid ink densities for offset and flexo printing. It requires spectral data. The term ink balance comes from combined optimization of CMY and RGB overprints.

Run the curve building tool with the ⌘**R** key combination. The solid ink colors are displayed, followed by the initial color errors of the selected samples. These errors are the color differences between the measured press samples and corresponding colors computed using the reference ICC profile. Tone curves are built to minimize the color errors, which are then displayed again.

Tone curve graphs are displayed in your web browser, followed by error distribution graphs, before and after optimization. The residual color error is a good measure of how well the print matches the reference profile.

Disabled Settings

Some of the settings are disabled by a **#** at the start of the line. You can enable these settings by deleting the **#** character. The user manual contains an explanation of each setting in the **Settings Reference** section. By enabling the settings, one by one, you can see the effects they have, and experiment with different setting values.

Other Basic Settings

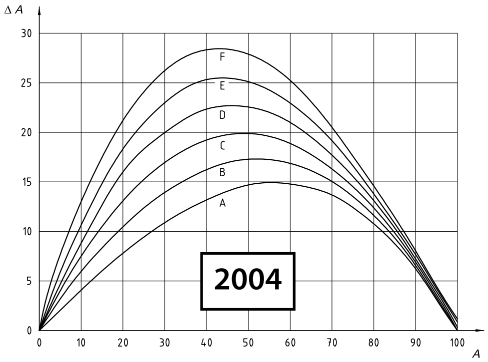
The purpose of the default basic settings is to introduce the **Optimal Method** and **PressCal** software. Check the index to locate other basic settings that address your specific needs.

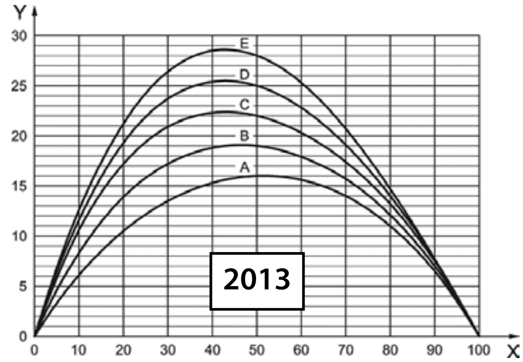
TVI Basic Settings

TVI (tone value increase) is a tone metric derived from density measurements. It is the difference between a sample's %-dot value, computed from density, and the corresponding image value. The **ISO 12647-2** standard specifies TVI curves for various paper types. PressCal will make tone reproduction curves to achieve these aims.

ISO Standard Versions

The ISO 12647-2 standard was revised in **2004**, and again in **2013**.





The curves are labeled A - F in the 2004 standard, and A - E in the 2013 standard. Although the labels are common, the curves are different. Curve usage for the various paper types is specified in the standards. **FOGRA39** is based on the 2004 standard, using TVI curve **A** for **CMY** and TVI curve **B** for **K**. **FOGRA51** is based on the 2013 standard, using TVI curve **A** for all colors. This information is found within the FOGRA data sets.

The ISO 12647-2 standards also specify the color of the substrate and solid inks (**CMYKRGBI**) for each paper type. The 2004 standard lists 5 paper types. The 2013 standard lists 8 paper types. The 2013 standard uses **M1** measurements, while the 2004 standard uses **M0** (legacy) measurements.

The **`12647-2:`** setting selects the ISO standard version used for grading. PressCal uses the tolerances for an **OK print**. Production prints would normally be checked at the press console.

Reference Profile

PressCal uses a reference profile to obtain the target substrate and solid ink colors. This profile would normally be made from a FOGRA data set. Some commonly used profiles are available from the ECI. A reference profile is not required to make TVI curves, but is required for grading. The **`profile_path:`** setting selects the reference profile. This profile may be built-in or external.

Press Measurements

PressCal compares measurements of your printing process with your selected reference profile. The printing should be done carefully. Here are some guidelines for obtaining good measurements. Use linear plates, if possible. Otherwise, add the **`plate_curve_path:`** setting to input the initial plate curves.

The test chart must contain process color ramps. PressCal will locate these samples within a test chart containing them. We recommend the **PressCalF51** test chart, which includes samples for the ink balance tool.

The illustration below shows typical process ramp samples.

The **`press_path:`** setting should be the path to your measurements. If you measure multiple test charts, and wish PressCal to average them, place the individual files in a folder, and use the path to the folder.

If your instrument supports it, we recommend you measure M0, M1, and M2 data, and save it in CxF3 format (.mxf or .rmxf). Otherwise, you should select the measurement condition of the standard, and save the spectral data in CGATS ASCII format. *Spectral data is required to compute TVI.*

The **`condition:`** setting selects the data used from CxF3 files containing multiple measurement conditions. Normally, this setting should match the measurement condition of the standard (M0 for 2004, M1 for 2013).

Initial Grading

At this point, you've measured your initial press sheet and entered your values for the settings just covered. In TextMate, with the settings file open, press the ⌘I key combination to run the grade tool. The test results will be displayed in the grade log. If your press sheet failed any tests, you'll need to make changes.

Color First

You should make any changes to the colorant strength and balance before making tone curves. Colorant changes will affect gray balance and tone, but tone curves won't affect solid ink colors (with the endpoints pinned).

The grading log example (below) indicates the solid colors are all within tolerance.

```
standard: 12647-2, version: 2013, level:

substrate color error

             ΔL: 0.20 ✔ [3.00]
             Δa: 0.36 ✔ [2.00]
             Δb: 0.39 ✔ [4.00]

CMYK solids color error

      cyan ΔEab: 3.10 ✔ [5.00]
   magenta ΔEab: 2.56 ✔ [5.00]
    yellow ΔEab: 2.25 ✔ [5.00]
     black ΔEab: 2.80 ✔ [5.00]

CMYK solids color error

        cyan ΔH: 1.43 ✔ [3.00]
     magenta ΔH: 0.46 ✔ [3.00]
      yellow ΔH: 1.92 ✔ [3.00]
```

Even though the ISO 12647-2 standard supplies colors for the RGB overprints, they are not graded. Here is the explanation for this omission, "*The secondary colours red, green and blue depend on conditions that include the printing sequence, the rheological and transparency properties of the inks, mechanics of the press and the surface characteristics of the print substrate. Thus, it is not possible to state tolerance windows for both solids and overprints.*"

Nevertheless, the overprint colors are important. The hue of these colors is controlled by the ink balance. In this example, the green error is large (4.66), primarily due to the b* value, suggesting the yellow ink is too strong.

```
          abs L*a*b* values   ->   ref L*a*b* values     press L*a*b* values    ΔEab    ΔE00
  paper  95.0   1.5   -6.0       95.0   1.5   -6.0       94.8   1.9   -6.4     0.56    0.56
   cyan  56.1 -34.9  -52.5       56.1 -34.9  -52.5       55.7 -32.2  -51.0     3.10    1.04
magenta  48.1  75.3   -5.2       48.1  75.3   -5.2       49.9  73.6   -4.6     2.56    1.86
 yellow  88.9  -4.0   92.4       88.9  -4.0   92.4       89.4  -6.0   93.3     2.25    1.08
    red  48.0  69.3   45.9       48.0  69.3   45.9       48.4  67.5   45.4     1.90    0.63
  green  49.4 -65.9   24.3       49.4 -65.9   24.3       50.1 -65.0   28.9     4.66    2.03
   blue  24.7  21.1  -47.5       24.7  21.1  -47.5       25.1  21.3  -46.0     1.48    0.88
    iso  23.2  -1.4   -1.7       23.2  -1.4   -1.7       22.9  -0.4   -2.3     1.25    1.60
  black  16.0   0.0   -0.4       16.0   0.0   -0.4       17.8   0.9    1.6     2.80    2.54
   cmyk  12.2   0.4    4.9       12.2   0.4    4.9        9.9   0.7   -0.2     5.57    4.90
```

Ink Balance Tool

The ink balance tool will help you make solid color adjustments. This tool was designed for offset and flexo printing. It could be helpful when adjusting other printing processes.

The ink balance tool (⌘**B** key combination) builds a spectral model from the current measurements, and uses that to determine the optimal ink densities. Here is the end of the ink balance log, showing the suggested density changes.

```
status E densities:

          nom    opt    change
   cyan  1.321  1.356   +0.03
magenta  1.309  1.328   +0.02
 yellow  1.315  1.278   -0.04
  black  1.600  1.672   +0.07
```

Program exited with code #1 after 2.18 seconds.   copy output

All of the inks have suggested changes (above). The cyan density is **increased by 0.03**, and the yellow **decreased by 0.04**. This reduces the green error (**4.66** to **1.84** ΔEab), without pushing the other colors out of tolerance.

```
optimized solid ink errors:

          abs L*a*b* values   ->   ref L*a*b* values     press L*a*b* values    ΔEab    ΔE00
  paper  95.0   1.5   -6.0       95.0   1.5   -6.0       94.8   1.9   -6.4     0.56    0.56
   cyan  56.1 -34.9  -52.5       56.1 -34.9  -52.5       54.8 -31.7  -51.8     3.51    1.71
magenta  48.1  75.3   -5.2       48.1  75.3   -5.2       49.6  73.9   -4.1     2.36    1.59
 yellow  88.9  -4.0   92.4       88.9  -4.0   92.4       89.6  -6.2   91.9     2.33    1.24
    red  48.0  69.3   45.9       48.0  69.3   45.9       48.3  68.1   44.4     1.94    0.57
  green  49.4 -65.9   24.3       49.4 -65.9   24.3       49.3 -65.4   26.1     1.84    0.79
   blue  24.7  21.1  -47.5       24.7  21.1  -47.5       24.2  20.9  -46.0     1.54    0.74
    iso  23.2  -1.4   -1.7       23.2  -1.4   -1.7       22.0  -1.0   -4.4     2.98    2.61
  black  16.0   0.0   -0.4       16.0   0.0   -0.4       16.0   0.9    1.6     2.08    2.19
   cmyk  12.2   0.4    4.9       12.2   0.4    4.9         sample missing      ----    ----
```

Notice that some of the errors have increased. This give-and-take behavior is the reason we call the tool "ink balance."

Making small ink density adjustments is tricky, and may require several tries. It is best to leave inks that are close to the suggested values unchanged, and focus on the inks with larger changes. You should measure each pull, and run the ink balance tool to see if further adjustments are indicated. Be sure to mark each pull in the delivery, so you can retrieve additional sheets for curve building. Run the grade tool to see if your sheet passes the solid color tests.

When you are satisfied with your ink densities, look at the grade tool tests for the **CMYK TVI error**.

```
CMYK TVI error

     tone range: 0 to 30
      cyan-A ΔT: 11.17 ✘ [3.00]
   magenta-A ΔT: 14.21 ✘ [3.00]
    yellow-A ΔT: 12.86 ✘ [3.00]
     black-A ΔT: 19.50 ✘ [3.00]

     tone range: 30 to 60
      cyan-A ΔT: 10.34 ✘ [4.00]
   magenta-A ΔT: 14.05 ✘ [4.00]
    yellow-A ΔT: 13.58 ✘ [4.00]
     black-A ΔT: 19.14 ✘ [4.00]

     tone range: 60 to 100
      cyan-A ΔT: 7.14 ✘ [3.00]
   magenta-A ΔT: 8.58 ✘ [3.00]
    yellow-A ΔT: 9.85 ✘ [3.00]
     black-A ΔT: 13.23 ✘ [3.00]

  max spread ΔT: 3.72 ✔ [5.00]
```

If your press sheet failed any of these tests, you'll need to make tone curves. In this example, all of the tests failed except the TVI spread.

Curve Settings

When making tone curves, it is good practice to average the measurements of several press sheets, using opposed target pairs. Put the measurements in a folder, and copy the folder path to your **`press_path:`** setting.

The **`tvi_std:`** setting selects the ISO 12647-2 version used for the curve functions. Normally, this is the same as the **`12647-2:`** setting, which selects the grading rules. The **`ink_map:`** setting selects the curve functions for each ink channel in the press measurements. These are letter values, **`A – F`** for the 2004 standard, or **`A – E`** for the 2013 standard.

Making Curves

Once you are satisfied with your settings, press the **⌘R** key combination to run the curve building tool. A log window will open, showing the software's progress. The log begins with the same output as the grade and ink balance tools. This includes your settings, and the solid ink errors. A message is displayed as each curve is calculated.

The Bernstein curve parameters are displayed, followed by a message as each curve format is output. In this example, only the text format is output. You may wish to add output tokens for additional format(s), to simplify importing the curves into your DFE.

```
making TVI type 2013:A curve, channel 0
making TVI type 2013:A curve, channel 1
making TVI type 2013:A curve, channel 2
making TVI type 2013:A curve, channel 3

curve parameters:

             HLV    1/8    2/8    3/8    4/8    5/8    6/8    7/8    SHV
     cyan  0.000  0.243  0.465  0.063  1.152  0.386  0.878  0.884  1.000
  magenta  0.000  0.243  0.527  0.144  1.078  0.429  0.935  0.876  1.000
   yellow  0.000  0.218  0.535  0.070  1.213  0.316  1.059  0.866  1.000
    black  0.000  0.271  0.657 -0.045  1.537  0.176  1.157  0.883  1.000

writing curves in 'text'        format to /Users/wbirkett/Desktop/tab_delim.txt

Program exited with code #0 after 2.82 seconds.                    copy output
```

G7* Basic Settings

The G7* method is a calibration technique promoted by IDEAlliance. The technique is documented as an ANSI CGATS technical report (TR 015), and as such, may be used freely without involving IDEAlliance. However, most of the time printers are seeking G7 Master Qualification, which requires a trained G7 expert to submit qualified proofs and press sheets to IDEAlliance, plus payment of fees, annually.

Compliance Levels

The rules by which a G7 submission is graded are found in the document **G7 Master Pass/Fail Requirements**, available from IDEAlliance. This document defines three compliance levels – **G7 Grayscale**, **G7 Targeted**, and **G7 Colorspace**. Under certain conditions, the reference data set may be adjusted using SCCA. This creates two additional levels – **G7 Targeted Relative** and **G7 Colorspace Relative**. G7 Colorspace has two sub levels – **Proof** and **Press**.

The **`g7_level:`** setting selects the compliance level. This setting only affects the grading function.

Reference Profile

For G7 Targeted and G7 Colorspace compliance, you must choose a **CRPC data set**. These data sets represent the characteristics of offset printing on common paper types. Therefore, it may not be possible, or even desirable to calibrate your printing process for G7 Targeted or G7 Colorspace compliance. In that case, G7 Grayscale compliance is an option; but be aware that G7 Grayscale compliance provides no assurance of accuracy in colored image areas.

Digital printing processes are usually color-managed to match a standard reference profile. For G7 qualification, this profile should be built from a CRPC data set. Be sure the digital printing process has a large enough gamut to render the CRPC data set.

The **`profile_path:`** setting should be the path to an ICC profile, built from the chosen CRPC data set. This profile may be built-in or external.

Press Measurements

PressCal compares measurements of your printing process with your selected reference profile. The printing should be done carefully. Here are some guidelines for obtaining good measurements. Use linear plates, if possible. Otherwise, add the **`plate_curve_path:`** setting to input the initial plate curves.

Press sheets containing test charts are submitted to IDEAlliance. The test charts must contain specific **CMYK** samples. All compliance levels require a ramp of **CMY** gray samples and a ramp of K samples. G7 Targeted compliance also requires samples of the solid **CMY** inks, and the **RGB** overprints. G7 Colorspace compliance further requires all unique IT8.7/4 samples.

We recommend the **P2P51** test chart for G7 Grayscale or G7 Targeted compliance. For G7 Colorspace compliance, use a **TC1617** or **IT8.7/5** test chart. These charts are available for various instruments and configurations.

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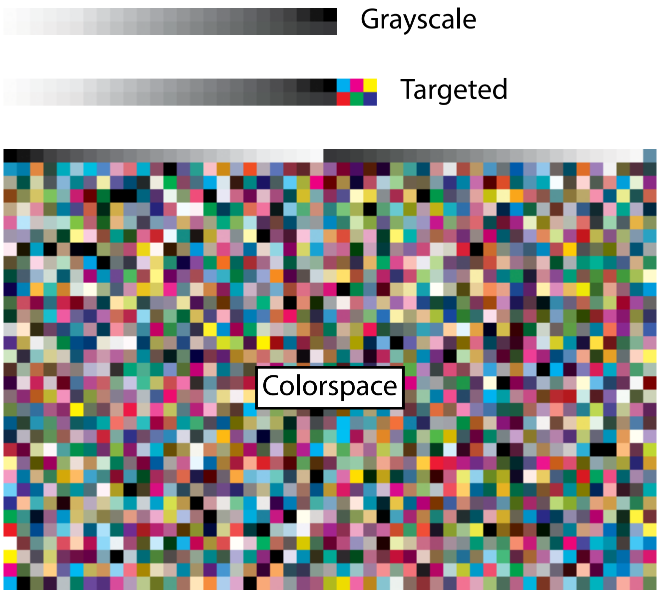
* G7 is a registered trademark of IDEAlliance

The illustration below shows the data samples required for the G7 compliance levels.



The **`press_path:`** setting should be the path to your measurements. If you measure multiple test charts, and wish PressCal to average them, place the individual files in a folder, and use the path to the folder.

If your instrument supports it, we recommend you measure M0, M1, and M2 data, and save it in CxF3 format (.mxf or .rmxf). Otherwise, you should select the measurement condition of the reference profile, and save the spectral data in CGATS ASCII format. Note that some PressCal functions require spectral data.

The **`condition:`** setting selects the data used from CxF3 files containing multiple measurement conditions. Normally, this setting should match the measurement condition of the reference profile. But, for Grayscale compliance, you may use M0, M1, or M2 measurements.

Initial Grading

At this point, you've measured your initial press sheet and entered your values for the settings just covered. In TextMate, with the settings file open, press the **⌘I** key combination to run the grade tool. The test results will be displayed in the grade log. If your press sheet passed all of the tests, you may submit it to IDEAlliance. If your press sheet failed any tests, you'll need to make changes.

Color First

You should make any changes to the colorant strength and balance before making tone curves. Colorant changes will affect gray balance and tone, but tone curves won't affect solid ink colors (with the endpoints pinned).

For **G7 Grayscale** compliance, there are no tests of the CMYRGB colors. However, the colorants should be adjusted to make the isometric solid (C+M+Y) close to gray. The ΔCh tolerance for this solid is 12 – so you have considerable latitude.

Ink Balance Tool

For **G7 Targeted** and **G7 Colorspace** compliance, the ink balance tool will help you make solid color adjustments. This tool was designed for offset and flexo printing. It could be helpful when adjusting other printing processes.

Here is an example of the grade log, showing test results for the solid colors.

```
substrate color error

           ΔE00: 1.96 ✔ [3.00]

CMYK solids color error

      cyan ΔE00: 2.46 ✔ [3.50]
   magenta ΔE00: 1.20 ✔ [3.50]
    yellow ΔE00: 0.41 ✔ [3.50]
     black ΔE00: 3.40 ✔ [5.00]

RGB solids color error

       red ΔE00: 2.12 ✔ [4.20]
     green ΔE00: 0.94 ✔ [4.20]
      blue ΔE00: 5.93 ✘ [4.20]

failed 2 tests
```

In this example, the substrate (paper) and solid colors are within tolerance, except for blue (C+M). It may be possible to fix this by adjusting the cyan and/or magenta ink densities, but that risks pushing those colors and/or their secondaries (CMRG) out of tolerance. This is a complex problem because of these interactions, and the non-linear relation between ink density and color error.

The ink balance tool (⌘**B** key combination) builds a spectral model from the current measurements, and uses that to determine the optimal ink densities. Here is the end of the ink balance log, showing the suggested density changes.

```
status T densities:

            nom     opt    change
     cyan   1.266   1.321   +0.06
  magenta   1.528   1.452   -0.08
   yellow   1.034   1.055   +0.02
    black   1.709   1.669   -0.04

Program exited with code #1 after 2.73 seconds.                copy output
```

All of the inks have suggested changes (above). The cyan density is **increased by 0.06**, and the magenta **decreased by 0.08**. This reduces the blue error (**5.93** to **3.64** ΔE_{00}) which passes G7 Targeted, without pushing the other colors out of tolerance.

```
optimized solid ink errors:

            abs L*a*b* values   ->   ref L*a*b* values       press L*a*b* values     ΔEab     ΔE00
   paper    95.0    1.0   -4.0       95.0    1.0   -4.0       95.4    1.6   -6.2     2.34     1.96
    cyan    56.0  -37.0  -50.0       56.0  -37.0  -50.0       56.5  -32.2  -52.6     5.48     2.27
 magenta    48.0   75.0   -4.0       48.0   75.0   -4.0       49.6   77.8   -4.9     3.30     1.70
  yellow    89.0   -4.0   93.0       89.0   -4.0   93.0       88.4   -4.3   93.8     1.02     0.43
     red    47.0   68.0   48.0       47.0   68.0   48.0       49.4   70.1   47.5     3.25     2.54
   green    50.0  -66.0   26.0       50.0  -66.0   26.0       48.9  -63.9   25.5     2.42     1.26
    blue    25.0   20.0  -46.0       25.0   20.0  -46.0       23.7   27.6  -49.4     8.41     3.64
     iso    23.0    0.0   -0.0       23.0    0.0   -0.0       21.9   -0.5   -2.6     2.85     2.65
   black    16.0    0.0   -0.0       16.0    0.0   -0.0       16.0    1.8    2.4     3.02     3.35
    cmyk     9.0    0.2    0.4        9.0    0.2    0.4         sample missing       ----     ----
```

Notice that some of the errors have increased. This give-and-take behavior is the reason we call the tool "ink balance."

Making small ink density adjustments is tricky, and may require several tries. It is best to leave inks that are close to the suggested values unchanged, and focus on the inks with larger changes. You should measure each pull, and run the ink balance tool to see if further adjustments are indicated. Be sure to mark each pull in the delivery, so you can retrieve additional sheets for curve building. Run the grade tool to see if your sheet passes the solid color tests.

When you are satisfied with your ink densities, look at the grade tool tests for the **CMY gray ramp** and **black ramp**.

```
CMY gray ramp color errors using TR 015 (G7) formulas

    average wΔL: 0.35 ✔ [1.50]
    maximum wΔL: 1.25 ✔ [3.00]
   average wΔCh: 1.35 ✔ [1.50]
   maximum wΔCh: 2.67 ✔ [3.00]

black ramp color errors using TR 015 (G7) formulas

    average wΔL: 1.38 ✔ [1.50]
    maximum wΔL: 4.64 ✘ [3.00]
```

If your press sheet failed any of these tests, you'll need to make tone curves. In this example, the black ramp maximum wΔL test failed. Other tests barely passed.

Curve Settings

When making tone curves, it is good practice to average the measurements of several press sheets, using opposed target pairs. Put the measurements in a folder, and copy the folder path to your **`press_path:`** setting.

In this example, the **`ink_map:`** setting is **`[0, 1, 2, N]`**. This indicates the **CMY** curves are optimized to match the reference profile. The black curve is built separately, using the TR 015 tone formula. See this section for more information on the ink map.

The **`select:`** setting is a list of tokens that select the samples. The **CMY** curves are built from samples with G7 gray balance, as defined in TR 015. PressCal will locate these samples in any test chart that contains them. The **`g7`** token selects samples with G7 gray balance. The **`nosub`** token filters substrate samples. The **`sort(1)`** token sorts the samples by the cyan value. There is no reason to change this setting, except to remove bad samples with the **`minus`** token. The black curve is built using all of the black ramp samples in the test chart. There is no setting for selecting these samples.

The **`rendering:`** setting controls the color mapping of the reference profile for comparison with the press measurements. The normal setting for G7 curves is media relative (**`[0, 0]`**), as stipulated by the **G7 Master Pass/Fail Requirements**. Oddly, this conflicts with the grading of G7 Targeted and G7 Colorspace samples, which requires absolute rendering, unless the substrate error is between 2 and 5 ΔE_{00}, and SCCA is used. This suggests you should choose a substrate with a very small error, or an error slightly greater than 2 (to permit SCCA).

Although the grading rules are stipulated by IDEAlliance, you are free to make tone curves by any means you choose. The **`rendering:`** setting allows you to fine-tune the color mapping to suit your needs. By default, rendering is media relative. This maps the white point of the reference profile to the color of your paper stock. If the printing paper and proofing media are different colors, you might try luminance relative rendering. This will bend the tone curves subtly to provide a better visual match. Ideally, the proofing media would be the same color as the printing paper, but this is not always possible.

The **`deltaE:`** setting selects the optimization error function. The **`dLCh`** function computes wΔL* and wΔCh for each sample. Mathematically, the G7 method boils down to minimizing these values.

Making Curves

Once you are satisfied with your settings, press the ⌘**R** key combination to run the curve building tool. A log window will open, showing the software's progress. The log begins with the same output as the grade and ink balance tools. This includes your settings, and the solid ink errors. Then, you will see a single line with information about the sample selection. In this example, 32 samples were selected. For each sample, the initial device values, L*a*b* values, and error values are displayed.

```
       green    50.0  -66.0   26.0      50.3  -65.9   25.1      50.5  -63.2   26.3     2.99     1.06
        blue    25.0   20.0  -46.0      25.2   20.4  -47.5      23.3   29.8  -46.5     9.65     6.34
         iso    23.0    0.0   -0.0      23.2    0.2   -0.8      21.8    4.5   -2.7     4.87     5.80
       black    16.0    0.0   -0.0      16.1    0.2   -0.6      15.0    1.8    2.4     3.60     3.67
        cmyk     9.0    0.2    0.4       9.1    0.4   -0.1      10.3    1.3    3.5     3.86     3.60


degree: 8, sample selection: 'g7 nosub sort(1)', samples: 32

sample        device values              ref L*a*b* values      press L*a*b* values      wΔL*     wΔCh
17      0.020  0.015  0.015  0.000      93.7    1.8   -6.0      94.3    1.0   -6.9     0.59     1.22
29      0.040  0.030  0.030  0.000      92.1    1.9   -5.8      92.4    1.1   -6.7     0.33     1.21
41      0.060  0.045  0.045  0.000      90.5    1.9   -5.7      90.4    1.2   -6.2    -0.09     0.88
53      0.080  0.060  0.060  0.000      88.9    1.8   -5.6      88.9    1.0   -5.7    -0.05     0.74
65      0.100  0.075  0.075  0.000      87.3    1.7   -5.5      87.0    1.2   -5.4    -0.30     0.45
```

The average initial errors are displayed, and the optimization commences. After a short time, the optimization is complete, and the sample data is displayed again, this time with the newly computed curves applied.

```
257     0.900  0.853  0.853  0.000      29.0    0.7   -0.7      28.0    5.4    0.9    -0.42     1.97
269     0.950  0.925  0.925  0.000      25.8    0.3   -0.8      25.1    7.7    2.2    -0.22     2.60
281     0.980  0.969  0.969  0.000      24.1    0.2   -0.8      23.5    6.0   -1.5    -0.16     1.62
1       1.000  1.000  1.000  0.000      23.2    0.2   -0.8      21.8    4.5   -2.7    -0.33     1.17
293     1.000  1.000  1.000  0.000      23.2    0.2   -0.8      21.8    4.5   -2.7    -0.33     1.17

                                              initial weighted average error    0.34     1.34

optimizing curves for minimum ΔLCh...

L-M optimization completed at 836 iterations

error values with optimized curves are below...

sample        device values              ref L*a*b* values      press L*a*b* values      wΔL*     wΔCh
17      0.020  0.015  0.015  0.000      93.7    1.3   -6.5      94.3    1.0   -6.9     0.68     0.47
29      0.040  0.030  0.030  0.000      92.0    1.1   -6.5      92.4    1.1   -6.7     0.39     0.26
41      0.060  0.045  0.045  0.000      90.5    1.1   -6.3      90.4    1.2   -6.2    -0.07     0.11
53      0.080  0.060  0.060  0.000      88.9    1.1   -6.1      88.9    1.0   -5.7    -0.06     0.33
```

The average optimized errors and final gamut scale factor are displayed. The average optimized errors should be less than the initial values. These values are for the **CMY** gray ramp. The black curve is computed separately, as specified in TR 015.

```
281     0.980  0.969  0.969  0.000      23.1    3.2    0.1      23.5    6.0   -1.5     0.10     0.90
1       1.000  1.000  1.000  0.000      21.9    0.2   -0.6      21.8    4.5   -2.7    -0.01     1.20
293     1.000  1.000  1.000  0.000      21.9    0.2   -0.6      21.8    4.5   -2.7    -0.01     1.20

                                            optimized weighted average error    0.26     0.52

final gamut scale factor = 1.004

making G7 black curve, channel 3
```

The Bernstein curve parameters are displayed, followed by a message as each curve format is output. In this example only the text format is output. You may wish to add output tokens for additional format(s), to simplify importing the curves into your DFE.

```
curve parameters:

            HLV    1/8    2/8    3/8    4/8    5/8    6/8    7/8    SHV
    cyan  0.000  0.199  0.001  0.873  0.090  0.519  1.075  0.613  1.000
 magenta  0.000  0.076  0.382  0.251  0.457  0.790  0.591  0.999  1.000
  yellow  0.000  0.104  0.332  0.275  0.470  0.526  0.775  0.863  1.000
   black  0.000  0.113  0.377  0.047  1.042  0.256  1.094  0.802  1.000

writing curves in 'text'        format to /Users/wbirkett/Desktop/tab_delim.txt
```

Program exited with code #0 after 5.23 seconds. copy output

Verification Press Run

The curves are used to produce a new press sheet, which should now conform with the G7 requirements.

If your printing process uses plates, you will need to make new ones, using the curves. The press should be run without any changes other than the plates. That said, it may still be necessary to make some small changes to obtain the prior ink densities.

If your printing process is digital, you will need to incorporate the curves into your workflow. If they cannot be loaded directly into your DFE, it is possible to apply them to ICC profiles, as explained here.

The new press sheets should be measured and graded to verify they pass all tests. If not, it may be possible to obtain passing sheets with small density adjustments, guided by the grading results.

Occasionally, it may be necessary to compute a second set of curves from the verification measurements. These measurements already have plate curves applied. The **`plate_curve_path:`** setting includes the plate curves into the calculations for the next set of curves.

G7 Qualification

Typically, G7 qualification is driven by sales and marketing considerations. Although widely used, the G7 method has some technical shortcomings. It is our experience that pressmen are often disappointed with the technique, because it made matching proofs more difficult.

If your G7 tone curves are wonky, activating the gb_fade: setting may improve the match to proofs, without causing the press sheet to fail G7 certification.

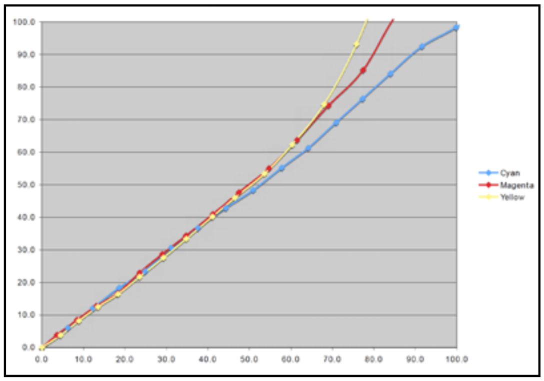
Fortunately, there is no requirement to use the G7 qualification curves in production. The Optimal method overcomes the limitations of the G7 method by building curves from the color samples likely to appear in your images. With the PressCalC6 test chart, it is possible to make both G7 and Optimal curves from the same press measurements.

G7 Plus* Basic Settings

G7+ Improvements

G7+ is an improved version of the original G7 Method. Here is a link promoting G7+ from Printing United Alliance. To summarize, G7+ is vastly improved in every way, yet there is hardly any discernible difference in the printed results.

All kidding aside, there are some big changes. Foremost is a fix for the long-standing problem we identified in 2006. When the CMY solid is not neutral, G7 curves diverge in the shadows, causing poor rendition of dark colors. This is fixed in G7+ by splicing TVI curves into the shadow region (where %-dot is greater than 75%). TVI curves are made from pure process ramps, and are generally well behaved. This change fixes divergent curves, but may cause a discontinuity where the curves join at 75%.



Divergent Curves from TC-130 Presentation

Other improvements were borrowed from PressCal. G7+ now uses a correct definition of gray, which we suggested in 2009. This fixes some subtle problems involving gray balance. The desired tonality of gray ramps is now taken from a reference ICC profile, and is adjusted in XYZ space to match the print gamut. These are all standard features of PressCal.

PressCal Implementation

This basic setting implements G7+ correctly, except for one thing – the use of TVI to define the curve shape for tone values > 75%. Instead, we use PressCal's optimization algorithm to minimize the color error of the G7+ samples. This produces perfectly smooth curves in a single operation, correctly implementing what G7+ intended.

Curve Building Tool

The CRPC data sets don't have G7+ gray balance. So, we've included tentative G7+ data sets and profiles in the built-in data. These may be replaced in the future with so-called Universal data sets and profiles.

The supplied press data, **'wonky_CMYK_test_data.mxf'**, has poor trapping of the yellow ink, and will produce "wonky" G7 curves. So, it is a good test for G7+.

Samples are selected with this setting,

```
select: g7(80) cmy(60) k nosub
```

G7 gray samples whose cyan %-dot is 80% or less -and- C/M/Y samples whose %-dot is 60% or more are selected. This selection simulates the G7+ concept, but with some overlap. The overlap ensures a smooth transition from the G7 to C/M/Y regions. We add the 'k' token to include black ink samples, and the 'nosub' token to remove any substrate samples.

* G7+ is a registered trademark of IDEAlliance

We don't compute TVI curves for the shadow region. Instead, curves are adjusted to minimize ΔEab of the pure process colors, compared to the reference profile. The G7 gray samples are adjusted simultaneously to have minimal ΔL* and ΔCh*. The resulting curves are perfectly smooth.

Run the curve building tool with the ⌘**R** key combination. Next, compute original G7 curves by running the tool again with this line enabled,

```
select: g7 k nosub
```

The original G7 curves are definitely "wonky" compared to the G7+ curves.

Grading Tool

At this time (March 2025) we don't have final information on G7+, so grading is set for the original G7 pass/fail.

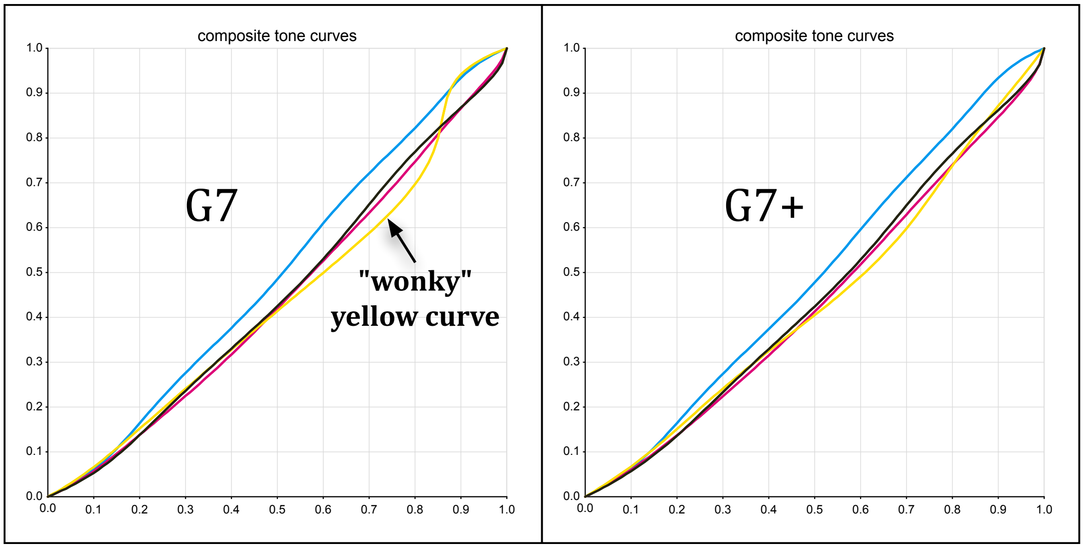
A Better Solution

G7+ makes some improvements to the original G7 technique. But, before you invest in that solution, you should consider the Optimal Method.

The **Optimal Method** has many advantages compared to other calibration techniques. These are listed at the end of our 2018 TAGA presentation, and throughout this user manual. The Optimal method matches printing to a reference ICC profile, and lets you choose the samples for that purpose. You're not restricted to a particular conception of gray balance. It works with all printing processes – conventional or digital, RGB, CMYK or ECG.

The **Optimal+ Method** adds blending of SCTV curves in the shadow region, similar to G7+ splicing TVI curves. This increases print contrast, and gives consistent rendering of shadow detail, while still matching the color of your reference profile(s). The blending algorithm produces perfectly smooth curves.

Best of all, PressCal software is open source. So your "investment" is just the time spent to learn its use.



Optimal Basic Settings

The **Optimal method** is a print calibration technique that builds tone curves by minimizing the combined color errors for a set of samples. Unlike the TVI and G7 methods, which are bound to specific sample sets, PressCal will make curves from any sample set. This flexibility leads to the question, which samples to use? The answer is to use samples that are likely to occur in actual jobs. We call these **realistic** samples.

Realistic Samples

Images are normally converted to **CMYK** with ICC profiles. These profiles are created from standard data sets and provided to the public by organizations like IDEAlliance and ECI. Graphic designers use these profiles to convert their images and vector art to **CMYK**. Realistic samples are derived from these profiles. PressCal test charts are available with samples from the **GRACoL2013_CRPC6.icc** and **PSOcoated_v3.icc** profiles.

If you're using a conventional test chart, realistic samples may be selected using the **`rt()`** token. Selection is done by comparing the sample's black value, before and after a round-trip through the reference profile. If the black value changes less than the threshold value (e.g., 10), the sample is selected. Selected samples may not be exactly realistic, but are close. More important, unrealistic samples are excluded. For example, here are the realistic samples from an IT8.7/4 test chart.

Gray Axis Samples

For good color reproduction, the gray axis must be rendered accurately. The Optimal method implements this principle correctly by using realistic gray samples. This table shows realistic gray samples (on the right), using the GRACoL2013 reference profile. Up to a cyan value of about 20%, the gray axis consists of **CMY** only. Then, as the L* value decreases, GCR limits the **CMY** values, and black becomes the dominant ink.

The CMY-only gray samples (on the left), do not represent the gray axis correctly, and often have a significant color cast in the dark tones, due to irregular ink trapping. Curves built from this data are unreliable. This is a well known problem that we call shadow incongruence. See this section for a detailed explanation.

Reference Profile

The reference profile supplies the target colors for samples in the test charts. This includes the samples defining the gray axis. There is no arbitrary **CMY** gray balance, as with the G7 method. The Optimal method works equally well using FOGRA-based profiles, or CRPC-based profiles, or your own reference profile. The profile may have any number of channels, including **RGB** profiles.

The **`profile_path:`** setting should be the path to an ICC printer profile. This profile may be built-in or external.

Press Measurements

PressCal compares measurements of your printing process with your selected reference profile. The printing should be done carefully. Here are some guidelines for obtaining good measurements. Use linear plates, if possible. Otherwise, add the **`plate_curve_path:`** setting to input the initial plate curves.

The **`press_path:`** setting should be the path to your measurements. If you measure multiple test charts, and wish PressCal to average them, place the individual files in a folder, and use the path to the folder.

If your instrument supports it, we recommend you measure M0, M1, and M2 data, and save it in CxF3 format (.mxf or .rmxf). Otherwise, you should select the measurement condition of the reference profile, and save the spectral data in CGATS ASCII format.

The **`condition:`** setting selects the data used from CxF3 files containing multiple measurement conditions. Normally, this setting should match the measurement condition of the reference profile. However, if there's a large color difference between the reference and press paper, the **`auto`** value may give better results by blending the M1 and M2 measurements to minimize that difference.

Initial Grading

At this point, you've measured your initial press sheet and entered your values for the settings just covered. In TextMate, with the settings file open, press the **⌘I** key combination to run the grade tool. The test results will be displayed in the grade log. If your press sheet failed any tests, you'll need to make changes.

Color First

You should make any changes to the colorant strength and balance before making tone curves. Colorant changes will affect gray balance and tone, but tone curves won't affect solid ink colors (with the endpoints pinned).

Ink Balance Tool

PressCal includes an ink balance tool to help you make solid color adjustments. This tool was designed for offset and flexo printing. It could be helpful when adjusting other printing processes.

Here is an example of the grade log, showing test results for the solid colors.

```
standard: optimal, version: 2020, level: offset

process solids color error

      cyan ΔE00: 2.02 ✔ [3.00]
   magenta ΔE00: 2.66 ✔ [3.00]
    yellow ΔE00: 1.93 ✔ [3.00]
     black ΔE00: 4.03 ✔ [5.00]

RGB solids color error

       red ΔE00: 2.85 ✔ [3.00]
     green ΔE00: 1.19 ✔ [3.00]
      blue ΔE00: 1.63 ✔ [3.00]

gray axis color errors
```

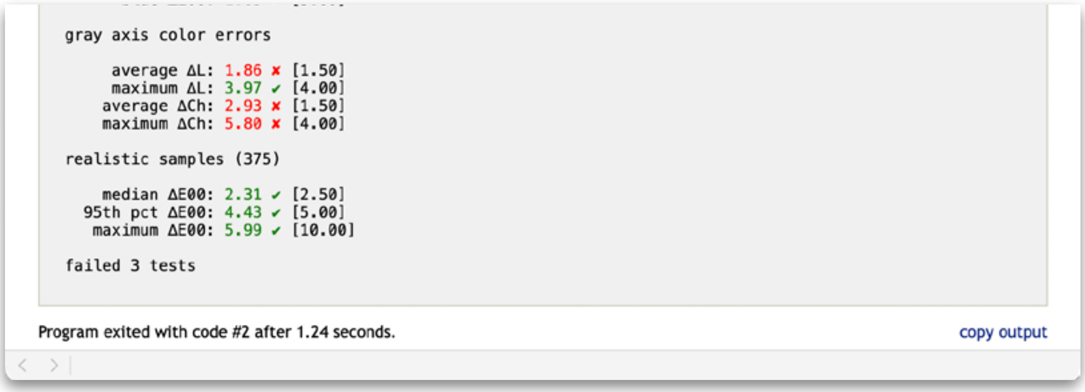
These solid ink colors are all within tolerance, but it may be possible to improve on this result. The ink balance tool (**⌘B** key combination) builds a spectral solid ink model to calculate the optimal ink densities. The output of this tool is a list of density changes for the next pull.

```
status T densities:

                  nom     opt    change
      cyan (R)   1.265   1.299   +0.03
   magenta (G)   1.278   1.326   +0.05
    yellow (B)   0.933   1.008   +0.07
     black (V)   1.484   1.677   +0.19

Program exited with code #1 after 1.45 seconds.                copy output
```

This is an iterative process, with the goal to have all changes near zero. After a few pulls, you may decide to use a previous one, so be sure to mark them in the delivery.

If you're unable to pass the solid ink tests, it's possible the press is running a non-standard ink sequence. For offset printing, the normal ink sequences is KCMY.

When you're satisfied with your ink densities, run the grade tool using measurements of your new press sheet. Look at the tests for the **gray axis color errors** and **realistic samples**.



If you failed any of these tests, you'll need to make tone curves. In this example, three of the gray axis tests failed. Other tests barely passed.

Curve Settings

When making tone curves, it is good practice to average the measurements of several press sheets, using opposed target pairs. Put the measurements in a folder, and copy the folder path to your **`press_path:`** setting.

The **`select:`** setting is a list of tokens that select the samples. As mentioned previously, the **`rt(10)`** token selects realistic samples. The **`k`** token selects black only samples, and the **`nosub`** token removes substrate samples.

For the **PressCalC6T** and **PressCalF51T** test charts, realistic samples are in rows 6 - 20, and black samples are in row 4. These samples are selected with the token **`rows(4, 6 .. 20)`**. This is the preferred selection for these test charts, and will yield well defined curves of degree 6.

There are many other settings that affect curve generation. These settings all have default values. You may override the defaults, as you see fit. For instance, adding the setting **`degree: 6`** will force degree 6 curves, overriding the value determined from the sample set.

Making Curves

Once you are satisfied with your settings, press the **⌘R** key combination to run the curve building tool. A log window will open, showing the software's progress. The log begins with the same output as the grade and ink balance tools. This includes your settings, and the solid ink errors. Then, you will see a single line with information about the sample selection. In this example, 480 samples were selected. For each sample, the initial device values, L*a*b* values, and error values are displayed.

```
         red    47.0   68.0   48.0        46.9   68.1   47.9        49.0   66.6   42.9      5.64      2.85
       green    50.0  -66.0   26.0        49.9  -65.7   26.0        50.9  -63.8   25.1      2.39      1.19
        blue    25.0   20.0  -46.0        24.9   20.1  -45.9        26.3   21.0  -44.5      2.16      1.63
         iso    23.0    0.0   -0.0        22.9    0.1    0.0        24.2    0.3   -4.2      4.40      3.97
       black    16.0    0.0   -0.0        15.9    0.1    0.0        21.0    1.0    1.7      5.43      4.03
        cmyk     9.0    0.2    0.4         9.0    0.3    0.4        12.1    0.8   -0.4      3.22      2.22

degree: 6, sample selection: 'rt(10) k nosub', samples: 480

sample        device values              ref L*a*b* values      press L*a*b* values      ΔE00
7        0.000  0.833  0.500  0.000      53.7   60.2   22.6     53.7   60.2   25.1      1.28
8        1.000  0.021  0.255  0.499      35.4  -30.0  -19.4     34.5  -27.3  -13.6      3.18
9        0.138  0.513  0.146  0.037      62.5   28.8   -3.8     61.6   28.1   -1.6      1.52
10       0.100  0.117  0.892  0.083      75.3   -1.4   66.3     72.8   -2.5   62.7      2.20
11       0.665  0.091  0.491  0.095      58.3  -28.1    2.2     55.9  -28.9    8.2      4.43
```

The average initial errors are displayed, and the optimization commences. After a short time, the optimization is complete, and the sample data is displayed again, this time with the newly computed curves applied.

```
497      0.000  1.000  0.333  0.000      48.5   72.1   12.7     49.7   69.2   15.3      1.99
498      0.667  0.000  0.000  0.000      68.0  -23.4  -35.9     66.9  -22.1  -37.1      1.24
499      0.728  0.448  0.493  0.485      31.6   -7.1   -4.5     30.7   -7.1   -0.5      3.46
500      0.000  0.967  1.000  0.127      43.4   59.3   42.9     43.8   56.5   37.7      2.00

                                                               initial average error:   2.35

optimizing curves for minimum ΔE00...

L-M optimization completed at 216 iterations

error values with optimized curves are below...

sample        device values              ref L*a*b* values      press L*a*b* values      ΔE00
7        0.000  0.833  0.500  0.000      53.7   59.3   27.0     53.7   60.2   25.1      1.13
8        1.000  0.021  0.255  0.499      34.5  -27.7  -14.3     34.5  -27.3  -13.6      0.42
9        0.138  0.513  0.146  0.037      60.6   28.0   -1.8     61.6   28.1   -1.6      0.93
10       0.100  0.117  0.892  0.083      72.8   -1.0   62.8     72.8   -2.5   62.7      0.95
11       0.665  0.091  0.491  0.095      56.5  -28.2    8.0     55.9  -28.9    8.2      0.64
```

The average optimized errors and final gamut scale factor are displayed. The average optimized errors should be less than the initial values.

```
497      0.000  1.000  0.333  0.000      49.1   70.0   16.8     49.7   69.2   15.3      0.91
498      0.667  0.000  0.000  0.000      67.7  -23.6  -36.2     66.9  -22.1  -37.1      1.08
499      0.728  0.448  0.493  0.485      30.7   -6.4   -1.0     30.7   -7.1   -0.5      0.82
500      0.000  0.967  1.000  0.127      43.6   56.8   38.9     43.8   56.5   37.7      0.59

                                                             optimized average error:   1.05

final gamut scale factor = 0.993, linearity = 0
```

The Bernstein curve parameters are displayed, followed by a message as each curve format is output. In this example only the text format is output. You may wish to add output tokens for additional format(s), to simplify importing the curves into your DFE.

```
           HLV    1/6    2/6    3/6    4/6    5/6    SHV
    cyan  0.000  0.229  0.342  0.571  0.679  0.804  1.000
 magenta  0.000  0.222  0.382  0.484  0.715  0.832  1.000
  yellow  0.000  0.248  0.415  0.696  0.669  0.869  1.000
   black  0.000  0.185  0.427  0.440  0.868  0.742  1.000

CED sample selection same as optimization, samples: 480

writing curves in 'text' format to        /Users/wbirkett/Desktop/tab_delim.txt
```

Program exited with code #0 after 4.77 seconds. copy output

Verification Press Run

The curves are used to produce a new press sheet, which should now conform with the Optimal requirements.

If your printing process uses plates, you will need to make new ones, using the curves. The press should be run without any changes other than the plates. That said, it may still be necessary to make some small changes to obtain the prior ink densities.

If your printing process is digital, you will need to incorporate the curves into your workflow. If they cannot be loaded directly into your DFE, it is possible to apply them to ICC profiles, as explained here.

The new press sheets should be measured and graded to verify they pass all tests. If not, it may be possible to obtain passing sheets with small density adjustments, guided by the grading results.

Occasionally, it may be necessary to compute a second set of curves from the verification measurements. These measurements already have plate curves applied. The **`plate_curve_path:`** setting includes the plate curves into the calculations for the next set of curves.

Optimal Plus Basic Settings

The **Optimal Method** is a technique for matching color printing to an ICC profile using tone curves. The matching algorithm minimizes the overall color error to get the best possible color match. In theory, the resulting calibration is optimal (lower case 'o'). There's nothing more to do.

But consider this – does the ICC profile we've matched so well represent the best possible printing with your equipment and materials? Maybe not. There's a growing faction of printers who've adopted linear SCTV as their calibration method for both process and spot colors. They claim to get excellent print quality, especially the rendering of shadow detail, and reduced banding. This is likely the result of increased print contrast, and shadow linearity.

The downside to SCTV calibration is that gray balance and tonality are not controlled, so matching standard proofs will be hit or miss. Fortunately, universal data sets, with better shadow rendition, are under development.

In support of these trends, we developed the **Optimal+ Method**, which blends Optimal and SCTV curves. You get the best properties of each technique – a good color match to reference profiles and improved shadow rendition.

Run Basic Setting

You can visualize the Optimal+ Method by running the basic settings file. Open the file in TextMate and hit the ⌘**R** key combination. Curves are built and graphed in your web browser. Compared to the plain Optimal Method, there are three additional graphs titled **SCTV curves**, **blending function** and **SCTV blended curves**, as shown on the next page.

The **SCTV curves** are built from your press data to make SCTV linear. For each enabled ink channel, the data samples with only that ink are located and used to build the SCTV curves. Note the black ink channel is *not enabled* by default.

The **blending function** controls the blending of the Optimal curves with the SCTV curves. A function value of 0 selects the Optimal curves, and a value of 1 selects the SCTV curves. Values between 0 and 1 blend the curves proportionately.

The **SCTV blended curves** are the result. If you compare these curves to the others, you will see how blending works. The blended curves resemble the Optimal curves in the highlights and midtones, transitioning smoothly to the SCTV curves in the shadows.

Blend SCTV Setting

The **`blend_sctv:`** setting is a hash with three keys – **`'median'`**, **`'slope'`** and **`'map'`**.

```
blend_sctv: {'median' => 75, 'slope' => 4, 'map' => [0, 1, 2]}
```

The **'median'** and **'slope'** values control the shape of the **blending function** curve. The **`'median'`** is the %-dot value where the blending is 0.5 (50/50). The **`'slope'`** is the inclination of the curve at the median point. Feel free to experiment with these settings and see how they change the curve shape.

The **'map'** value is an array containing the ink channels to be blended. The value **`[0, 1, 2]`** selects the CMY channels. You may add other channels if you like.

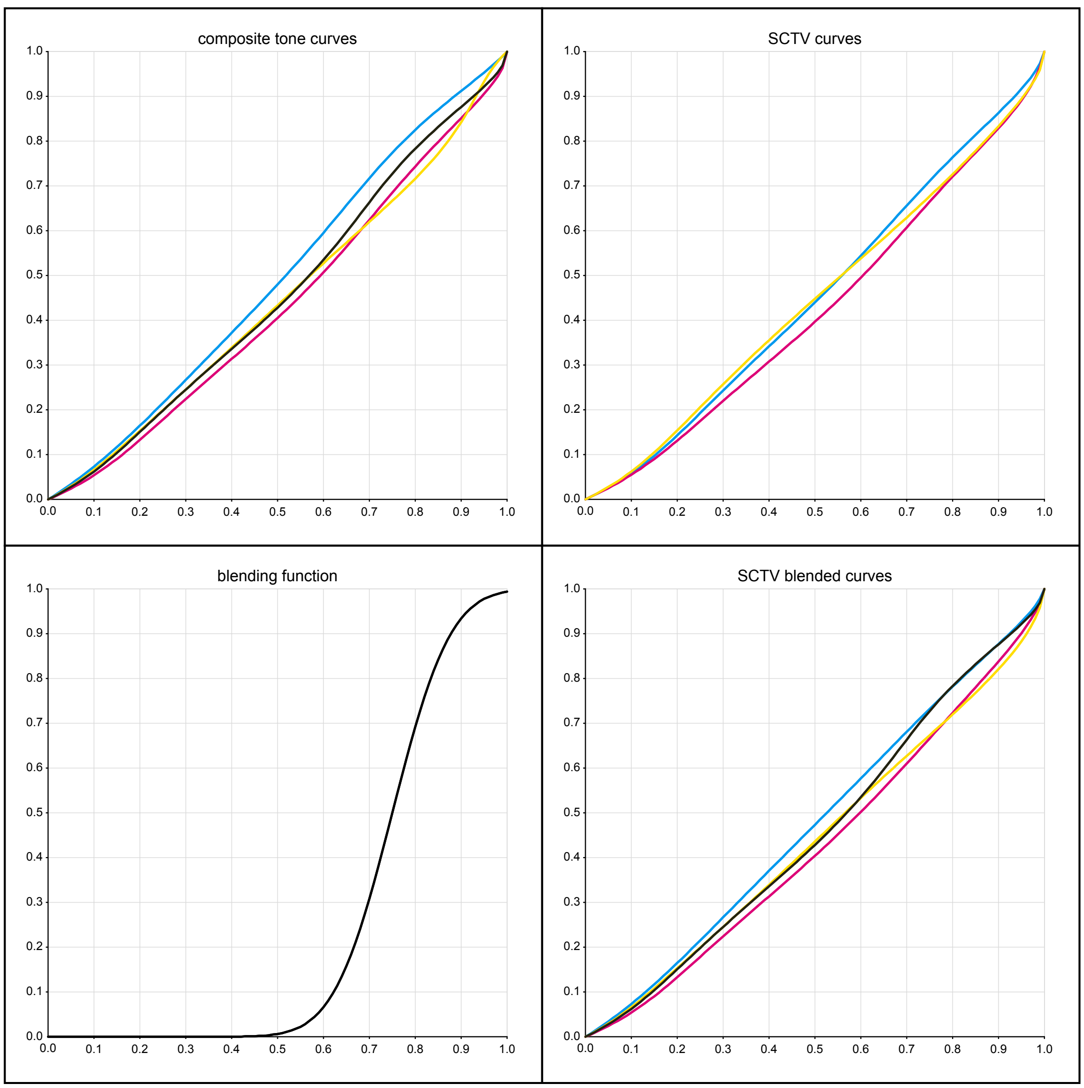
Match Quality

As mentioned earlier, the Optimal Method matches printing to an ICC profile with minimal color error. PressCal analyzes this error statistically and plots it as a graph **before** and **after** optimization. The median color error is a good measure of the color match quality.

When we blend Optimal curves with SCTV curves, the median color error increases slightly, meaning the color match is less good. You can check this by comparing the **after** median color error with the `blend_sctv:` setting enabled and disabled.

Print Contrast

The effect of blending SCTV curves is a slight increase in print contrast, and a more consistent curve shape in the shadow region. Print contrast is a pressroom measure computed for each ink from the 70% and solid density values. Greater print contrast enables higher print densities and better rendition of shadow detail. The process control report lists print contrast of the curve-adjusted process.



SCTV Basic Settings

SCTV (spot color tone value) is a tone metric derived from L*a*b* measurements, as defined by the **ISO 20654** standard. The SCTV of the substrate is 0 and the SCTV of a solid ink is 1. For offset printing, the relationship between %-dot and SCTV is roughly linear. Furthermore, since SCTV is derived from L*a*b* values, it is visually uniform. This applies to both spot and process colors.

Linear SCTV Curves

PressCal can make tone curves so that SCTV values are linear with respect to %-dot values. This practice is not in the ISO standard, but is a reasonable use of the metric, when no other guidance is provided. Although SCTV was originally intended for spot colors, it is sometimes used to calibrate process colors. According to print expert Gerry Gerlach, *"SCTV for CMYK linearizes the ink to make an accurate color space based on the ink rather than with TVI or grey balance. ... Visually, the SCTV print has more contrast and fuller color."*

However, SCTV curves are based solely on the process color ramps, so the resulting gray balance is indeterminate. If you need to match a standard reference, consider using the **Optimal+** technique, which blends Optimal and SCTV curves.

Ink Map

The **`ink_map:`** setting allows you to specify the method used to calculate curves for each individual ink channel. This setting is an array of values corresponding to the ink channels. In this example, the ink map is **`[S, S, S, S]`**, which indicates SCTV will be used to compute each of the CMYK channels.

SCTV References

The **`sctv_reference:`** setting allows you to specify reference tone ramps for SCTV curves. With this setting activated, the SCTV of the calibrated process matches that of the reference. This is very similar to using TVI curves, except that SCTV is based on colorimetry, rather than density. In this example, the setting,

```
sctv_reference: [['~~/Data/Test/CGATS21-2-CRPC6.txt', 0 .. 3]]
```

selects the **CGATS21-2-CRPC6.txt** data set as the SCTV reference. The number range **`0 .. 3`** maps the channels in the data set to curves C, M, Y, K. This data set was used to build the **GRACoL2013_CRPC6.icc** profile. The alternate setting,

```
sctv_reference: [['profile', 0 .. 3]]
```

selects the reference profile as the source, rather than the data set. The resulting curves are identical.

Initial Grading

In TextMate, with the settings file open, press the **⌘I** key combination to run the grade tool. The test results will be displayed in the grade log. Depending on the grade settings, the log will contain pass/fail info for various grading tests (CMYK).

The grading function graphs the SCTV values of all ink channels before calibration, which should be checked for smoothness. For offset printing, the graphs should be roughly linear. For other printing processes (e.g., flexo), the graphs may be bowed.

Ink Balance

In TextMate, with the settings file open, press the ⌘**B** key combination to run the ink balance tool. The purpose of this tool is to help you adjust the solid ink densities, to match the color gamut of the reference profile. It creates a spectral model of the solid ink colors, then adjusts the parameters of the model to minimize the weighted overall color errors. Suggested ink density adjustments are then computed and printed in the log.

With these settings, the color errors are small to begin with and the adjustments are minor. The reason the tool is called 'ink balance' is because the two-color overprints are considered in the calculations. Process color errors may actually increase, so the overprint color errors are less. Thus, the calculation is a balancing act. The **`ink_weight:`** setting controls the weight given each of the CMYRGB/ISO color errors.

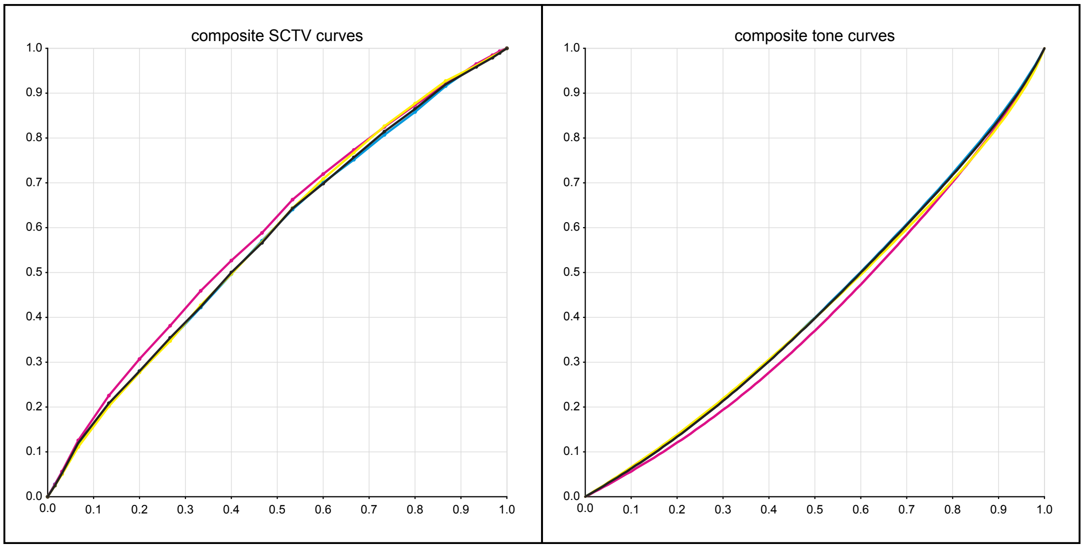
The ink balance tool also displays spectral reflectance graphs of each process color. When the solid ink colors are not as expected, you may be able to detect ink contamination, or other issues from these graphs.

Making Curves

In TextMate, with the settings file open, press the ⌘**R** key combination to make curves. A log window will open, showing the software's progress. The log begins with the same output as the grade and ink balance tools. This includes your settings, and the solid ink errors. A log entry will appear as each curve is calculated, indicating whether the curve is **linear** or was computed using an **SCTV reference**.

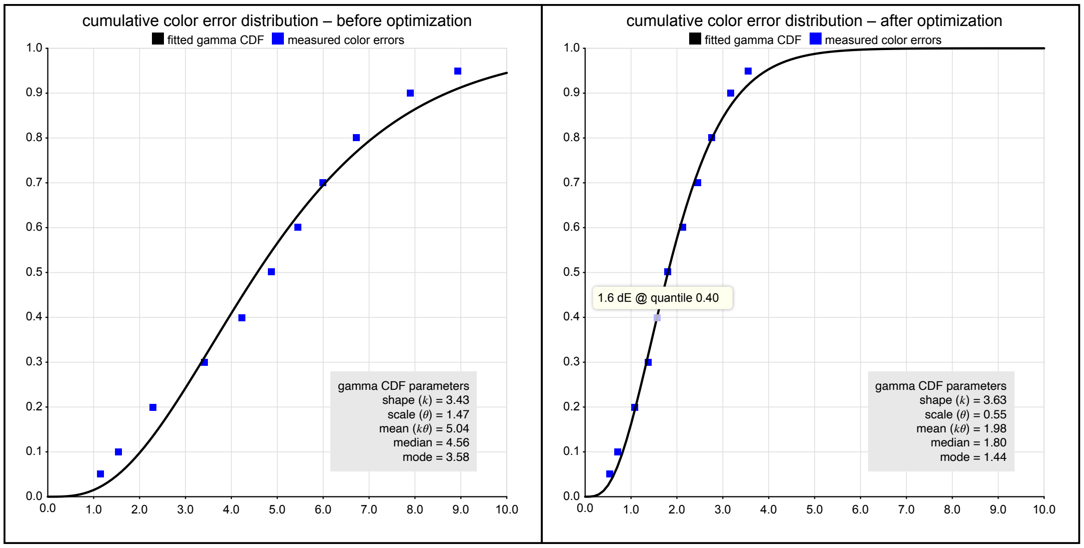
The Bernstein curve parameters are displayed, followed by a message as each curve format is output. With these settings, only the text format is output. You may wish to add output tokens for additional format(s), to simplify importing the curves into your DFE.

Finally, the tone curves (right) are graphed. Notice the tone curves are perfectly smooth, even though the SCTV data (left) is not. That's because they are Bernstein polynomials, fitted to the SCTV data. The tone curves are the inverse of the SCTV data. When combined, the result is linear SCTV.



Comparisons

PressCal makes it easy to evaluate the efficacy of the tone curves it produces. Cumulative error distribution (CED) graphs are plotted from the error statistics before and after applying the curves. The **median color error** is a good indicator of how well the printing will match the reference profile. The lower the color error, the better the match. This allows us to compare various options included in the basic settings file.



Initially, the curve building tool (⌘**R**) produces linear SCTV curves. These curves reduce the median color error from **4.56** ΔE_{00} (left) to **1.80** ΔE_{00}, (right) using the **GRACoL2013_CRPC6** profile as a reference.

Next, compute curves with an SCTV reference by deleting the **#** at the start of this line,

```
sctv_reference: [['~~/Data/Test/CGATS21-2-CRPC6.txt', 0 .. 3]]
```

The calibrated color error drops to **1.68** ΔE_{00}, a slight improvement.

Next, compute curves using the Optimal method by deleting the **#** at the start of these lines,

```
ink_map: [0, 1, 2, 3]
select: rt(10) k nosub
```

The residual color error is **1.25** ΔE_{00}, which is the lowest value possible.

Conclusions

Linear SCTV calibration curves are useful when there is no other guidance. Although intended for use with spot colors, SCTV may also be used to calibrate CMYK printing. The **`sctv_reference:`** setting allows you to optionally specify the desired tonality.

For CMYK printing, gray balance is indeterminate using SCTV curves. This may be acceptable for a color-managed workflow. Otherwise, we suggest using the Optimal method to match a reference profile.

Proof Basic Settings

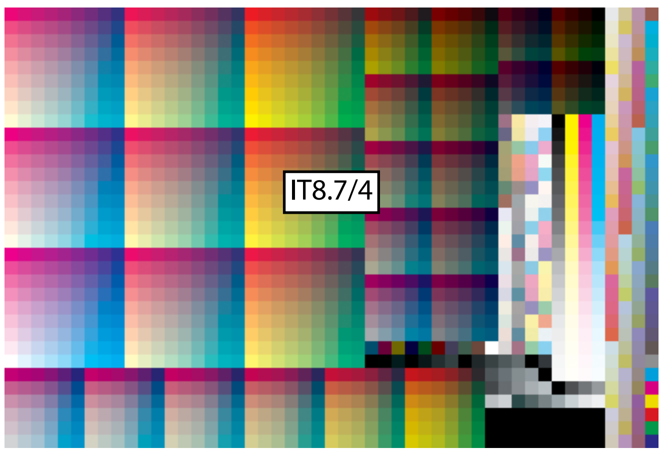
The ISO 12647-7 standard defines measurements and tolerances for "proofing processes working directly from digital data." The standard was originally released in 2007, then revised in 2013 and 2016. The edition is selected using the **12647–7:** setting. It is recommended to use the 2016 edition.

Compliance Levels

PressCal supports two compliance levels for proofs – **colorspace** and **control_strip**. For **colorspace** compliance, an IT8.7/4 test chart is used. For **control_strip** compliance, a smaller test strip is used, typically with less than 100 patches. The patches of the control strip are loosely defined, so different versions exist. In Europe, the UGRA/FOGRA MediaWedge v3.0 is used. In the US, the IDEAlliance ISO 12647-7 Control Wedge 2013 is used.


12647-7 (UGRA/FOGRA)


12647-7 (IDEAlliance)



You may wonder about the difference between G7 and ISO 12647-7 grading, since the IDEAlliance control wedge includes "ISO 12647-7" in its name. The ISO 12647-7 standard defines the patches in the control strip and the color tolerances agreed to by ISO TC 130, an international standards body. Idealliance defined their own proprietary color tolerances in their G7 pass/fail document.

Grading Only

Proofs are normally produced with a color-managed process, using multi-dimensional look-up tables built from colorimetric measurements. There is no need to set solid ink colors (⌘**B**) or make tone curves (⌘**R**) in a color-managed printing process. We only need to grade (⌘**I**) the proof, to determine if it meets the ISO 12647-7 specifications. If the proof fails any tests, the remedy is to build a new media profile and/or color-tune the workflow, depending on the DFE. Under certain circumstances, it may be possible to use tone curves to color-tune the process. But this may not yield a passing proof, so it may be better to use the other remedies.

Reference Profile

PressCal uses a standard reference ICC profile to define the reference color of the proof. Generally speaking, the reference profile should be the same one used by the proofing DFE. The profile is selected with the **`profile_path:`** setting. In the US, the 2013 CRPC profiles (M1), or the older GRACoL2006 and SWOP2006 profiles (M0) are used. In Europe, the PSO profiles, based on FOGRA data sets, are used.

Proof Measurements

As mentioned previously, the test chart is chosen for the compliance level, IT8.7/4 for **colorspace**, or the appropriate test wedge for **control_strip**.

The **`press_path:`** setting should be the path to your measurements. If you measure multiple test charts, and wish PressCal to average them, place the individual files in a folder, and use the path to the folder.

If your instrument supports it, we recommend you measure M0, M1, and M2 data, and save it in CxF3 format (.mxf or .rmxf). Otherwise, you should select the measurement condition of the reference profile, and save the data in CGATS ASCII format. The grading functions works with both spectral and L*a*b* data.

The **`condition:`** setting selects the data used from CxF3 files containing multiple measurement conditions. Normally, this setting should match the measurement condition of the reference profile (M1 or M0).

Grading

At this point, you've measured your proof and entered your values for the settings just covered. In TextMate, with the settings file open, press the **⌘I** key combination to grade the proof. The test results will be displayed in the grade log. If your proof failed any tests, you'll need to make changes.

Whether your proof passed the tests or not, we recommend you check the SCTV graphs for linearity. Also, check the highlight dot retention (minimum printable %-dot) values. The values should be near 0. Check the **CMY** gray color error graph. The G7 pass/fail requirements apply a weighting factor, which reduces the significance of **CMY** color errors for samples darker than the mid tone. For an offset press, these errors are diminished by UCR/GCR, so this makes sense. However, for a color-managed proof, these errors will be fully visible.

Curves

As mentioned previously, the normal way to correct a failed proof is to make a new media profile and/or color-tune the workflow, depending on the DFE software. If your DFE supports it, you could alternately build curves (**⌘R**), and apply them. This may be sufficient to pass the failed tests, depending on the source of the color errors. This should be viewed as a quick fix for small variations in ink and media. If the color errors are large, the normal remedies are preferred.

G7* Proof Basic Settings

The G7* method is a calibration technique promoted by IDEAlliance. The technique is documented as an ANSI CGATS technical report (TR 015), and as such, may be used freely without involving IDEAlliance. However, most of the time, printers are seeking G7 Master Qualification, which requires a trained G7 expert to submit qualified proofs and press sheets to IDEAlliance, plus payment of fees, annually.

Compliance Levels

The rules by which a G7 submission is graded are found in the document G7 Master Pass/Fail Requirements, available from IDEAlliance. This document defines three compliance levels – G7 Grayscale, G7 Targeted, and G7 Colorspace. Under certain conditions, the reference data set may be adjusted using SCCA. This creates two additional levels – G7 Targeted Relative and G7 Colorspace Relative. G7 Colorspace has two sub levels – Proof and Press.

The **`g7_level:`** setting selects the compliance level. This setting only affects the grading function. The compliance levels for proofs are either **colorspace_proof** or **colorspace_proof relative** depending on the white point of the proof, as compared to the reference data set.

Grading Only

Proofs are normally produced with a color-managed process, using multi-dimensional look-up tables built from colorimetric measurements. Therefore, it is unnecessary to set solid ink colors (⌘**B**) or make tone curves (⌘**R**). We only need to grade (⌘**I**) the proof, to determine if it complies with the G7 specifications. If the proof fails any tests, the remedy is to build a new media profile and/or color-tune the workflow, depending on the DFE software.

Reference Profile

For G7 Colorspace compliance, you must choose a **CRPC data set**. These data sets represent the characteristics of offset printing on common paper types. The **`profile_path:`** setting should be the path to an ICC profile, built from the chosen CRPC data set. This profile may be built-in or external. The built-in profiles are listed in the basic settings. The CRPC profiles are built from M1 measurements. You may also use the GRACoL2006 and SWOP2006 profiles, which are built from M0 measurements. To select the reference profile, comment out the other choices (blue lines beginning with '#' are comments).

Proof Measurements

For G7 Colorspace compliance, your proof must contain test charts with both gray scale (P2P) and IT8.7/4 samples. The TC1617 and IT8.7/5 test charts contain the required samples. These charts are available for various instruments and configurations.

The **`press_path:`** setting should be the path to your measurements. If you measure multiple test charts, and wish PressCal to average them, place the individual files in a folder, and use the path to the folder. You may also combine measurements from P2P and IT8.7/4 test charts using matrix notation for the **`press_path:`** setting.

* G7 is a registered trademark of IDEAlliance

If your instrument supports it, we recommend you measure M0, M1, and M2 data, and save it in CxF3 format (.mxf or .rmxf). Otherwise, you should select the measurement condition of the reference profile, and save the data in CGATS ASCII format. The grading functions works with both spectral and L*a*b* data.

The **`condition:`** setting selects the data used from CxF3 files containing multiple measurement conditions. Normally, this setting should match the measurement condition of the reference profile (M1 or M0).

Grading

At this point, you've measured your proof and entered your values for the settings just covered. In TextMate, with the settings file open, press the **⌘I** key combination to run the grade tool. The test results will be displayed in the grade log. If your proof passed all of the tests, you may submit it to IDEAlliance. If your proof failed any tests, you'll need to make changes.

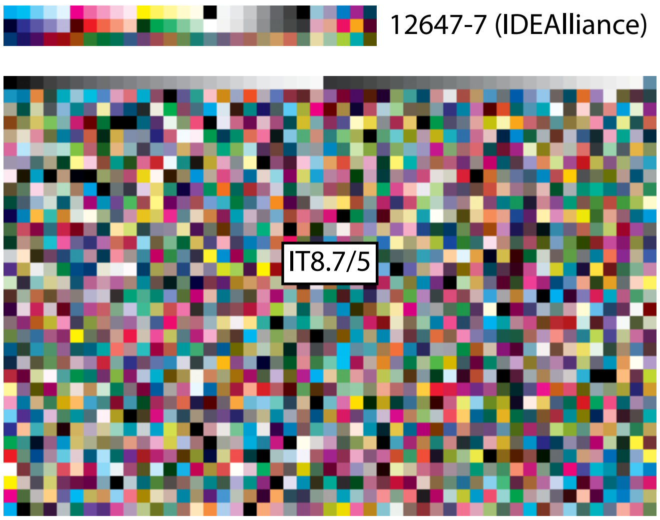
Whether your proof passed the tests or not, we recommend you check the SCTV graphs for linearity, and the highlight dot retention values. Also, look at the **CMY** gray color error graph. The G7 pass/fail requirements apply a weighting factor, which reduces the significance of **CMY** color errors for samples darker than the mid tone. For an offset press, these errors are diminished by UCR/GCR, so this makes sense. However, for a color-managed proof, these errors will be fully visible.

Curves

As mentioned previously, the normal way to correct a failed proof is to make a new media profile and/or color-tune the workflow, depending on the DFE software. If your DFE supports it, you could alternately build curves (**⌘R**), and apply them. This may be sufficient to pass the failed tests, depending on the source of the color errors. This should be viewed as a quick fix for small variations in ink and media. If the color errors are large, the normal remedies are preferred.

ISO 12647-7 Control Wedge

Production proofs may be verified using the IDEAlliance ISO 12647-7 Control Wedge 2013, which contains 84 samples, and is a subset of the IT8.7/5 test chart.



Flexo Basic Settings

Flexography is a popular printing process for many products, especially packaging. Spot colors are commonly used in combination with **CMYK** inks. Color matching may be critical, for both process and "brand" colors. Color control of a flexo press is somewhat limited, since there are no ink keys, as in offset printing. It is costly and time consuming to make a set of flexo plates. Therefore, accurate color calibration, done efficiently, is important.

Specifications and Standards

The Flexographic Technical Association (FTA, www.flexography.org) publishes a book of specifications titled *FIRST* (Flexographic Image Reproduction Specifications & Tolerances), which covers all aspects of flexo printing, from initial project planning to the pressroom. The CGATS TR 012-2020 technical report summarizes the main elements of the *FIRST* methodology. The ISO 12647-6 standard provides guidance on flexo substrates and inks.

FIRST Methodology

The *FIRST* methodology consists of five steps: optimization, fingerprinting, process control, characterization, and process improvement. Color calibration is typically performed in the fingerprinting step by measuring a printed test form and building calibration curves from the data. These curves are then used in the following steps. The characterization step makes an ICC profile of the calibrated printing process. This profile could be used in the prepress function to convert image files and make color-managed proofs. Of course, this adds cost and complexity to flexo printed jobs. Some printers have successfully formulated inks and calibrated their process to match offset standards, allowing files prepared for offset to be printed without additional prepress work.

PressCal supports *FIRST* by calibrating to a reference profile. A table of process control values is output by adding the **`process`** token to the **`output:`** setting. A curve-adjusted data set for building an ICC profile is output by adding the **`adjust_path:`** setting. As a result, three of the *FIRST* steps may be completed with a single press run with PressCal. If a standard reference profile (e.g., GRACoL or FOGRA) is used, and the residual color error is small, the flexo process will simulate the standard. Otherwise, the curve adjusted data set may be used to make a custom ICC profile for prepress. That custom ICC profile may become the reference profile for future press runs, or for calibrating multiple presses to print identically.

Color Variations

Measurements of a calibration test chart may contain variations that interfere with the generation of tone curves and ICC profiles. If present, you should try to eliminate these variations, as they will degrade the quality of your printing, and cause waste. That is the goal of the *FIRST* optimization step.

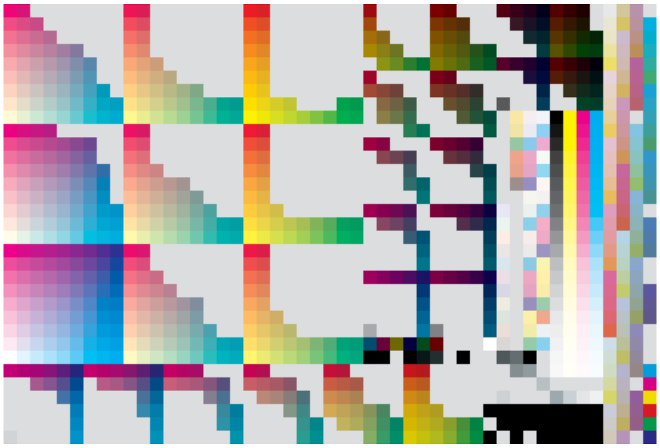
If your data is rough, you can still obtain a good calibration with the Optimal method. The trick is to use a large sample set, arranged randomly. The Optimal method will generate smooth curves from rough data. The resulting curves will properly calibrate the average printing process. Of course, any spatial color variations will remain after calibration, which is why you should try to eliminate them at the start.

Realistic Samples

PressCal will make curves from any sample set. This flexibility leads to the question, which samples to use? The answer is to use samples that are likely to occur in actual jobs. We call these realistic samples.

Images are normally converted to **CMYK** with ICC profiles. These profiles are created from standard data sets and are provided to the public by organizations like IDEAlliance and ECI. Graphic designers use these profiles to convert their images and vector art to **CMYK**. Realistic samples are derived from these profiles. PressCal test charts are available with samples from the GRACoL2013_CRPC6.icc and PSOcoated_v3.icc profiles.

If you're using a conventional test chart, realistic samples may be selected using the **`rt()`** token. Selection is done by comparing the sample's black value, before and after a round-trip through the reference profile. If the black value changes less than the threshold value, the sample is selected. Selected samples may not be exactly realistic but are close. More important, unrealistic samples are excluded. For example, here are realistic samples from an IT8.7/4 test chart, using the GRACoL2013_CRPC6.icc profile.



Reference Profile

The reference profile supplies the target colors for samples in the test charts. This includes the samples defining the gray axis. There is no arbitrary **CMY** gray balance, as with the G7 method. The Optimal method works equally well using FOGRA-based profiles, or CRPC-based profiles, or your own reference profile. The profile may have any number of channels, e.g., **CMYK, CMYKOV, CMYKOGV**.

The **`profile_path:`** setting should be the path to an ICC printer profile. This profile may be built-in data or external.

Press Measurements

PressCal compares measurements of your printing process with those derived from your selected reference profile. The printing should be done carefully. Here are some guidelines for obtaining good measurements. Use linear plates, if possible. Otherwise, add the **`plate_curve_path:`** setting to input the initial plate curves. Some DFEs support pre-compensation curves. In that case, there is no need to use this setting.

The **press_path:** setting should be the path to your measurements. If you measure multiple test charts, and wish PressCal to average them, place the individual files in a folder, and use the path to the folder.

In these settings, we use matrix notation to combine **CMYK** measurements with those of two spot colors. The **CMYK** measurements are from a TC1617 test chart and are mapped to channels 0 - 3. The spot color measurements are from CxF/X-4 files and are mapped to channels 4 and 5. Any number of charts with any number of ink channels may be combined in this way.

If your instrument supports it, we recommend you measure M0, M1, and M2 data, and save it in CxF3 format (.mxf or .rmxf). Otherwise, you should select the measurement condition of the reference profile and save the spectral data in CGATS ASCII format.

The **condition:** setting selects the data used from CxF3 files containing multiple measurement conditions. Normally, this setting should match the measurement condition of the reference profile. However, if there's a large color difference between the reference and press paper, the **auto** value may give better results by blending the M1 and M2 measurements to minimize that difference.

Typically, flexo substrates don't contain OBAs, so there is no difference between M0, M1, and M2 measurements. When there are no OBAs, the **condition:** setting may be set to **ignore**.

Initial Grading

At this point, you've measured your initial press run and entered your values for the settings just covered. In TextMate, with the settings file open, press the **⌘I** key combination to run the grade tool. The test results will be displayed in the grade log. If your press sheet failed any tests, you'll need to make changes.

Here is the grade log for this example, showing test results for the solid colors.

```
standard: 12647-6, version: 2020, level:

process solids color error

      cyan ΔE00: 2.79 ✔ [6.00]
   magenta ΔE00: 5.05 ✔ [6.00]
    yellow ΔE00: 2.75 ✔ [6.00]
       black ΔL: 1.06 ✔ [5.00]

process solids color error

      cyan Δhab: 5.76 ✔ [6.00]
   magenta Δhab: 2.96 ✔ [6.00]
    yellow Δhab: 1.75 ✔ [6.00]
      black ΔCh: 3.26 ✘ [3.00]

spot solids color error

      blue ΔE00: 0.33 ✔ [6.00]
       red ΔE00: 1.10 ✔ [6.00]

spot solids color error

      blue Δhab: 0.09 ✔ [6.00]
       red Δhab: 0.06 ✔ [6.00]

failed 1 test
```

Program exited with code #2 after 2.74 seconds. copy output

The colors are all within the rather loose tolerance of ISO 12647-6, except for the black ink, which is slightly reddish. That is probably OK. The other solid inks are within tolerance but could be improved.

Color First

You should make any changes to the colorant strength and balance before making tone curves. Colorant changes will affect gray balance and tone, but tone curves won't affect solid ink colors (with the endpoints pinned).

Ink Balance Tool

PressCal includes an ink balance tool to help you make solid color adjustments. The ink balance tool builds a spectral solid ink model to calculate the optimal ink densities. The output of this tool is a list of density changes for the next pull. Press the **⌘B** key combination to run the ink balance tool.

```
status T densities:

                  nom     opt    change
     cyan (R)   1.318   1.338    +0.02
  magenta (G)   1.213   1.327    +0.11
   yellow (B)   1.086   0.989    -0.10
    black (V)   1.654   1.709    +0.05
     blue (R)   1.765   1.765    +0.00
      red (G)   1.459   1.459    +0.00
```

Program exited with code #1 after 2.44 seconds. copy output

With these settings, the recommended adjustments improve the red, green, and blue solids at the expense of the cyan, magenta, and yellow solids. Notice that the trapping is nearly perfect (values are near 1). The reference profile is for offset printing, which doesn't trap as well, so we won't be able to match all the solid ink colors. Nevertheless, it is worthwhile to improve the red, green, and blue overprints, which are generally more important than the cyan, magenta, and yellow solids.

With the Optimal method, you can achieve good color calibration, even when the solid colors are slightly off from the target values.

The **`ink_ref_colors:`** setting defines the target colors used by the ink balance tool, when missing from the reference profile. In this example, we use the same CxF/X-4 files as for the spot color measurements. Therefore, the color errors are zero, and no density change is indicated. Normally, the press and reference colors would be different. The ink_ref_colors: setting has several options, which are illustrated in this example. The Pantone deck files are copyrighted, so we can't include them with PressCal, but you can obtain them from X-Rite.

Curve Settings

When making tone curves, it is good practice to average the measurements of several sheets, using opposed target pairs, if space permits. Put the measurements in a folder and copy the folder path to your press_path: setting.

The **`ink_map:`** setting specifies how the curves for each ink channel are computed. In this example, ink channels 0, 1, 2, and 3 (**CMYK**) are mapped to channels 0, 1, 2, and 3 of the reference profile. These curves are computed using the Optimal method. Ink channels 4 and 5 (spots) are computed to produce linear SCTV.

The **`sctv_reference:`** setting defines the desired tonality for curves computed with SCTV. In this example, we have CxF/X-4 files which contain tone ramps for the spot colors. Without this setting, the SCTV curves produce a linear calibration.

The **select:** setting is a list of tokens that select the samples. As mentioned previously, the **`rt(10)`** token selects realistic samples. The **k** token selects black only samples, and the **`nosub`** token removes substrate samples.

The **`output:`** setting determines the file format(s) for the computed curves. In this example, we output a tab-delimited table.

The **`process:`** setting outputs a process control report, which contains the densities and TVI/SCTV values of the curve adjusted process, for *FIRST*.

The **`adjust_path:`** setting is the path to measurements of a profiling chart. The computed curves are used to modify this file, so an ICC profile of the calibrated process may be computed. This can save a press run when a characterization profile is needed.

There are many other settings that affect curve generation. These settings have default values. You may override the defaults, as you see fit. For instance, adding the setting **`degree: 4`** will force degree 4 curves, overriding the value determined from the sample set. This will cause the curves to be "simpler" or less detailed.

Making Curves

Once you are satisfied with your settings, press the **⌘R** key combination to run the curve building tool. A log window will open, showing the software's progress. The log begins with the same output as the grade and ink balance tools. This includes your settings, and the solid ink errors. Then, you will see a single line with information about the sample selection. In this example, 995 samples were selected. For each sample, device values, reference and press L*a*b* values, and error values are displayed.

```
          cmyk      9.0     0.4    62.2         8.3     1.6    97.2         5.1     1.4   138.5      1.08      1.06
          blue       sample missing            26.6    61.6   283.9        26.6    61.6   283.9      0.00      0.00
           red       sample missing            51.4    79.9    27.8        51.4    79.9    27.8      0.00      0.00

  degree: 6, sample selection: 'rt(10) k nosub', samples: 995

  sample               device values                        ref L*a*b* values       press L*a*b* values       ΔE00
  4         1.000  1.000  0.400  1.000  0.000  0.000         7.6     3.0    -0.6        5.8     0.2    -3.1      4.71
  5         0.200  0.200  1.000  0.400  0.000  0.000        49.5    -3.9    47.3       52.9    -4.9    54.1      3.93
  6         0.000  0.400  1.000  0.000  0.000  0.000        68.6    21.3    71.9       70.1    22.9    78.4      1.89
  7         0.400  1.000  0.400  0.800  0.000  0.000        15.8    16.3     1.8       18.0    18.7    -1.3      3.09
```

The average initial errors are displayed, and the optimization commences.

```
  1612      0.000  0.070  0.000  0.070  0.000  0.000        83.4     3.5     1.0       84.9     3.0     1.4      1.19
  1613      0.100  0.100  0.400  0.100  0.000  0.000        74.5    -2.1    25.1       77.8    -3.7    26.0      2.77
  1614      0.200  0.400  0.400  0.100  0.000  0.000        59.2    12.2    14.0       62.3    12.6    14.0      2.74
  1615      0.000  0.000  1.000  0.200  0.000  0.000        72.9    -5.7    77.9       76.8    -8.0    84.8      3.37
  1616      0.200  0.200  0.700  0.000  0.000  0.000        71.3    -2.1    45.3       73.5    -3.8    44.9      2.01
  1617      0.000  0.200  1.000  0.600  0.000  0.000        42.8     1.7    43.5       47.3     0.0    49.3      4.76

                                                                              initial average error:   3.07

  optimizing curves for minimum ΔE00...

  L-M optimization completed at 254 iterations

  error values with optimized curves are below...

  sample               device values                        ref L*a*b* values       press L*a*b* values       ΔE00
  4         1.000  1.000  0.400  1.000  0.000  0.000         8.3     3.0    -0.7        5.8     0.2    -3.1      4.81
  5         0.200  0.200  1.000  0.400  0.000  0.000        54.1    -3.9    52.2       52.9    -4.9    54.1      1.42
  6         0.000  0.400  1.000  0.000  0.000  0.000        69.4    19.9    72.5       70.1    22.9    78.4      1.70
  7         0.400  1.000  0.400  0.800  0.000  0.000        18.1    18.4     0.7       18.0    18.7    -1.3      1.35
  9         1.000  1.000  0.200  0.600  0.000  0.000        17.4     8.3   -18.7       18.2     3.6   -20.9      5.67
  10        0.700  0.400  0.200  0.400  0.000  0.000        38.4    -6.2   -17.2       38.7    -7.7   -14.7      2.16
  11        0.100  1.000  0.300  0.000  0.000  0.000        44.8    64.9     7.5       48.7    62.5    10.0      4.03
```

After a short time, the optimization is complete, and the sample data is displayed again, this time with the newly computed curves applied.

```
 1614    0.200  0.400  0.400  0.100  0.000  0.000       61.9   12.2   13.3       62.3   12.6   14.0      0.59
 1615    0.000  0.000  1.000  0.200  0.000  0.000       76.3   -5.6   81.5       76.8   -8.0   84.8      1.41
 1616    0.200  0.200  0.700  0.000  0.000  0.000       72.7   -2.2   44.0       73.5   -3.8   44.9      1.23
 1617    0.000  0.200  1.000  0.600  0.000  0.000       47.4    1.7   48.1       47.3    0.0   49.3      1.19

                                                                optimized average error:    1.97

 final gamut scale factor = 0.999

 sctv reference(s):

        ~~/Data/FTA/FTA_Blue.cxf mapped to [4]
        ~~/Data/FTA/FTA_Red.cxf mapped to [5]

 making SCTV curve, channel 4 (using SCTV reference)
 making SCTV curve, channel 5 (using SCTV reference)
```

The average optimized errors and final gamut scale factor are displayed, followed by information on any non-optimized curves. In this case, SCTV curves were created for the spot colors.

The Bernstein curve parameters are displayed, followed by a message as each curve format is output. In this example 'text' and 'process' formats are output. You may wish to add output tokens for additional curve file format(s), to simplify importing into your DFE.

```
 curve parameters:

              HLV    1/6    2/6    3/6    4/6    5/6    SHV
      cyan   0.000  0.051  0.488  0.373  0.852  0.721  1.000
   magenta   0.000  0.056  0.534  0.178  0.947  0.554  1.000
    yellow   0.000  0.210 -0.162  1.156  0.140  0.999  1.000
     black   0.000  0.136  0.157  0.523  0.582  0.718  1.000
      blue   0.000  0.121  0.455  0.422  0.652  0.772  1.000
       red   0.000  0.269  0.373  0.764  0.626  0.819  1.000

 writing curves in 'text' format        to /Users/wbirkett/Desktop/tab_delim.txt
 writing process control info           to /Users/wbirkett/Desktop/process_control.txt

 CED sample selection same as optimization or 'all', samples: 995
```

Curve Endpoints

It has traditionally been difficult to render small halftone dots on flexo plates. A common practice is to limit the smallest dot size with "bump" curves, which are combined with tone reproduction curves in the DFE. PressCal has settings which allow you to specify the minimum dot size as a constraint during optimization. This could be an alternative to using separate bump curves.

Removing Outliers

PressCal does a good job of filtering random measurement variations. But occasionally, there are bad measurements caused by defects in the printing, or other reasons. These bad measurements, called outliers, are easily removed from the sample selection using the **`minus`** token. Suppose you've identified samples 363, 342, 321, and 300 as outliers. Add the token **`minus(363, 342, 321, 300)`** to the **`select:`** setting.

```
 240     0.000  0.950  0.000  0.000       48.4   71.1   -2.1       56.7   66.6  -17.3      10.25
 259     0.000  0.816  0.526  0.250       43.9   45.7   20.9       53.5   39.7   12.4      10.57
 219     1.000  1.000  0.000  0.000       24.5   19.5  -43.2       33.5   13.9  -54.4      11.35
 369     1.000  1.000  0.000  0.250       22.0   15.0  -34.3       29.0    7.0  -45.2      12.18
 481     1.000  1.000  0.000  0.600       16.8   10.5  -22.0       22.6    1.0  -32.4      13.67
 363     0.398  0.650  0.000  0.000       51.0   28.4  -20.7       32.1    7.2  -16.3      21.37
 342     1.000  0.312  0.312  0.600       25.9  -16.9  -13.6       58.7   25.6  -25.0      41.46
 321     0.000  1.000  0.859  0.000       46.8   67.1   42.1       28.5  -17.0  -17.9      59.41
 300     0.859  0.000  1.000  0.000       54.0  -57.0   34.8       53.5   63.5   39.0      72.74

                                                         initial average error:    5.15
```

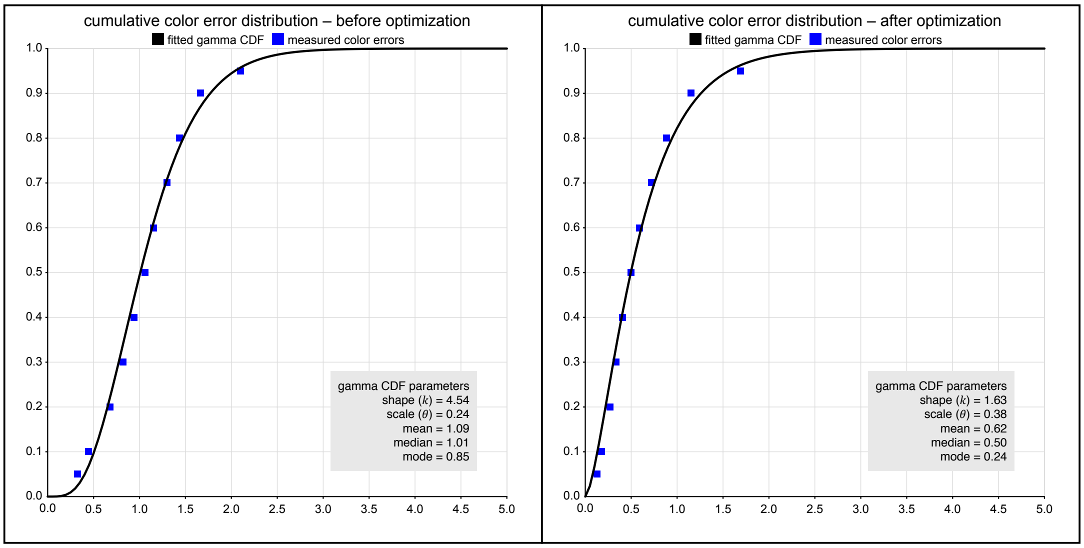
An easy way to spot outliers is to add the **`sort(error)`** token to the selection. This will sort the samples by the error value, so any outliers will appear near the end of the sample listing. Outliers will have error values that are abnormally large and/or L*a*b* values that are completely different.

Verification Run

The *FIRST* methodology implicitly verifies curves built from the fingerprinting step, in the subsequent process control and characterization steps. We've suggested that the results of those steps can be obtained directly from PressCal, without further press runs. Nevertheless, you may want to verify the curves are working correctly, at least until you're familiar with the Optimal method. If the curves have been built for a specific job, verification could be proofing that job, with test charts added to obtain color measurements.

Color Statistics

If your objective is to match the reference profile, the [cumulative error distribution] is a good indicator of your success. This is computed and graphed at the end of the curve building function, so it doesn't require a verification run. **Median error values below 2.0 ΔE_{00} are considered good for flexo printing.** If you do a verification press run, keep in mind that any changes in the printing process will probably increase the statistical error values.



Iterations

Some practitioners believe that curve building is an iterative process requiring multiple press runs. With the Optimal method iterations are performed in software, and there is generally no benefit from additional press runs. That said, PressCal supports additional iterations with the **`plate_curve:`** [setting].

Test Charts

The Optimal method works with any test chart providing sufficient information to define the curves. It works best with a full gamut of realistic samples, as explained previously. We have provided [test charts] based on commonly used reference profiles. These charts contain samples with the black generation of the reference profile. It is possible to make a test chart from a custom profile. Contact the authors for details.

If you intend to make curves -and- a characterization profile, we suggest you use the **PressCalP** test chart. This is a relatively small chart (625 patches) designed to make good ICC profiles of press work.

Extended Gamut Basic Settings

The color gamut of a printing process may be extended (enlarged) by using additional inks to complement the normal **CMYK** inks. These additional inks are typically orange, green and violet, or some combination thereof. The inks are mixed with the **CMYK** inks, as appropriate for the color being printed. So, it is correct to call them process colors, rather than spot colors, as they are an integral part of the printing process.

The Optimal method may be used to calibrate an extended gamut (**ECG**) process to a reference profile. These settings use data from a **CMYKOGV** ink jet printer and its corresponding ICC profile. Aside from that, the settings are identical to the **Optimal Basic Settings**. The optimization math is the same, but with additional device channels. Amazingly, all the ink interactions are properly accounted for.

The material in the **Optimal Basic Settings** section also applies to **ECG** processes. We won't repeat that material here. So, please read that section now, and return to this section for further information pertaining to **ECG** processes.

ECG Profiles

The number of samples needed to build an ICC profile increases exponentially with the number of ink channels. The chart below shows the number of samples needed for a simple profiling chart. The columns are the number of steps per ink channel.

	2	3	4	5	6	7
4/C	16	81	256	625	1296	2401
5/C	32	243	1024	3125	7776	16807
6/C	64	729	4096	15625	46656	117649
7/C	128	2187	16384	78125	279936	823543

For instance, a 7/C profile with 3 steps per ink channel requires 2187 samples. It is impractical to use more than a few thousand samples (i1Profiler limits test charts to 6000 samples). Therefore, ICC profiles for extended gamut printing will have fewer steps and be less accurate. Despite this limitation, PressCal can build curves to match **ECG** profiles with the same accuracy as **CMYK** profiles.

Sample Selection

The sample selection tokens work correctly with extended gamut data. Realistic samples are selected with the `rt()` (round-trip) token. For **CMYK** data, it is sufficient to use the black channel difference to choose the samples. But when you add inks to extend the gamut, all the ink channel differences must be considered. The `rt()` token has an optional mode parameter which controls how the round-trip difference is computed. For instance, the token `rt(10, -2)` selects the RMS (root mean square) difference. Mode parameter options are: **-1** for the average difference, **-2** for the RMS difference, and **-3** for the maximum difference.

These settings use **CMYKOGV** measurements of an Epson P5000 ink jet printer. The **PANTONE+ Extended Gamut Coated** test chart contains 2033 samples. Run the curve building tool with the ⌘**R** key combination. Each of the 2033 samples is listed before and after curve optimization. In this case the error values are extremely low because the reference profile was built from the press measurements. Consequently, the resulting curves are nearly linear.

Now, delete the **#** at the start of the **# select: rt(10) k nosub** line to activate that setting, and run the curve building tool again. This time, 1002 samples are selected. However, these are not realistic samples because they are **CMYKOGV**, not **CMYK**. Next, delete the **#** as the start of the **# select: rt(10, -2) ramps nosub** line to activate that setting. Notice the second parameter in the **rt()** token, and the use of the **ramps** token. Run the curve building tool again. This time, only 248 samples are selected.

Realistic Test Chart

Out of 2033 samples used to build the ICC profile, only 248 are realistic. This suggests using a calibration test chart consisting of more realistic samples. Unfortunately, there are no standard **CMYKOGV** ICC profiles at this time, so this would require a custom test chart built from your profile. If you're interested in how to make such a chart, contact the authors.

Grading Tool

Run the grading tool with the **⌘I** key combination. This example uses Optimal grading for offset, which was created by the authors, and is not an official standard or specification. However, unlike the official alternatives, it does grade extended gamut and spot colors. The test chart doesn't contain a gray axis ramp, so those tests are skipped. Otherwise, the measurements pass with flying colors, which is expected, since the profile was built from them.

The SCTV curve graphs are smooth, but not linear. This is an ink jet printer that was calibrated by the RIP software, so there is reason to expect linear curve shapes. In this case we don't have a **CMY** gray ramp, so that error graph is built from a few samples where the **CMY** values are equal.

Ink Balance Tool

Run the ink balance tool with the **⌘B** key combination. This tool is designed to work with offset and flexo printing, where the ink is applied in sequential layers, and the ink density is controlled by the ink film thickness. So, this tool shouldn't be used for ink jet printers. If you wish to adjust the gamut of an ink jet printer, it is better to use the **shadow:** setting to unpin the curve endpoints. For offset and flexo **ECG** printing, the tool works as expected, providing recommended density adjustments for each ink. The **CMY** inks are adjusted together, so the red, green, and blue overprints are considered, as explained in the ink balance section.

Multi Basic Settings

This basic setting demonstrates PressCal's capability to combine multiple reference profiles and measurement files. The example data comes from the flexo industry, where extended gamut printing is used to simulate spot colors. Profiles and measurement files with three ink colors and black are combined to define a **CMYKOGV** process. This is not the only use for PressCal's multi capability. **CMYK** measurements may be combined with spot color measurements, as shown in the Flexo basic setting.

It should be noted that combining multiple profiles and measurements may not produce a complete color space! For instance, in this example we know nothing about combinations of **OGV** inks. Nevertheless, we can perform good calibrations with the data available, using the Optimal method.

Matrix Notation

This basic setting file is identical to the Optimal basic setting file, except for the **`profile_path:`** and **`press_path:`** settings, which use a similar notation to select multiple profiles and measurements. For instance, this setting selects and combines four ICC profiles.

```
profile_path: [['~~/Data/FTA/FTA_CMYK.icc', 0, 1, 2, 3], ['~~/Data/FTA/FTA_Omyk.icc', 4, 1, 2, 3], ['~~/Data/FTA/FTA_cGyk.icc', 0, 5, 2, 3], ['~~/Data/FTA/FTA_cmVk.icc', 0, 1, 6, 3]]
```

Here is a simplified version of the matrix notation,

profile_path: [[profile 1], [profile 2], [profile 3], [profile 4]]

where,

[profile 1] is ['path_to_profile_1', mapping to the combined profile]

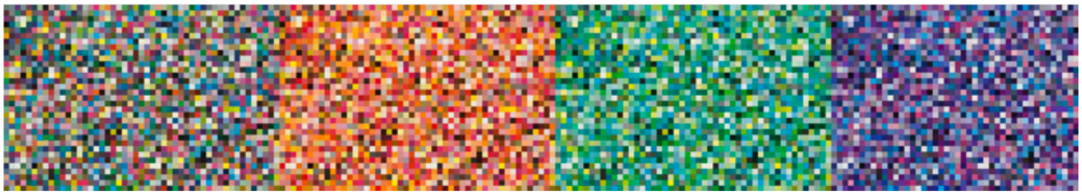
[profile 2] is ['path_to_profile_2', mapping to the combined profile]

[profile 3] is ['path_to_profile_3', mapping to the combined profile]

[profile 4] is ['path_to_profile_4', mapping to the combined profile]

The combined profile has 7 channels, 0, 1, 2, 3, 4, 5, 6 (**CMYKOGV**). Profile 1 maps to channels 0, 1, 2, 3 (**CMYK**). Profile 2 maps to channels 4, 1, 2, 3 (**OMYK**). Profile 3 maps to channels 0, 5, 2, 3 (**CGYK**). Profile 4 maps to channels 0, 1, 6, 3 (**CMVK**).

The **`press_path:`** setting uses the same notation, except the paths are to measurement files, rather than profiles. When you run PressCal, the measurements are combined into a single object, with the device values mapped to the indicated channels. Here is an image representing the combined data set.



Although you can export this data and open it in profiling software, you cannot make a proper **CMYKOGV** profile from it. Essential information is missing. However, you can make profiles from each individual measurement file, and use these profiles to compute color mixtures matching spot inks.

PressCal Tools

All PressCal tools work correctly with multiple profiles and/or measurement files. When you run the curve building tool (⌘**R**), you will see the individual profiles and measurement files displayed, along with their mapping.

```
PressCal version 16.3U modified 2022-10-04

reference profile(s):

        ~/Data/FTA/FTA_CMYK.icc mapped to [0, 1, 2, 3]
        ~/Data/FTA/FTA_Omyk.icc mapped to [4, 1, 2, 3]
        ~/Data/FTA/FTA_cGyk.icc mapped to [0, 5, 2, 3]
        ~/Data/FTA/FTA_cmVk.icc mapped to [0, 1, 6, 3]

press chart(s):

        ~/Data/FTA/TC1617x_CMYK.txt mapped to [0, 1, 2, 3]
        ~/Data/FTA/TC1617x_Omyk.txt mapped to [4, 1, 2, 3]
        ~/Data/FTA/TC1617x_cGyk.txt mapped to [0, 5, 2, 3]
        ~/Data/FTA/TC1617x_cmVK.txt mapped to [0, 1, 6, 3]

file contains M0 measurement condition

chart type: unknown, nominal samples: 6468, colorspace: CMYKOGV, types: PPPPPPP
```

If you run the grading tool (⌘**I**), you will see the results of several tests defined by the authors (Optimal grading).

```
standard: optimal, version: 2020, level: offset

process solids color error

      cyan ΔE00: 0.11 ✔ [3.00]
   magenta ΔE00: 0.17 ✔ [3.00]
    yellow ΔE00: 0.24 ✔ [3.00]
     black ΔE00: 0.17 ✔ [5.00]
    orange ΔE00: 0.29 ℹ [3.00]
     green ΔE00: 0.18 ℹ [3.00]
    violet ΔE00: 0.17 ℹ [3.00]

RGB solids color error

       red ΔE00: 0.39 ✔ [3.00]
     green ΔE00: 0.41 ✔ [3.00]
      blue ΔE00: 0.82 ✔ [3.00]

gray axis color errors

    missing data to grade gray axis

round-trip samples (4285)

    median ΔE00: 0.27 ✔ [2.50]
  95th pct ΔE00: 0.65 ✔ [5.00]
   maximum ΔE00: 3.78 ✔ [10.00]

skipped 4 tests
```

You can choose to grade with other standards or specifications, but they only test **CMYK** properties.

Likewise, if you run the ink balance tool (⌘**B**), recommended density adjustments will be displayed for all ink colors. This tool should only be used with offset and flexo printing processes.

PSD* Basic Settings

PSD is a quality methodology developed by FOGRA for digital printing. It is similar to their long-standing PSO methodology for offset printing. It is described in the **ProcessStandard Digital Handbook**, freely available from FOGRA. Currently, there is considerable growth in digital printing, with the rapid adoption of high-speed ink jet presses. So, PSD has increasing significance for the printing industry.

Relationship to ISO Standards

While PSD is not an official ISO standard, it builds upon several existing ISO standards for color, prepress and print. Among these, the ISO/TS 15311-1 and ISO/TS 15311-2 specifications are used to evaluate color accuracy. These specifications define the metrics, but not the tolerances. PSD defines three different quality types, **A**, **B** and **C**, using two modes of color comparison, **Side-by-Side** and **Media Relative**. The **`psd_level:`** setting selects the quality type and comparison mode.

Evolution of Print Standards

The original ISO standards for print were first published in 1996. These standards apply to specific printing processes, e.g. offset (12647-2), gravure (12647-4), and flexography (12647-6). Later, standards were added for direct digital proofing (12647-7 and 12647-8). Direct digital proofs are generally color-managed, because the inks or toners used are not equivalent to the inks used in conventional printing processes. Today's high-speed ink jet and toner presses are similar, in that the colorants are proprietary. Unlike offset inks, these colorants cannot be standardized. Therefore, the approach of earlier ISO print standards, to define the process colors and their tonality, doesn't work for digital printing.

This difference led to the development of the ISO/TS 15311 specifications, which define many quality measures for digital printing. These specifications don't specify which attributes to use, or their tolerances. That is left to other parties, most likely regional standards groups such as FOGRA and IDEAlliance.

Reference Profile

PressCal uses an ICC profile to define the reference color of the print. This conforms with the ISO/TS 15311-2 specification, which states that "The intended printing condition shall be defined by the ICC output profile." Typically, the ICC profile will be based on a standard data set, such as CGATS21-CRPC6.txt or FOGRA51.txt. However, this is not required - a profile of the raw digital print process could be used, if the files were created for that process. In that case, the printing process would not be color-managed, and its full color gamut could be utilized. PressCal can build tone curves for both color-managed and raw digital printing processes.

The **`profile_path:`** setting should be the path to an ICC printer profile. This profile may be built-in or external.

Press Measurements

PressCal compares measurements of your printing process with your selected reference profile. For process calibration, the IT8.7/4 test chart should be used. To check sheets from a production run, a control strip may be used, as defined in Annex B of the

* PSD is a registered trademark of Fogra Research Institute for Media Technologies

ISO/TS 15311-2 specification. This target could be an ISO 12647-7 media wedge, or an ISO 12647-8 control strip.

The **press_path:** setting should be the path to your measurements. If you measure multiple test charts, and wish PressCal to average them, place the individual files in a folder, and use the path to the folder.

If your instrument supports it, we recommend you measure M0, M1, and M2 data, and save it in CxF3 format (.mxf or .rmxf). Otherwise, you should select the measurement condition of the reference profile, and save the spectral data in CGATS ASCII format.

The **condition:** setting selects the data used from CxF3 files containing multiple measurement conditions. Normally, this setting should match the measurement condition of the reference profile. However, if there's a large color difference between the reference and press paper, the **auto** value may give better results by blending the M1 and M2 measurements to minimize that difference.

Initial Grading

At this point, you've measured your initial press sheet and entered your values for the settings just covered. In TextMate, with the settings file open, press the **⌘I** key combination to run the grade tool. The test results will be displayed in the grade log. If your press sheet failed any tests, you'll need to make changes.

Color Adjustments

The software (DFE) driving your printer/press probably has controls for color. Some devices have built-in measuring devices and software to automatically maintain color control. In this case, you should initiate the calibration procedure to bring the device into conformance. PressCal provides independent verification of the color properties, but cannot calibrate these systems.

Other devices give you access to color management settings and profiles, as a means of controlling color. In this case, you could build a new ICC profile to bring the device into conformance. Another option is to let PressCal compute tone curves, and apply them to the existing profiles, as explained in this section.

Some devices provide controls similar to an offset process, such as ink density and/or tone curves. In this case, you may use PressCal to build tone curves, and load them into the DFE, as with a conventional printing process.

Color Gamut

Before making curves, the color gamut of the printer/press and the reference profile should be roughly the same. This may be accomplished by choosing the reference profile to match the ink/toner and paper combination. Depending on the device, it may also be possible to adjust ink densities to match the reference profile. The ink balance tool (**⌘B**) will not work with digital presses, so you must make these adjustments by trial and error, using the solid ink measurements. PressCal provides L*C*h values of the solid inks for this purpose. For colored inks, the C* values correlate with ink density. For black ink, the L* values serve that purpose.

L*C*h values are enabled with the **`print_LCh:`** setting.

```
             abs L*C*h values     ->   ref L*C*h values       press L*C*h values      ΔCh      ΔH
   paper    95.0    6.2  284.0        95.0    6.2  284.0        95.0    6.2  284.0     0.03     0.00
    cyan    56.1   63.1  236.4        56.1   63.1  236.4        56.1   63.1  236.4     0.02     0.01
 magenta    48.1   75.5  356.1        48.1   75.5  356.1        48.1   75.5  356.1     0.01     0.01
  yellow    88.9   92.4   92.5        88.9   92.4   92.5        88.9   92.5   92.5     0.01     0.01
     red    48.0   83.1   33.5        48.0   83.1   33.5        48.0   83.1   33.5     0.01     0.01
   green    49.4   70.3  159.7        49.4   70.3  159.7        49.5   70.3  159.7     0.01     0.01
    blue    24.7   52.0  294.0        24.7   52.0  294.0        24.7   51.9  294.0     0.01     0.00
     iso    23.2    2.2  229.9        23.2    2.2  229.9        23.3    2.2  229.6     0.02     0.01
   black    16.0    0.4  275.3        16.0    0.4  275.3        16.0    0.3  282.0     0.04     0.04
    cmyk    12.2    4.9   84.9        12.2    4.9   84.9        12.7    4.9   83.8     0.09     0.09
```

Curve Settings

The **`select:`** setting selects the samples used to compute tone curves. We recommend using a realistic sample selection. With an IT8.7/5 test chart, you could choose a G7 sample selection, but keep in mind that the **CMY** gray balance of toner devices is notoriously unstable, and may be significantly different from your reference profile.

The **`psd_level:`** setting selects the quality type and comparison mode. A **side-by-side** comparison is literal (absolute rendering). A **media relative** comparison maps the white point of the print to that of the reference profile (media relative rendering). The **`rendering:`** setting, if any, is overridden by the PSD comparison mode. The quality type (**A**, **B**, or **C**) only affects the grading, not the curves.

Making Curves

Once you're satisfied with your settings, press the **⌘R** key combination to run the curve building tool. A log window will open, showing the software's progress. The log begins with the same output as the grade and ink balance tools. This includes your settings, and the solid ink errors. Then, you will see a single line with information about the sample selection. In this case, 996 samples were selected. For each sample, the initial device values, L*a*b* values, and error values are displayed.

```
    blue    24.7   21.1  -47.5        24.7   21.1  -47.5        24.7   21.1  -47.5     0.01     0.01
     iso    23.2   -1.4   -1.7        23.2   -1.4   -1.7        23.3   -1.4   -1.7     0.03     0.02
   black    16.0    0.0   -0.4        16.0    0.0   -0.4        16.0    0.1   -0.3     0.05     0.06
    cmyk    12.2    0.4    4.9        12.2    0.4    4.9        12.7    0.5    4.9     0.51     0.35


degree: 6, sample selection: 'rt(10) k nosub', samples: 996

sample        device values              ref L*a*b* values      press L*a*b* values      ΔE00
2       0.000  0.100  0.000  0.000       90.1    8.2   -7.5       90.1    8.2   -7.4     0.04
3       0.000  0.200  0.000  0.000       85.2   14.7   -8.3       85.2   14.7   -8.3     0.02
4       0.000  0.300  0.000  0.000       80.3   21.4   -8.9       80.3   21.4   -8.9     0.02
5       0.000  0.400  0.000  0.000       75.4   28.5   -9.3       75.4   28.4   -9.2     0.01
```

The average initial errors are displayed, and the optimization commences. After a short time, the optimization is complete, and the sample data is displayed again, this time with the newly computed curves applied.

```
1614    0.000  0.000  1.000  0.100       82.9   -4.3   86.1       82.9   -4.3   86.3     0.06
1615    0.000  1.000  1.000  0.100       44.6   64.5   41.9       44.5   64.5   41.8     0.07
1616    1.000  0.000  1.000  0.100       46.3  -61.8   22.6       46.4  -61.9   22.7     0.02
1617    1.000  1.000  0.000  0.100       23.4   19.5  -44.3       23.5   19.5  -44.2     0.03

                                                              initial average error:    0.08

optimizing curves for minimum ΔE00...

L-M optimization completed at 243 iterations

error values with optimized curves are below...

sample        device values              ref L*a*b* values      press L*a*b* values      ΔE00
2       0.000  0.100  0.000  0.000       90.1    8.2   -7.5       90.1    8.2   -7.4     0.04
3       0.000  0.200  0.000  0.000       85.2   14.7   -8.3       85.2   14.7   -8.3     0.02
4       0.000  0.300  0.000  0.000       80.4   21.4   -8.9       80.3   21.4   -8.9     0.02
5       0.000  0.400  0.000  0.000       75.5   28.4   -9.3       75.4   28.4   -9.2     0.03
```

The average optimized errors and final gamut scale factor are displayed. The average optimized errors should be less than the initial values. In this example, the errors are extremely small because the reference profile was made from the press data.

```
1614    0.000  0.000  1.000  0.100       82.9   -4.3   86.1        82.9   -4.3   86.3     0.06
1615    0.000  1.000  1.000  0.100       44.6   64.5   41.9        44.5   64.5   41.8     0.08
1616    1.000  0.000  1.000  0.100       46.3  -61.8   22.6        46.4  -61.9   22.7     0.02
1617    1.000  1.000  0.000  0.100       23.4   19.5  -44.3        23.5   19.5  -44.2     0.03

                                                              optimized average error:   0.07

final gamut scale factor = 1.000
```

The Bernstein curve parameters are displayed, followed by a message as each curve format is output. In this example only the text format is output.

```
curve parameters:

             HLV    1/6    2/6    3/6    4/6    5/6    SHV
     cyan  0.000  0.171  0.323  0.511  0.658  0.840  1.000
  magenta  0.000  0.167  0.332  0.499  0.666  0.837  1.000
   yellow  0.000  0.167  0.334  0.499  0.664  0.838  1.000
    black  0.000  0.167  0.329  0.508  0.657  0.836  1.000

writing curves in 'text'        format to /Users/wbirkett/Desktop/tab_delim.txt

CED sample selection same as optimization, samples: 996
```

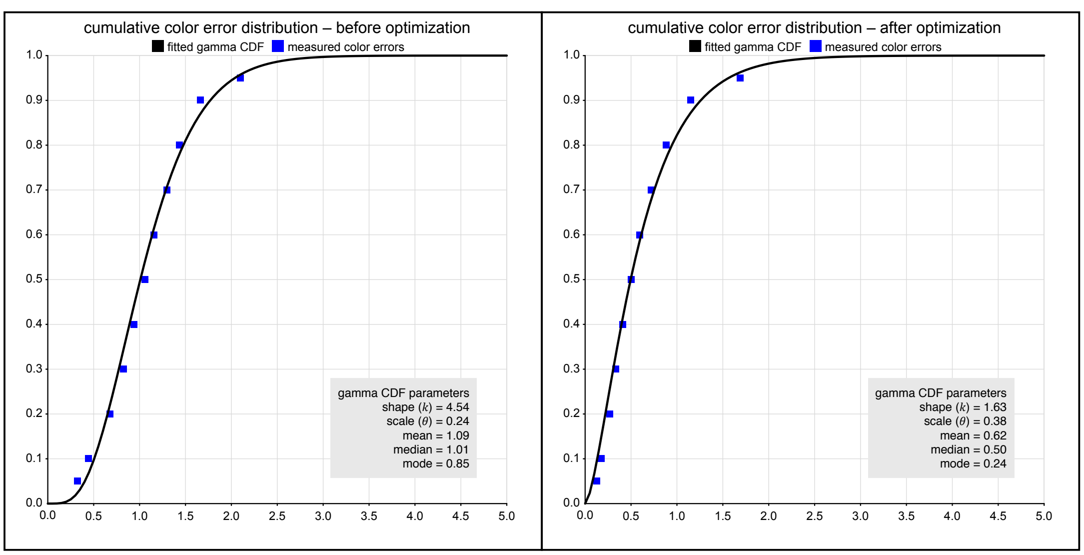
Program exited with code #0 after 30.17 seconds. copy output

Currently, the curve **`output:`** options for digital devices are limited, so you may need to enter the curve values by hand into the DFE. The **text** output token may be customized to calculate %-dot values required by the DFE. For example,

```
output: text(0, 5, 10, 25, 50, 75, 90, 100)
```

Cumulative Error Distribution

If you set the **`press_path:`** to **`~~/Data/Test/FOGRA39L.txt`**, and the **`psd_level:`** to **`rel_A`**, the resulting curves will be more typical. Although the initial color errors are small, the tone curves make a significant improvement, which is evident in the cumulative color error distribution (CED) graphs, before and after optimization.



Media Profile Basic Settings

PressCal can apply computed tone curves to ICC profiles, as explained in the Calibrating Color-Managed Processes section. In this example, we use the media profile from a color-managed printer as the reference profile. We print a test chart with color management turned off and measure it. PressCal computes curves and applies them to the reference profile. These curves are very close to linear, and would correct small changes in the printer, likely due to the inks and/or media. The modified profile replaces the media profile in the RIP. This is a simple way to keep a color-managed process calibrated.

New Profile vs. Curves

If a printer needs re-calibration, why not make a new media profile rather than curves? When there are large color errors, it is probably best to make a new profile.

An ink jet printer may have a surprising amount of spatial variation. You can check this by printing two identical calibration charts with different orientations and comparing their measurements. You would expect the measurements to be identical, but they may differ due to spatial variation. If the difference is significant, curves may be a better solution. PressCal can discern the "true" state of the printer, and re-calibrate with fine tone adjustments, avoiding the disruption of a new media profile.

Furthermore, re-calibration doesn't require a large test chart, as illustrated by this basic setting. The measurements are of an ISO 12647-7 verification chart, which has 84 patches. This chart is commonly used to verify the color accuracy of proofs. For re-calibration, the chart should be printed with color management turned off, as we are comparing it with the media profile, which was also made with color management turned off.

Modified Profile

Run the curve building tool with the **⌘R** key combination. Curves are built using all samples and applied to the reference profile. The modified profile is saved on the desktop, with a 10-digit number (Unix time) appended to the name. These curves are nearly linear and reduce the median color error from 0.56 ΔE00 to 0.40 ΔE00. The curves are applied to the B2A tags of the profile. These are the tags used in a color-managed workflow.

In addition, the white point tag is updated with the measured white point of the test chart. The white point tag is updated if the B2A tag is selected (default) and the **`rendering:`** setting is media relative [0, 0] (default). This modifies the profile for differences in the media color, which is needed when the RIP color management rendering intent is absolute colorimetric.

This profile replaces the current media profile in RIP. You will probably need to select the new profile in the RIP configuration. It is possible to eliminate this manual step by moving the original media profile to a safe location and changing the **`adjust_profile_path:`** setting to the original profile path. With that setting, the modified profile directly replaces the original. This arrangement makes it very simple to re-calibrate the printer. Just print the test chart, measure it, and run PressCal with the path to the new measurements.

Other Options

Normally, curves are pinned at 0% and 100%. If the solid ink density of the printer changes, pinned curves cannot properly account for that. However, you can unpin the 100% curve values by adding the **`shadow: [undef, undef, undef, undef]`** setting. A caveat is that while you can reduce the solid ink density, you cannot increase it. Nevertheless, this adjustment may be exactly what's needed because the color gamut of the raw printer is larger than with color management enabled.

There are situations where you may wish to modify the white point of the media profile, without applying curves. To do this, add the setting **`ink_map: [L, L, L, L]`**. This will force the curves to be linear, so the B2A tags are unchanged.

RGB Basic Settings

If you're reading this section, you probably have some interest in calibrating an **RGB** device. Normally **RGB** suggests an additive color device, such as a camera or display. It is generally better to calibrate these devices with an ICC profile, or some other software. But if you have a printer that is driven with **RGB** data, calibrating with curves may be a good solution.

In this case, the device is an Epson P5000 ink jet printer, driven in **RGB** mode. This printer has 10 inks, **CMYKcmkOGV**, with ink mixing hardware and software to make it appear as an **RGB** device.

New Profile vs. Curves

If a printer needs re-calibration, why not make a new media profile rather than curves? When there are large color errors, it is probably best to make a new profile.

An ink jet printer may have a surprising amount of spatial variation. You can check this by printing two identical calibration charts with different orientations and comparing their measurements. You would expect the measurements to be identical, but they may differ due to spatial variation. If the difference is significant, curves may be a better solution. PressCal can discern the "true" state of the printer, and re-calibrate with fine tone adjustments, avoiding the disruption of a new media profile.

Reversed Polarity

The Optimal method was originally developed using **CMYK** profiles and data. When additional process colors are added to make an extended color gamut (**ECG**) process, it works the same, without any changes. This is almost true for **RGB** processes, but for the fact that **RGB** data has reversed polarity.

	CMYK	RGB
White	0	255
Black	100	0

Consequently, for **RGB** processes, the highlight region of **RGB** curve graphs is the upper-right, and the shadow region is the lower-left. Internally, PressCal adapts for **RGB** data, so the settings and functions are the same as for **CMYK**.

Grading Tool

With the RGB Basic Settings opened in TextMate, run the grading tool with the ⌘**I** key combination. The log will list the solid ink colors and their overprints. Keep in mind that these colors are **RGB** values, which are inverted. For instance, the **RGB** values for the cyan color are 0, 255, 255. The color printed might not be 100% cyan ink because the **RGB** values are converted to **CMYKOGV** values by hardware and software within the printer. But the dominant ink color is cyan. The same is true for all the solid colors listed. The **`iso`** color is **RGB** 0, 0, 0, and that will appear black.

There are no standards for **RGB** printing, so we use the Optimal grading for offset. Since this is an ink jet printer, the tolerances could be made tighter with a custom grading scheme. The gray axis color errors are computed from the **isometric** samples, which have equal **RGB** values, e.g., 150, 150, 150. For most **RGB** colorspaces, these samples are nominally gray.

```
standard: optimal, version: 2020, level: offset

process solids color error

     cyan ΔE00: 0.00 ✔ [3.00]
  magenta ΔE00: 0.00 ✔ [3.00]
   yellow ΔE00: 0.00 ✔ [3.00]

RGB solids color error

      red ΔE00: 0.00 ✔ [3.00]
    green ΔE00: 0.00 ✔ [3.00]
     blue ΔE00: 0.00 ✔ [3.00]

gray axis color errors

    average ΔL: 0.00 ✔ [1.50]
    maximum ΔL: 0.00 ✔ [4.00]
   average ΔCh: 0.00 ✔ [1.50]
   maximum ΔCh: 0.00 ✔ [4.00]

all samples (2432)

   median ΔE00: 0.00 ✔ [2.50]
 95th pct ΔE00: 0.00 ✔ [5.00]
  maximum ΔE00: 0.00 ✔ [10.00]

passed all tests
```

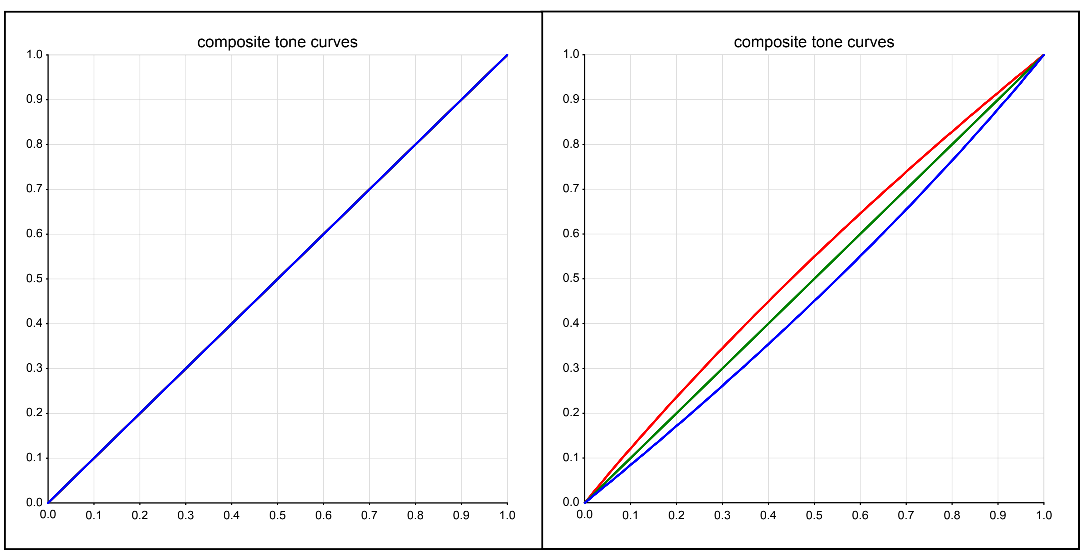
Program exited with code #2 after 2.26 seconds. copy output

The grading tool plots graphs of the red, green, and blue SCTV ramps. The actual colors of these ramps are cyan, magenta, and yellow, but we call them red, green, and blue because those are the channels that are varied to make the ramp. These graphs should be smooth, but not necessarily linear.

Curve Building Tool

When updating a media profile, the test chart should be printed with color management turned off. We are comparing the test chart measurements to the media profile which is also built with color management turned off. These test measurements were derived from the reference profile.

Run the curve building tool with the ⌘R key combination. All the samples (2432) are selected, and they match the profile computed colors exactly. So, the computed curves are linear, as expected.



Next, enable the line **`# press_path: ~~/Data/Test/P5000_RGB_Hahnemuhle_Photo_Rag_188gm_mod.txt`** by deleting the **#**, and run the tool again. This data set has been modified using simple curves to compute the L*a*b* values. The computed curves show this, and the color error values after optimization are nearly 0.

Now, set the degree to 2, deleting the **#** to activate that setting, and run the curve tool again. Look at the curve parameters near the bottom of the log screen.

```
final gamut scale factor = 1.000

curve parameters:

            HLV    1/2    SHV
     red   0.000  0.400  1.000
   green   0.000  0.500  1.000
    blue   0.000  0.600  1.000
```

These are the exact curves that were used to modify the test data. PressCal is able to discern the color changes from the L*a*b* data.

Sample Selection

With **RGB** data, all samples are realistic, so there is no need to use the **`rt()`** token. Other selection tokens like **`ramps`**, **`gray`** and **`iso`** work as expected. If you wish to use gray samples, keep in mind that equal **RGB** values generally produce gray, and these samples are selected with the **`iso`** token. We suggest using **`all`** samples.

As an experiment, enable the sample selection **`select: plus(1 .. 1216)`** and build curves again. This selects the first half of the samples. You will see that the resulting curves are the same. Now, enable **`select: plus(1 .. 20)`** and build curves again. With just 20 random samples, PressCal makes the same curves. So, you don't need a large test chart to re-calibrate an **RGB** printer.

Ink Balance Tool

The ink balance tool is not supported with **RGB** data. This tool is meant to suggest ink density adjustments for offset and flexo processes. If you want to adjust the color gamut of your **RGB** process, we suggest you use the **`shadow:`** setting, as shown in the basic settings. This will unpin the shadow values during optimization, which has the effect of adjusting solid ink densities for an ink jet device. You should also enable the **`gsf: 1`** setting for this to work properly.

```

# set curve output token(s) (see user manual for options)
output: text

# set gamut scale factor (comment out to optimize)
gsf: 1

# set shadow endpoints (0 to 25 RGB, -or- undef)
shadow: [undef, undef, undef] # shadows floating

```

Applying RGB Curves

The computed curves may be output using certain tokens. But you might prefer to apply the curves directly to the media profile. This is done with the **`adjust_profile_path:`** setting. Assuming you have network access to your RIP, you could write the modified profile directly to the folder where media profiles reside.

Normalize Basic Settings

This basic setting illustrates how to normalize a print data set, so it has the "same color appearance" as a reference profile. *Normalizing seeks the best color rendition when an exact match is not possible*.

Color Appearance

A great deal of research exists on the factors affecting how we see color. This science is incorporated into "color appearance models," such as CIECAM16. The CIECAM model takes into account viewing illumination and surround. It provides a way to render images under a variety of viewing conditions. Needless to say, the math required is very complex.

Fortunately, normalizing doesn't require a color appearance model. We compare printed materials under standard illumination in a viewing booth. The main variables are the substrate (paper) and the color gamut (inks). PressCal normalizes a data set by applying curves to the device values. These curves are created using the Optimal method, which minimizes color differences between the reference profile and the press data set.

Color Gamut

When calibrating with the Optimal method, we normally choose a reference profile similar to our printing process. Ideally, the paper and inks would be identical. But when normalizing, these materials could be quite different. While curves will adjust tonality and gray balance, they won't change the color gamut (when pinned at 0% and 100%). When color gamuts differ, the curves are distorted in a futile effort to compress or expand the gamut.

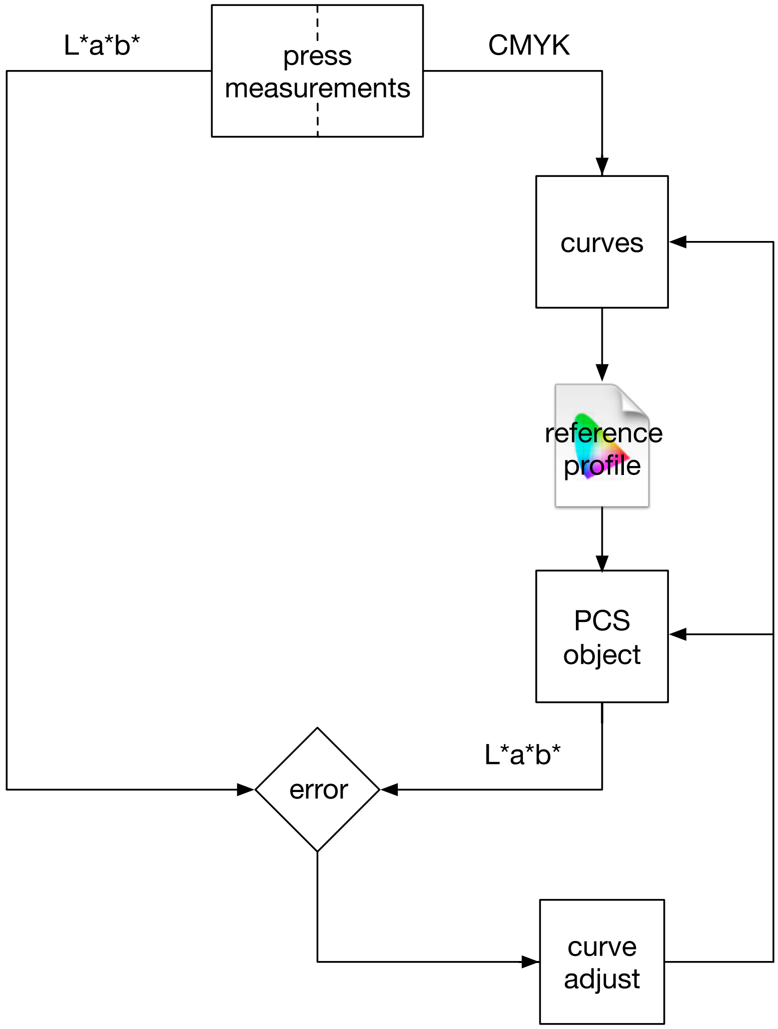
PressCal solves this problem by adjusting the gamut of the reference profile to match that of the data set. This is accomplished by modifying the xyz color values calculated from the reference profile during optimization. The flowchart at the top of the next page shows the PCS object, which performs this function.

The primary function of the PCS object is to convert the profile's output values, which are encoded in the profile's connection space (PCS), into normal L*a*b* values. This is a three step process. First, the profile's output values are converted to xyz values. These values range from 0 (black) to 1 (white). The xyz values may be scaled, according to the rendering intent and media white values. The scaled xyz values are then converted to normal L*a*b* values.

Tone Compression

It is possible to adjust the size of the color gamut by modifying the xyz black point. This is known as black point compensation, a term made popular by Adobe in Photoshop. By default, PressCal uses black point compensation when optimizing. The **`gsf:`** setting (gamut scale factor) allows you to set a fixed amount of black point compensation.

Black point compensation adjusts the xyz values linearly. A small amount of white light is added or subtracted to decrease or increase the color gamut. This is an acceptable way to make small gamut changes. But when the changes are large, a linear curve is not ideal. PressCal provides a **`linearity:`** setting, which allows you to make subtle changes to the gamut compression contrast. The linearity value is 0 by default, which

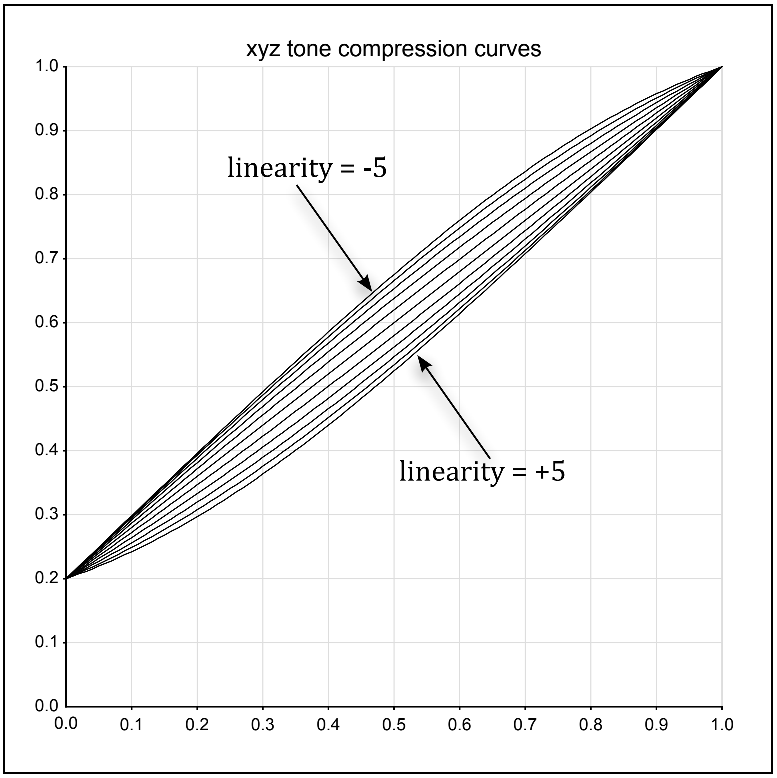


corresponds to linear tone compression. Positive values, e.g., 2, add contrast to the highlights, while negative values, e.g., -2, add contrast to the shadows. The graph at the top of the next page illustrates xyz tone compression curves for linearity settings from -5 (upper curve) to +5 (lower curve). The linear curve (0) is in the middle.

Notice that the linearity setting shifts contrast subtly, to emphasize the highlights or shadows. The purpose of these effects is to fine-tune the color appearance. We find that a linearity value of 2 works well for a typical assortment of high-key, average, and low-key images.

Rendering

The **`rendering:`** setting is media relative, by default. This maps the media white point of the reference profile to that of your press measurements. When these values are significantly different, you will see a color shift in a side-by-side comparison. Normally, this is not a problem, as your vision will adapt to the paper color when a printed piece is viewed alone. But there are situations when it is desirable to improve the side-by-side match.



You can reduce the color shift by using luminance relative color rendering. This maps the luminance (Y-value) of the reference profile to that of your press measurements. The resulting curves will reduce the color shift, while leaving the curve endpoints fixed. You may uncomment the **`rendering:`** settings to see what this does. A cast value to 0.5 seems to give the most pleasing result for this example.

Making Normalized Profiles

After the tone curves are computed, PressCal outputs curve-adjusted press measurements. Note that device values (CMYK) are adjusted, not color values (L*a*b*). Use these measurements to make a new reference profile with your preferred profiling software and settings. This new reference profile will have the same color appearance as the original reference profile, while retaining essential characteristics of your printing process, such as the paper and solid ink colors.

The ISO/PAS 15339-2:2015 specification provides a collection of offset litho data sets on various substrates. There are 7 data sets known as CRPC1-CRPC7. The method used to produce these data sets is described in CGATS TR-015 technical report (commonly known as G7). These data sets were developed with the aim of having a common appearance. The normalizing procedure we've described allows you to create your own CRPCs from your presswork, using your materials

The normalized printer profile completely describes the color of your printing process, unlike density and TVI, which are process control measures. You can use the profile as a reference to re-calibrate your process for future work, or to calibrate additional presses in your plant, or elsewhere. It can also serve as a reference for making color-critical proofs.

Dissimilar Basic Settings

When calibrating with curves, a basic assumption is that the printing process is equivalent to the color reference. Equivalent means that, with the right tone curves applied, the printing process is identical to the color reference. In other words, the printing process and color reference are identical, but for differences in tonality. In this case, it is easy to determine the right tone curves, by comparing the individual ink ramps with a measure such as TVI or SCTV.

In reality, the printing process is never exactly equivalent to the reference. There will always be residual color errors, regardless of the method used to compute tone curves. So, the objective of a calibration method should be to minimize the residual errors, so that images, while not perfectly matched, will still appear to be identical. PressCal accomplishes this by mathematical optimization, using color samples that are likely to appear in images.

We normally try to match the gamut of the printing process with the color reference before computing tone curves. There are many standard data sets and profiles to choose from, for various printing processes and medias. Once that is done, we may be able to adjust the individual ink colors to bring the color gamuts into close alignment. The white and black points of the reference may be adjusted, as well. Then, we build the tone curves by optimization.

When the printing process and color reference are not equivalent, we say they are dissimilar. As just explained, this is a matter of degree, since there will always be some residual color errors after curves are applied. PressCal makes curves by reducing the residual error of the selected sample to an overall minimum. The different curve building techniques (e.g. TVI, G7, SCTV, and Optimal) are distinguished by the sample selection, and color error metric.

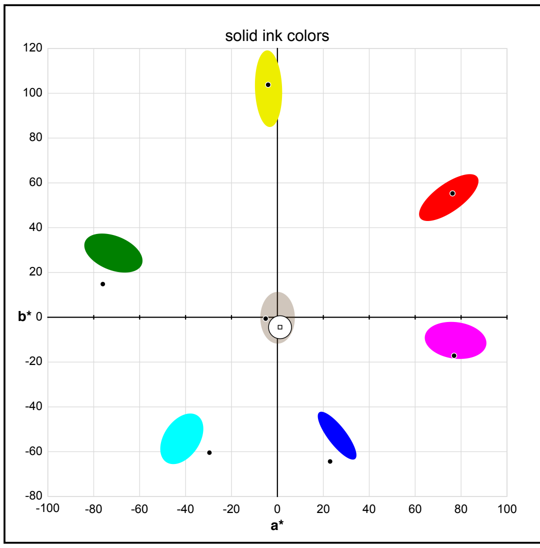
The Optimal method is very good at calibrating dissimilar printing processes. For instance, a client might supply files created with the GRACoL2013 reference for flexo printing. The Optimal method will match these dissimilar processes successfully, where other techniques might fail. This basic setting uses an extreme example of dissimilar color matching to illustrate this point.

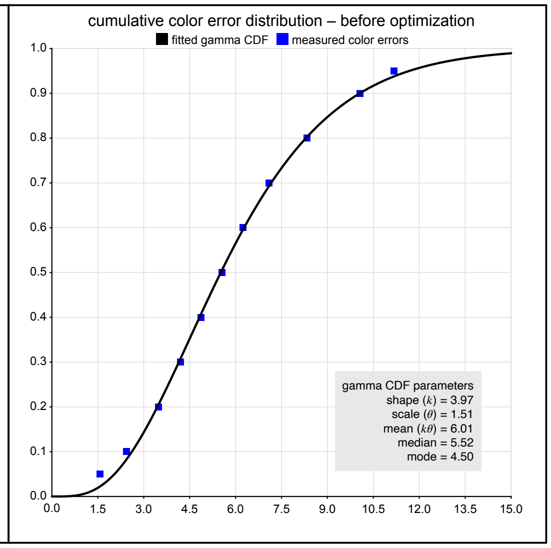
Printer and References

The press data is from an **Epson S80600** printer, printing on **Sihl 3699 PhotoArt** media. This printer has 9 inks, **CMYK**, lightC, lightM, lightK, orange and red. The printer mixes these inks internally, and is seen by the DFE/RIP as a **CMYK** device. The color reference, **CGATS21_CRPC7.icc**, is based on an average of large format printers, on a very white media. The printer and reference profile are very dissimilar. Normally, this printer would be color-managed, but we use it here as an example of dissimilar color matching with curves.

Initial Grading

The initial color errors between printer and reference are determined by running the grade tool (⌘**I**). All of the solids ink colors fail, except yellow and red. There are 102 samples with a color error > 10 $\mathbf{\Delta E_{00}}$. The median color error of realistic samples is 5.6 $\mathbf{\Delta E_{00}}$. The 95th percentile is 11.2 $\mathbf{\Delta E_{00}}$. This is a very poor initial match.

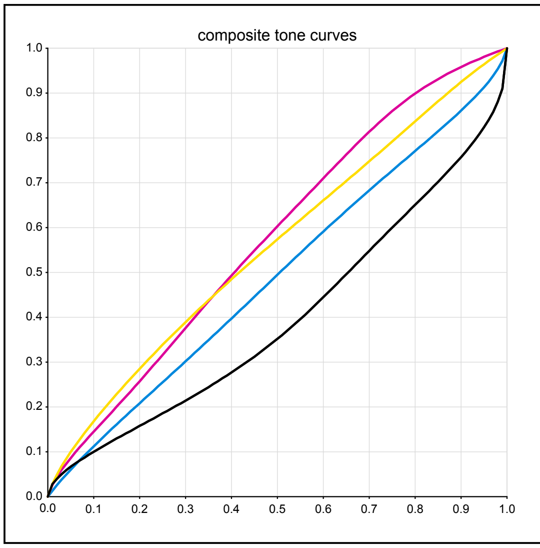


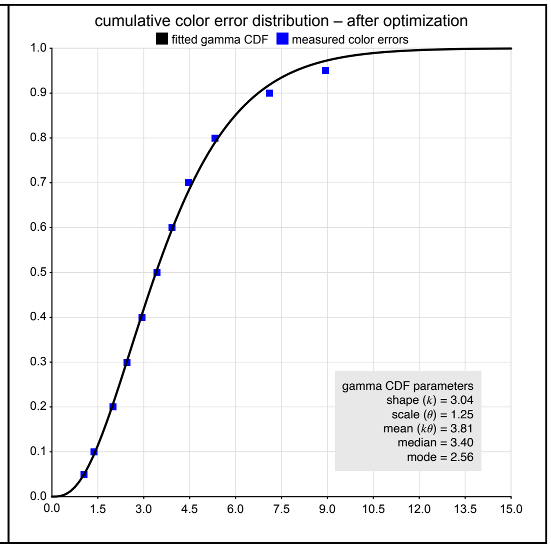


Optimal Curves

The initial **`select:`** setting is **rt(10) k nosub sort(error)**. These are the realistic samples, sorted in order of color error. The IT8.7/5 data set contains 1617 samples. Of these, 981 samples are selected because they represent realistic colors in images generated using the **CGATS21_CRPC7.icc** profile. The decision to include an individual sample involves calculating the **round-trip CMYK values** using that profile. If the black printer change is less than 10%, the sample is included. Black-only samples are also included, as they are deemed important, but will fail the round-trip test.

Curves are calculated by running the curve building tool (⌘**R**). The software log will show the solid ink errors, followed by a list of the realistic samples, sorted by the initial color errors. Then, the optimization will commence, followed by a list of the same samples, but with the optimized color error, again sorted by that value. Finally, the curve parameters are displayed, and curve formats selected by the **`output:`** setting are saved. Graphs of the curves are then displayed in your web browser, followed by CED graphs, before (above) and after (below) optimization.





If you compare the before and after CED graphs, you will see the error is substantially reduced. The median color error dropped from 5.5 **ΔE_{00}** to 3.4 **ΔE_{00}**.

Statistically, this is a substantial improvement, but an offset press match, using curves, will generally have a median error less than 2 **ΔE_{00}**. So, this result is clearly imperfect, but utilizes the full gamut of the printer. We made actual prints of a test form, and the visual match of the images to a color-managed print was surprisingly good, despite the large color errors. The Optimal result might be preferred by some viewers, as it is slightly more colorful.

G7 Curves

You may easily compute G7 curves using the same press and reference by changing some settings, as shown below.

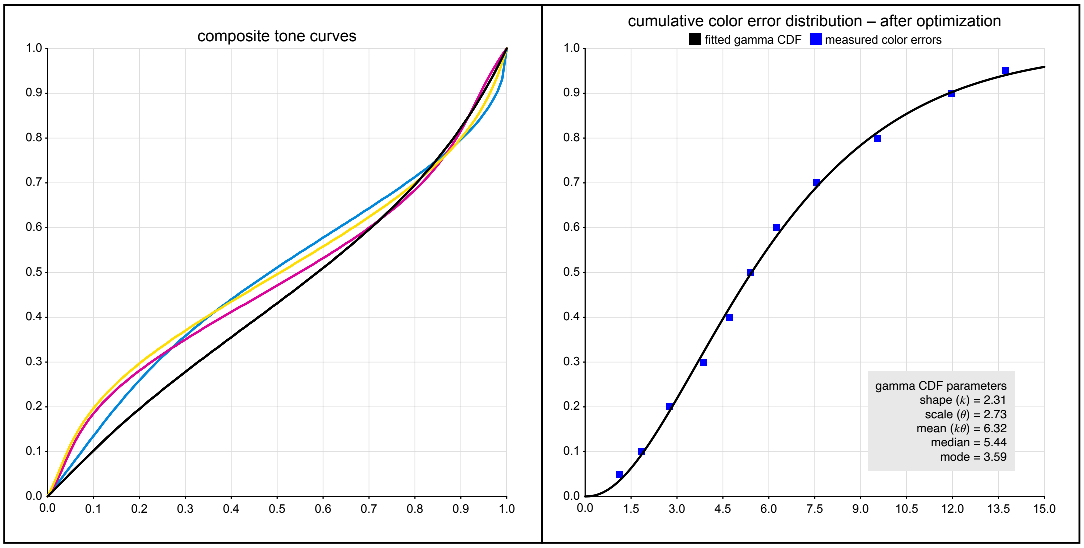
```
# set ink map, an array indicating how each tone curve is derived
# options are: 0, 1, 2, ... (optimize), S (SCTV), A - F (TVI), N (G7K), L (linear)
ink_map: [0, 1, 2, N] # enable for G7 curves

# set color error metric (dEab, dEcmc, dE94, dE99, dE00, dLCh, dLab)
deltaE: dLCh # enable for G7 curves

# set sample selection token(s) (see user manual for options)
# select: rt(10) k nosub sort(error)
select: g7 nosub sort(1) # enable for G7 curves
```

The **`select:`** setting is **g7 nosub sort(1)**. These are the G7 **CMY** gray samples, sorted by color error. The **`ink_map:`** is set to optimize the **CMY** curves, and build the black curve using the G7 formula. The **`deltaE:`** setting chooses the error measurements for the optimization routine. These are the normal settings for making G7 curves with PressCal.

Run the curve building tool again (⌘**R**). This time the software log will display the color errors for the G7 gray samples, sorted by the cyan value. Then, the optimization will commence, followed by a list of the same samples, but with the optimized color errors. Notice the final error values are very small, indicating a good G7 result.

```
error values with optimized curves are below...

sample        device values                     ref L*a*b* values        press L*a*b* values      wΔL*      wΔCh
281      0.020  0.015  0.015  0.000           93.6    1.2   -4.7          93.7    1.0   -4.8      0.09      0.27
327      0.040  0.030  0.030  0.000           92.6    1.2   -5.0          92.8    0.8   -4.6      0.26      0.48
373      0.060  0.045  0.045  0.000           91.6    1.0   -5.3          91.8    0.6   -5.0      0.19      0.49
419      0.080  0.060  0.060  0.000           90.7    0.8   -5.6          90.7    0.5   -5.2      0.08      0.45
465      0.100  0.075  0.075  0.000           89.7    0.6   -5.9          89.8    0.4   -5.3      0.08      0.61
511      0.150  0.112  0.112  0.000           87.4   -0.1   -6.6          87.2    0.2   -5.9     -0.13      0.76
557      0.200  0.150  0.150  0.000           84.7   -0.7   -7.0          84.4   -0.2   -6.2     -0.40      0.92
603      0.250  0.189  0.189  0.000           81.7   -0.9   -7.2          80.9   -0.2   -6.8     -0.77      0.81
649      0.300  0.228  0.228  0.000           78.2   -1.0   -7.2          77.4   -1.1   -7.4     -0.83      0.30
695      0.350  0.269  0.269  0.000           74.1   -0.8   -6.8          73.1   -1.5   -8.1     -0.96      1.41
741      0.400  0.311  0.311  0.000           69.4   -0.4   -6.3          68.5   -1.1   -7.2     -0.89      1.13
787      0.450  0.355  0.355  0.000           64.0    0.3   -5.8          64.0   -0.4   -7.0     -0.01      1.41
833      0.500  0.400  0.400  0.000           58.1    0.9   -5.2          59.5    0.9   -4.9      1.41      0.34
879      0.550  0.447  0.447  0.000           51.9    1.2   -4.7          53.5    1.4   -4.2      1.42      0.55
925      0.600  0.497  0.497  0.000           45.5    1.5   -4.2          47.1    1.7   -3.1      1.40      0.98
971      0.650  0.549  0.549  0.000           39.0    1.7   -3.7          40.3    2.4   -2.7      0.96      0.94
1017     0.700  0.604  0.604  0.000           32.8    1.3   -3.0          33.2    1.6   -2.7      0.33      0.33
1063     0.750  0.661  0.661  0.000           27.1    0.2   -2.4          27.1    1.9   -1.5     -0.02      1.17
1109     0.800  0.722  0.722  0.000           22.3   -1.1   -1.7          19.7   -2.0   -2.8     -1.39      0.78
1155     0.850  0.786  0.786  0.000           18.3   -2.5   -1.2          15.8   -4.7   -2.5     -1.16      1.21
1201     0.900  0.853  0.853  0.000           15.3   -3.1   -0.6          13.7   -4.0   -1.4     -0.62      0.48
1247     0.950  0.925  0.925  0.000           13.0   -2.1   -0.0          12.8   -2.7   -0.4     -0.08      0.22
1293     0.980  0.969  0.969  0.000           11.9   -0.9    0.1          13.3   -4.2   -0.7      0.39      0.95
1339     1.000  1.000  1.000  0.000           11.3   -0.0    0.1          14.1   -5.1   -0.6      0.69      1.29

                                                         optimized weighted average error     0.61      0.76
```

Graphs of the curves are then displayed in your web browser, followed by CED graphs, before and after optimization.



Notice the G7 tone curves are considerably different from those generated by the Optimal method. Then, look at the CED graph compared to the before optimization graph. The median and average color errors have increased! We made actual prints using these curves, and the G7 result was visually inferior to the raw printer output.

Mystery Explained

This may be surprising to G7 advocates, but is easily explained. Yes, the **CMY** gray scale is accurately rendered using the G7 curves, but these colors are not relevant, except in the highlights. The actual gray axis contains black ink as the dominant component in the midtones and shadows. Optimal curves are built from samples that are likely in images, unlike G7 curves. So, it is common sense that the Optimal result will be superior when measured by the color error of these samples. The visual results agree with the statistics.

Optimal Curves Are Reliable

It's true, this example of very dissimilar processes magnifies the difference between the Optimal and G7 methods. But even for normal color matching, the Optimal method is more reliable. When the **CMY** solid is not gray, the G7 method may falter. But the Optimal method is unfazed, because it doesn't use irrelevant **CMY** samples. Instead, the curves are based on colors that matter. With a PressCal test chart, that includes the actual gray axis, as generated by the reference profile, with black ink and UCR/GCR.

Bernstein Basic Settings

This basic setting explores individual settings controlling the structure and generation of curves. PressCal curves are Bernstein polynomials, an ideal mathematical function for modeling tone curves. These curves are described in more detail here.

We call them **parametric curves** because they are fully described by a small number of parameters – the coefficients of the Bernstein polynomial. This concept is similar to vector graphics, where a circle is described by its radius, or a square by its height and width. In fact, Bernstein polynomials are widely used in computer graphics.

Degree

The degree of a Bernstein curve is equal to the number of parameters minus one. Each parameter is the coefficient of its basis function. The graphs on this page show sets of basis functions with degrees of 3, 4, 5 and 6. If there are more parameters, the curve shape may have more detail or complexity. By default, PressCal determines the degree from the samples selected. The PressCal **`degree:`** setting allows you to override this value. A lower value will make the curves simpler and smoother.

Run the basic setting to build curves using the ⌘**R** key combination, then run it again with the degree: setting active (delete the leading #). Compare the curves. Change the degree to 4, and compare the curves again. You should also look at the median residual error in the **cumulative color error distribution – after optimization** graph. This error will increase slightly as you lower the degree of the curves.

Why use a lower degree, if it harms the color match to the reference profile? Wouldn't it be better to increase the degree? Like most things, the degree: setting has an optimum value. Depending on the selected samples, a high degree setting may yield strange looking curves. This is because there are insufficient samples to constrain the optimization function, which doggedly seeks minimum error. We suggest you only reduce the degree from the default value, to make your curves smoother.

Gamut Scale Factor

The **`gsf:`** setting controls black point compensation, which matches the gamut of the reference profile to the press measurements. A value of 1 indicates no adjustment. A value less than 1 means the gamut is reduced, and a value greater than 1 means the gamut is increased. By default, the value is optimized as curves are built. Run the basic setting with the gsf: setting disabled, and then again with it enabled, to see its effect. You should set the gsf: value to 1 when you are trying to match color exactly, or when you set shadow: values to **`undef`** (see below).

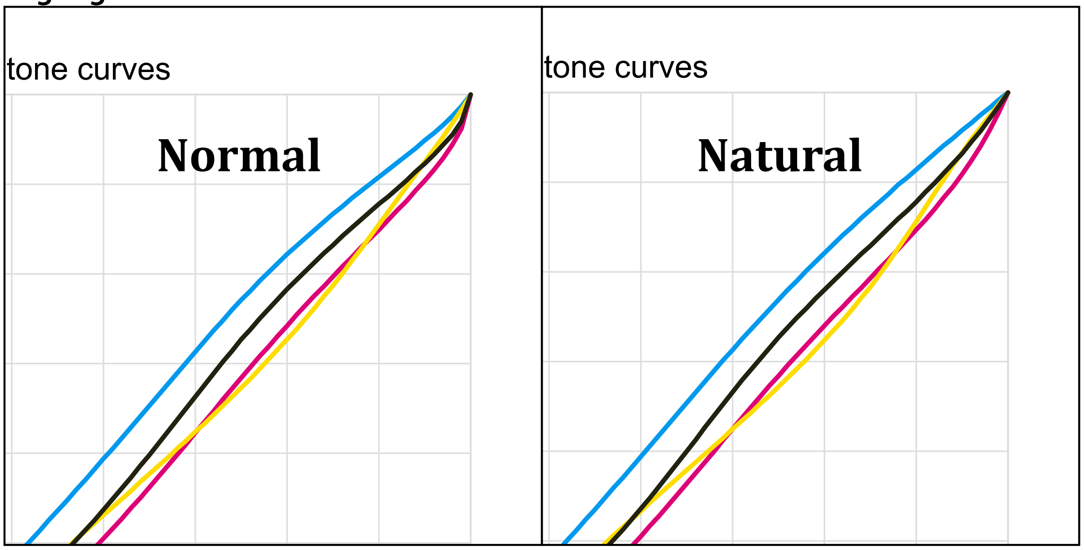
Linearity

The **`linearity:`** setting controls the adjustment of xyz values when the reference gamut is reduced or increased. By default, the xyz values are scaled linearly, which corresponds to a linearity value of 0. A positive value shifts the gamut change into the shadow region, while a negative value shifts the change into the highlight region. This setting is useful when the print gamut is small, and tones must be compressed significantly.

Natural

The **`natural:`** setting adds an optimization constraint forcing the curves to be straight at the shadow endpoint. The graphs below show the same curves produced with this setting off and on. Keep in mind, there may be a good reason your curves have an "unnatural" shape.

Highlight and Shadow



The **`highlight:`** and **`shadow:`** settings force the curve endpoints to specific values, or allow them to "float" during optimization. The setting value is an array of %-dot values for each ink. If a value is **`undef`**, that endpoint will float.

The **`highlight:`** setting is primarily used when the printing process has poor highlight dot retention, most common in flexo. Typically, the "min dot" value is 2% or less. When the highlight: setting is used, reproductions may appear dull and grayish, which is preferable to having "broken" highlight regions.

Prepress software used in flexo normally has the capability to apply "bump" curves in platemaking. If you use PressCal to do this, curve optimization includes the highlight effects, which might produce better results than applying bump curves later.

The **`shadow:`** setting could be used to keep shadows from filling in, but you probably don't want your solids to be screened in a conventional printing process. It is better to build ICC profiles with the right black composition, so only your images are affected.

If you're calibrating digital ink jet printing, setting the shadow values to **`undef`** allows you to control and stabilize the solid ink density. In this case, you should set your RIP's individual ink limits slightly higher, so your calibration curves will have endpoints slightly less than 100%.

Color References

Reference Profiles and Data Sets

PressCal uses an ICC profile to define the desired printing characteristics. We call this the reference profile. This profile typically comes from an industry technical resource. Examples of reference profiles are the GRACoL2013_CRPC6.icc profile from IDEAlliance, and the PSOcoated_v3.icc profile from ECI. These profiles are freely available, and are widely adopted by both printers and graphic designers. They are the basis for standardized printing, so any graphic designer may create proper files for any printer.

Reference profiles are made from reference data sets. The GRACoL2013_CRPC6.icc profile is made from the CGATS21-2-CRPC6.txt data set, published by ANSI/CGATS. The PSOcoated_v3.icc profile is made from the FOGRA51.txt data set, published by FOGRA. These standard data sets are based on carefully conducted print tests, numerically fine-tuned to conform with the ISO 12647 standards. These data sets describe the printing process in the greatest possible detail.

If your printing process is unique, you can make a reference profile from your own measured data. *The optimal method will match any reference profile, standard or custom.*

ICC Registries

The ICC (International Color Consortium) has a registry of standard reference profiles. We recommend you choose reference profiles from this list, as appropriate for your printing process, and your country. If you wish to make a custom profile (perhaps with different black generation), you should consider using a standard data set from the registry of standard characterization data.

Built-In Test Data

The PressCal bundle contains an assortment of commonly used profiles and data sets. Here is a table of those items, and an explanation of the path shortcut to access them.

Why ICC Profiles?

Reference ICC profiles contain color look-up tables (CLUTs) that allow us to quickly compute the L*a*b* values for any **CMYK** sample. Furthermore, the profiles also contain inverse CLUTs that give us the **CMYK** values for any L*a*b* sample. These inverse tables include black generation, according to the settings of the profiling software. Black generation is accounted for by the optimal method, which is not possible with the near-neutral and TVI calibration methods.

We believe a main goal of print calibration is to reduce make-ready costs. When color is critical, this means matching proofs quickly. The standard reference profiles we've been discussing are normally used to define the color of these proofs. So, it makes perfect sense to build press curves using the same ICC profiles.

TVI, Gray Balance, and NPDC

If you're familiar with print standards, you may wonder, what about TVI or gray balance? If you've used the G7 method, what about NPDC? The answer is that these characteristics are built into the standard data sets. The tonality of FOGRA data sets is defined by standard TVI curves. The tonality and gray balance of the CGATS data sets are defined by NPDCs. So, there is no conflict in basing your curves on a standard reference profile.

Measurements

The optimal method creates tone curves to minimize the color errors between the reference profile and your press measurements. This section deals with obtaining those measurements, which requires more care than you might think. To begin with, we are measuring the color of printed press sheets, not the press itself. These press sheets contain test chart(s) made up of many colored patches. The patches are measured with a spectrophotometer, and those measurements are used by PressCal.

Variability of Print

The main obstacle to obtaining good measurements is the variability of the printing process. You will find variations within a single press sheet, from side to side, and around the cylinder. Each successive press sheet is slightly different. It may take a few hundred sheets for color to stabilize at startup. Then, there will be variations throughout the run. Pressmen are generally aware of these facts, and use their skills to maintain consistency. Some presses are equipped with elaborate feedback control systems. Nevertheless, all printing processes vary.

A common way to measure a process is to take many samples, then use statistics to extract the desired information. When making press curves, it is impractical to do this in a scientifically rigorous way, since there are so many kinds of variation, and so many samples. The time and materials to measure a single press run would be prohibitive.

Simplifying Assumptions

So, we make a couple of simplifying assumptions. First, in a critical matching situation, with a print buyer in the pressroom, the OKed press sheet will be at the end of a short pull. There will be variations during the press run, but the okay is at the start. Second, if the press-to-proof match is good at the center of the sheet, a skilled pressman should be able to make the rest of the sheet match, using ink keys and other adjustments. Yes, there may be variations the pressman can't fix, but neither can your tone curves. With these assumptions, it is reasonable to take measurements in the center of the press sheet, at the end of a short pull.

Test Preparations

Before you start any testing, be sure the press is in good working order. This would be the time to replace blankets and repair any mechanical problems. If you're changing inks, make sure the new inks work well, and you're happy with the results aside from color-matching.

Next, make a list of the papers you want to test. You'll want to start with your house stock(s), then add other papers used by your color-critical clients. You should use the same size sheets you normally print on. Be sure to have enough paper to complete the testing. It may take many pulls to get the ink densities right. This is normally done with your house stocks. The other stocks are then run with the same ink settings. The coated stocks are normally run first, followed by the uncoated stocks.

If your printing process uses plates, they should be linear. This means disabling tone reproduction curves in your DFE. If you cannot disable these curves, you should use linear curves. (If your test plates were made with non-linear curves, it is possible to compensate for that with the optional plate curve setting). Halftone screening affects both tone and color. If you use different types of screening, you will need test plates for each type. Some printers have traditionally used coarser screening for uncoated stocks. If you make separate curves for uncoated stocks, there is no good reason to use coarse screens.

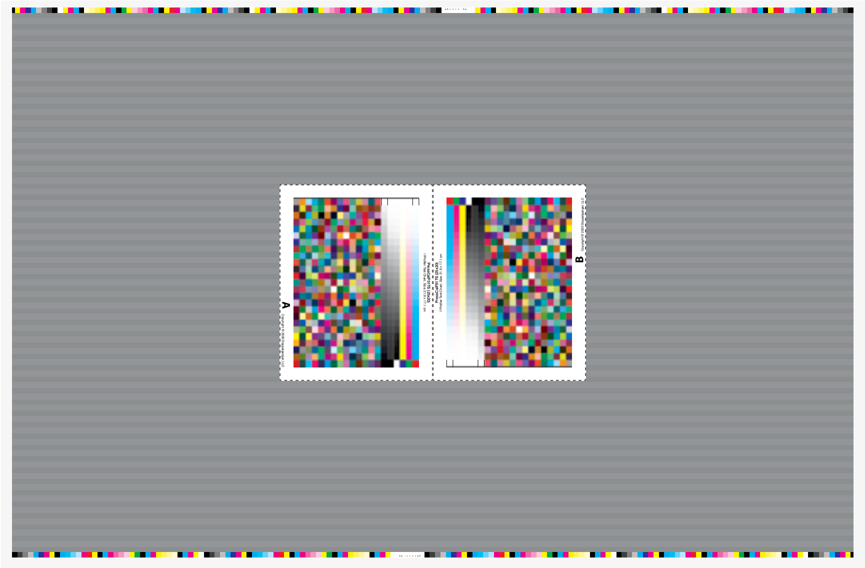
Digital presses should also be run linear, if the DFE has provision to accept tone curves. If not, tone curves may be applied to ICC profiles used for color management, or output as a device link profile for use with a PDF editor such as Callas pdfToolBox.

Choose your color reference profiles, based on the papers you plan to test, and your local preferences. In the US, the IDEAlliance GRACoL and SWOP profiles are typically used. In Europe, the PSO profiles are common.

Test Form Layout

Below is a typical test form. The background is alternating stripes of 50% black and 50%, 40%, 40% CMY. This serves two purposes. It is an ink load, and it gives a visual indication of gray balance over the entire sheet. The test charts are in the center of the sheet. There are two identical opposed charts, with the ink ramps butted. The gray areas above and below the charts should be left as they are, to avoid in-line effects. The areas to the right and left may be filled with other test charts and images.

Test Charts



PressCal works with any test chart, providing it contains enough data to define the curves. This includes charts meant for curves, e.g. P2P51, and charts meant for ICC profiles, e.g. IT8.7-4. It will even work with verification strip measurements, e.g. ISO 12647-7. Furthermore, by selecting samples, it is possible to simulate the TVI and G7 methods, assuming the required data is present.

If you are submitting your press sheets to IDEAlliance for G7 qualification, you should use their test charts, e.g. P2P51. Otherwise, you should use one of the PressCal charts available on our website. These charts are explained in the section on sample selection. You can place more than one type of chart on the test form.

Start as a Normal Job

Presswork should begin by running the test plates as a normal job, on your coated house stock, up to the point of color OK. This means the sheets are in register, color is at shop standard densities, and inking is fairly even across the sheet. Coatings should be used, if that is the normal practice. Verify the ink sequence is **KCMY** or **CMYK** (when matching standard color references).

Adjust Solid Ink Densities

Cut out the test charts from a good, dry press sheet, and measure one of them. If you're using a PressCal target, just measure the first 5 rows or columns. Paste the path to these measurements into the PressCal setting for **`press_path:`** and run the ink balance tool (**⌘B**). The output log will display the solid ink colors and error values, and suggest density adjustments. Make these adjustments and repeat until the suggested changes are very small. This is a difficult process and will probably take a few pulls. The error values will never be 0 – they can only be minimized.

If your measuring instrument allows you to set the 'measurement condition,' you should make sure it matches the reference profile. The measurement condition controls the amount of UV light illuminating the samples. This is important when the paper contains optical brighteners (OBAs). Older profiles (made before 2013) normally use the M0 measurement condition. More recent profiles use the M1 measurement condition. The M2 measurement condition is with a UV-cut filter. If you have a newer X-Rite instrument and i1Profiler, you can capture all of these measurement conditions in a single file by using the dual-scan mode. The supplied PressCal test charts are made for this software and mode.

Measurements for Curves

Once you have minimized the solid color errors, make note of the color bar densities, and even-up the inking across the sheet, especially in the area of the test charts. Pull five good sheets, and number them. Cut out the charts, and label them 1A, 1B, 2A, 2B, … 5B, A and B indicating left and right for the opposing charts. The use of opposing charts is intended to minimize the effect of ink variation around the cylinder. Measure the charts, and save the files to a folder, named as you see fit. Now copy the folder path and paste it into your settings file. PressCal will average the measurements automatically. Confirm your other settings, and run the curve building tool (⌘**R**).

Additional Papers

If you are testing an assortment of papers, you could run all of the coated papers with the same ink setting as the coated house stock. The ink densities will vary somewhat and you might want to record them. Uncoated papers will generally require more ink to match the reference profile. So they should be tested separately, as a group, after the coated papers.

Existing Measurements

Maybe you already have existing measurements from a prior test. PressCal is a very flexible tool, and will make curves from those measurements. Unlike other methods, you have the option to choose your color reference, and select the samples you deem important. In fact, it is possible to simulate the other calibration methods, as explained in the next section.

Built-In Test Data

Reference Profiles and Standard Data Sets

The table below lists common reference profiles and the standard data sets they are based on. These files are located in the PressCal bundle.

Reference Profile	Standard Data Set
CGATS21_CRPC1.icc	CGATS21-2-CRPC1.txt
CGATS21_CRPC2.icc	CGATS21-2-CRPC2.txt
CGATS21_CRPC3.icc	CGATS21-2-CRPC3.txt
CGATS21_CRPC4.icc	CGATS21-2-CRPC4.txt
CGATS21_CRPC5.icc	CGATS21-2-CRPC5.txt
CGATS21_CRPC6.icc	CGATS21-2-CRPC6.txt
CGATS21_CRPC7.icc	CGATS21-2-CRPC7.txt
GRACoL2013_CRPC6.icc	CGATS21-2-CRPC6.txt
GRACoL2013UNC_CRPC3.icc	CGATS21-2-CRPC3.txt
SWOP2013C3_CRPC5.icc	CGATS21-2-CRPC5.txt
SWOP2013C5.icc	SWOP2013C5.txt
GRACoL2006_Coated1v2.icc	GRACoL2006_Coated1.txt
SWOP2006_Coated3v2.icc	SWOP2006_Coated3.txt
SWOP2006_Coated5v2.icc	SWOP2006_Coated5.txt
ISOcoated_v2_eci.icc	FOGRA39L.txt
PSOcoated_v3.icc	FOGRA51.txt
PSOuncoated_v3_FOGRA52.icc	FOGRA52.txt
FOGRA55_CMYKOGV.icc	FOGRA55_beta_CMYKOGV.txt

Press/Printer Measurements

File Name	Description
Endurance_silk_105XL.mxf	Offset printing on coated paper
Starbrite_opaque_105XL.mxf	Offset printing on uncoated paper
P2P51_test_data.mxf	Offset printing on coated paper
ISO_12647-7_control_wedge_2013.mxf	Ink jet proof verification chart
P5000_CMYKOGV.mxf	P5000 ink jet printer
Ugra-Fogra_MediaWedge_V3.0a.mxf	Ink jet proof verification chart

Shortcut Path Notation

The path to the test data has a shortcut notation that may be used in PressCal setting files. Simply add the prefix **`~~/Data/Test/`** to the file name. For example,

`~~/Data/Test/GRACoL2013_CRPC6.icc`

This shorthand notation only applies to the built-in data. The paths to your data files should either be copied and pasted, or dragged into the settings window.

The folder containing the built-in data may be opened with the **⌘D** command.

CRPC Data Sets

There are seven CRPC data sets defined in CGATS.21-2, representing offset printing on various paper types, **measured with M1 illumination**.

Data Set	Name	Description
CRPC1	ColdsetNews	Small gamut printing (newsprint)
CRPC2	HeatsetNews	Moderate gamut printing (improved newsprint)
CRPC3	PremUncoated	Utility printing on matte uncoated paper
CRPC4	SuperCal	General printing on super-calendared paper
CRPC5	PubCoated	Publication printing (paper grade 3)
CRPC6	PremCoated	Large gamut (typically commercial) printing
CRPC7	ExtraLarge	Extra-large gamut printing processes

GRACoL2013 is the same as **CRPC6**.
GRACoL2013UNC is the same as **CRPC3**.
SWOP2013C3 is the same as **CRPC5**.
SWOP2013C5 is the same as **CRPC5**, with the white point adjusted for paper grade 5.

Original CGATS/IDEAlliance Data Sets

There are three CGATS data sets released as technical reports, representing offset printing on various paper types, **measured with M0 illumination**. These data sets are superseded by the CRPC data sets above, but are still used by some printers.

Data Set	Name	Description
TR 003	SWOP2006_Coated3	Web offset printing on U.S. Grade 3 coated publication paper
TR 005	SWOP2006_Coated5	Web offset printing on U.S. Grade 5 coated publication paper
TR 006	GRACoL2006_Coated1	Sheet-fed printing on U.S. Grade 1 coated paper

FOGRA Data Sets

FOGRA data sets are primarily based on the ISO 12647-2 standards. These three are widely used, and included in the built-in data.

Data Set	ISO 12647-2	Description
FOGRA39	2004	115 g/m2 glossy or matte coated (M0)
FOGRA51	2013	115 g/m2 glossy or matte coated (M1)
FOGRA52	2013	115 g/m2 uncoated white offset (M1)

Ink Mapping

PressCal computes curves by minimizing the color errors between a reference profile and your press measurements. Normally, these inputs have the same number of ink channels, in the same sequence. For instance, a **CMYK** reference profile and **CMYK** press measurements. The ink sequences match because the press sheets are measured with the same tools used to make ICC profiles.

PressCal is not limited to making **CMYK** curves. The optimization function works with any number of ink channels. For instance, the Pantone Hexachrome process has six colors – **CMYK** plus orange and green. These additional colors expand the color gamut, and are considered part of the standard process. In 2001, Pantone published ICC reference profiles describing this process. PressCal can calibrate a modern **CMYKOG** process to these ancient profiles.

But suppose we wish to calibrate a non-standard process, e.g. **CMYK** plus red ink. There is no standard reference profile for a **CMYKR** process. We could use a standard **CMYK** reference profile for the **CMYK** portion of this process, but what do we do with the red channel?

The ink map allows you to control PressCal's behavior when the reference profile and press measurements are not aligned. The ink map is an array of characters corresponding to the ink channels of the press measurements. If an array element is an **integer number**, that ink channel is mapped to the ICC profile, and its curve is optimized. The number refers to the device channel of the ICC profile (0 is the first channel). All of the numerically mapped curves are optimized simultaneously.

SCTV Curves

If the array element is the letter **S**, that ink channel is linearized using SCTV. SCTV stands for Spot Color Tone Value, as defined in ISO 20654:2017. The Flexographic Technical Association recommends to linearize spot colors using this metric.

Here are some examples:

Profile	Press	Ink Map	Comment
CMYK	CMYK	[0, 1, 2, 3]	standard mapping, CMYK optimized
CMYK	KCMY	[3, 0, 1, 2]	non-standard ink sequence, KCMY optimized
CMYK	CK	[0, 3]	CK optimized (duotone)
CMYK	CMYK	[S, S, S, S]	CMYK linearized using SCTV
-none-	CMYK	[S, S, S, S]	same as above, with no reference profile
CMYKOG	CMYKOG	[0, 1, 2, 3, 4, 5]	standard mapping, CMYKOG optimized
CMYK	CMYKOG	[0, 1, 2, 3, S, S]	CMYK optimized, OG linearized using SCTV
CMYKOG	CMYK	[0, 1, 2, 3]	CMYK optimized

TVI Curves

If the array element is **A**, **B**, **C**, **D**, **E**, or **F**, the curve for that channel is computed using TVI, per ISO 12647-2. There are two versions of this standard, 2004 and 2013, selected by the **12647−2:** setting. TVI is computed using **status E** densitometry.

Here are some examples:

Profile	Press	Ink Map	Comment
CMYK	CMYK	[A, A, A, A]	CMYK TVI curve A (Premium coated)
-none-	CMYK	[A, A, A, A]	same as above, with no reference profile
CMYK	CMYK	[E, E, E, E]	CMYK TVI curve E (Premium coated, stochastic screening)
CMYK	CMYKOG	[0, 1, 2, 3, A, A]	CMYK optimized, OG using TVI curve A (Premium coated)

Other Mapping Options

If the array element is **N**, the curve for that channel is based on the CGATS TR015 (G7) NPDC for black ink. If the array element is **L**, the curve for that channel is set to linear (the identity function).

Extended Gamut Process

An extended gamut process uses additional inks to expand the normal **CMYK** color gamut. Long before color management, it was common to use "touch plates" to enhance certain colors in an image. For instance, a red touch plate could "punch up" the color of a red car, or some lipsticks. These extra colors were ad hoc, and not part of a standard printing process.

In 1992, Precision Color introduced HDC, a standard **CMYKRGV** process. In 1995, Pantone introduced Hexachrome, a standard **CMYKOG** process. Today, efforts are underway to create a standard **CMYKOGV** process for the packaging industry.

As explained above, PressCal can calibrate an expanded gamut process with any number of inks. This simply requires an ICC reference profile describing that process. Ideally, that profile would come from a standards body, but it could also be a proprietary standard created by a printer or a brand.

It is possible to build curves for a subset of an extended gamut process. For instance, a package might be printed with orange, magenta, yellow and black inks (**OMYK**). This is a subset of the standard **CMYKOGV** process, and the ink map would be [4, 1, 2, 3].

Sample Set Filtering

The optimization sample set is filtered to remove samples containing non-zero values in channels not part of the optimization. For instance, in the example above, any samples containing C, G, or V would be removed.

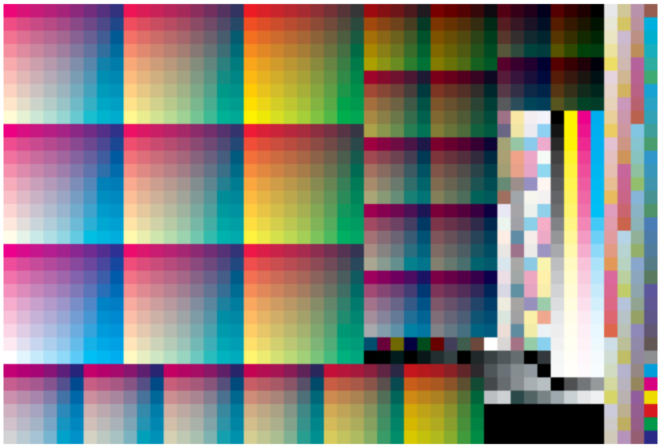
SCTV and TVI curves are computed from ramps of each individual ink, independently of the optimization sample set.

Default Ink Map

The default ink map contains the profile channels in ascending order. If there are more press channels than profile channels, these extra channels are linearized using SCTV.

Sample Selection

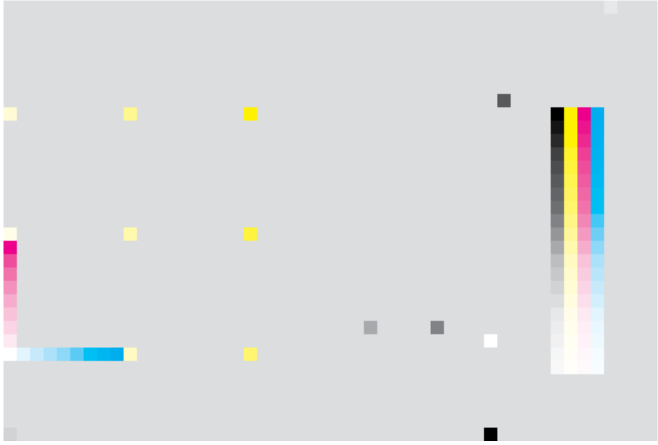
One of the main advantages of the Optimal method over legacy calibration techniques (e.g. TVI, G7) is the ability to use any sample set. For instance, the **IT8.7/4** sample set (below) consists of the 1617 **CMYK** samples, chosen to fully characterize the **CMYK** color space. The Optimal method can build curves using all 1617 samples.



By contrast, the TVI method can only use samples containing a single process ink. You could print and measure a test chart with just these samples, or you could select them from the IT8.7/4 chart measurements. The IT8.7/4 sample set contains 112 samples with one process ink. This selection is referred to as the "process ramps" and is shown in the image below (compare to the full IT8.7/4 sample set, above).

Sample Selection Tokens

PressCal uses tokens to select samples with some common property. For example, the process ramps are selected with the **`ramps`** token. Individual process ramps are selected with the **`c`**, **`m`**, **`y`**, and **`k`** tokens. Tokens may be combined. For **CMYK** measure-



ments, the token string '**`c m y k`**' produces the same result as **`ramps`**. The samples selected with multiple tokens are combined, and duplicates are removed. The token string is entered as the **`select:`** setting. If this setting is disabled, all of the measurement data set samples are used.

Simulating the TVI Method

One reason for selecting a subset of the samples is to simulate a legacy calibration technique. For instance, the TVI method requires the process ramp samples selected with the **`ramps`** token. TVI is calculated from density, and can only be approximated with our reference profile. However, Optimal curves computed using the PSO reference profiles are very similar to those made using TVI. Even if the reference profile was not based on a TVI calibration, it is possible to build curves from the process ramps, which is the essence of the TVI ideology.

Simulating the G7 Method

Another legacy technique is the G7 method. The samples used by the G7 method are said to be gray, and are either a mixture of C, M and Y, or just K. The **P2P51** test chart contains these samples in rows 4 and 5, or columns 4 and 5, depending on the orientation of the chart.

For this test chart, we can select the G7 samples using one of these token strings:

```
select: nr(12) rows(4, 5) # for landscape orientation
select: nr(25) cols(4, 5) # for portrait orientation
```

The **`nr()`** token tells the program how many rows the chart contains, and is needed when that information is missing from the measurements.

If you want to select G7 samples from an IT8.7/4 chart, there is a problem – the **CMY** samples are not in the chart. The IT8.7/4 gray samples are from 1993, and contain more cyan than the IDEAlliance gray values. But you can select "grayish" samples using the **`gray()`** token. This token selects **CMY** samples with a maximum chroma value. The '**`gray(5) k`**' setting selects 60 samples from the IT8.7/4 chart (see image below).

Even though these are not the exact samples dictated by IDEAlliance, they will produce nearly identical curves. How is that possible when the samples are not perfectly gray? The answer is that the reference values, which are derived from the reference profile, are the exact color values for those "grayish" samples.

To make proper G7 curves, you must select a reference profile that conforms to the G7 gray balance and tonality (NPDC). IDEAlliance provides a set of reference profiles made from the CGATS.21 data sets. These profiles represent standard offset printing on a variety of substrates. You should use the same profile(s) to make curves and proofs.

No Sample Constraints

Unlike TVI and G7, the Optimal method is not bound to a particular sample set. There are no constraints on the number or composition of the samples. This total freedom creates an unexpected problem – what samples should we use?

We suggest you choose samples you are likely to print. This might seem an inane remark, since you can print any **CMYK** color, but consider the origin of your **CMYK** images. Photos begin as **RGB**, and are converted to **CMYK** using an ICC profile. Vector art will become **CMYK** at some point in the production process. The black channel of these images will be determined by an ICC profile. So, the color samples you are likely to print are the **CMYK** values contained in an ICC profile.

Round-Trip Calculations

This table illustrates this idea. The **CMYK** values on the left side are taken from the G7 P2P51 target. These samples contain no black, and are said to be gray. Using the GRACoL2013_CRPC6 profile, we compute the L*a*b* values for each sample. These values are then converted back to **CMYK**, and are shown on the right side of the table. These calculations are known as the "round trip."

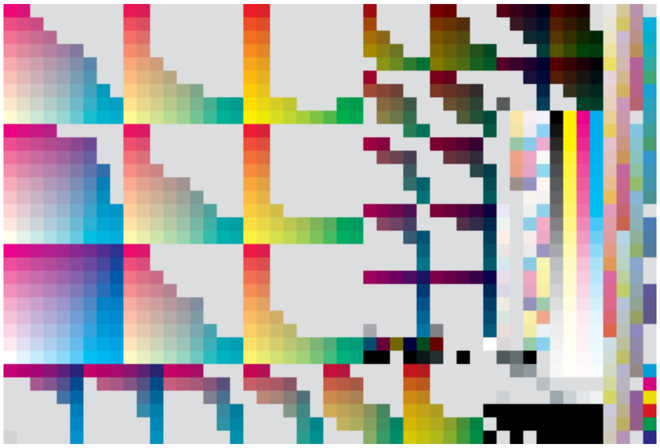
You will notice that the profile-generated samples (on the right) contain black, starting at 25% cyan (in the far left column). As the cyan value increases, black becomes the dominant ink. The four rows at the bottom of the table are gray samples added to complete the **CMYK** gray ramp. This profile has a total ink value of 320%, indicating a moderate amount of UCR.

Selecting Realistic Samples

The samples with more than 20% cyan (on the left) will never appear in images generated with GRACoL2013_CRPC6 profile! Instead, you will find the profile-generated values (on the right). These are the gray values you're likely to print.
This same logic applies to all colors, not just grays. Dark colors contain substantial amounts of black. The Optimal method can use these realistic samples to compute curves.

The **`rt()`** selection token uses the **round-trip black difference** to select samples. For instance, the token **`rt(10)`** selects samples where the black tone value difference is less than 10%. By this criteria, the gray samples in our table with cyan values greater than 50% would be discarded as unrealistic. The round-trip selection will usually produce good results from any test chart. We recommend combining this token with the **`k`** token, to include samples with only black ink, as in grayscale images.

The '`rt(10) k`' setting selects 1005 samples from the IT8.7/4 chart (below).



This sample set is much larger and more inclusive than the TVI and G7 sample sets. All colors and tones are represented. The dark samples contain realistic **CMYK** mixtures, with black ink values similar to those in the reference profile. The threshold value of **10%** is an arbitrary choice. If you use a smaller value, fewer samples will be selected, and they will be closer to the profile values, on average. The 3-D renderings below show a realistic sample set compared to the TVI and G7 sample sets.

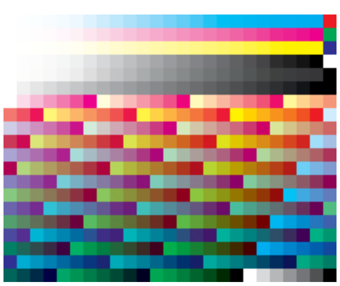
PressCalC6 Chart Samples

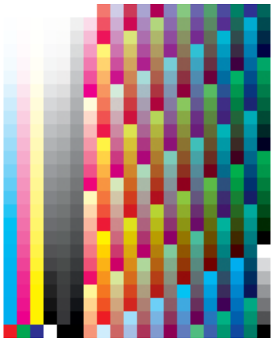
CMYK Ramps TVI Samples

Gray Ramp G7 Samples

Realistic Test Charts

The **PressCalC6** test chart, (below) was created using the colorimetric tags of the **GRACoL2013_CRPC6** profile to make realistic samples directly.





These samples are uniformly spaced, and fill the entire print gamut. The selection token is **`rows(6 .. 20)`** or **`cols(6 .. 20)`**, depending on the orientation. The PressCalC6 test chart was created with a software program, using the GRACoL2013_CRPC6 profile. For a different reference profile, you could make a custom test chart. The software program is available by request from the authors.

Optimization Paradox

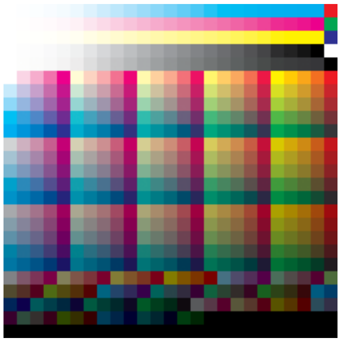
When we select samples from the test chart, we are ignoring information about the printing process contained in the unselected samples. **So, why not use all of the test data? Wouldn't that make the curves more accurate?**

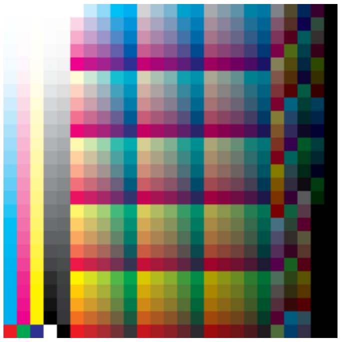
The answer to this question begins with understanding the limitation of tone curves. Tone curves cannot achieve a perfect match for all colors. There will always be color errors, and the best we can do is to minimize them. That is the essence of optimization. **We find the best overall solution, when a perfect solution is not possible**.

If we build curves with a sample selection of realistic colors, there will be residual color errors. If we then add samples that are not realistic, and recalculate the curves, the errors for the realistic colors will increase. This is the paradox of optimization. **Adding samples that don't matter will harm the outcome for those that do.**

Making Curves and ICC Profiles

If you wish to build an ICC profile, you will need samples that span the entire color space. An IT8.7/4 test chart is commonly used for this purpose. This chart contains 1617 samples, and is usually larger than a letter-sized page, depending on the measuring instrument. It is a good choice for a digital printing process, where there is





little variation over the printed sheet. When this variation is significant, as in offset printing, a smaller test chart is preferred.

The **PressCalP** test chart (above) is designed to make both curves and profiles. The first four rows/columns (depending on orientation) contain tone ramps of the pure process colors. The fifth row/column is a **CMY** tone ramp, calculated with the G7 conception of gray balance. The remaining twenty rows/columns are the **CMYK** samples needed to build an ICC profile. The **PressCalP** chart is ideal for profiling an offset or flexographic press.

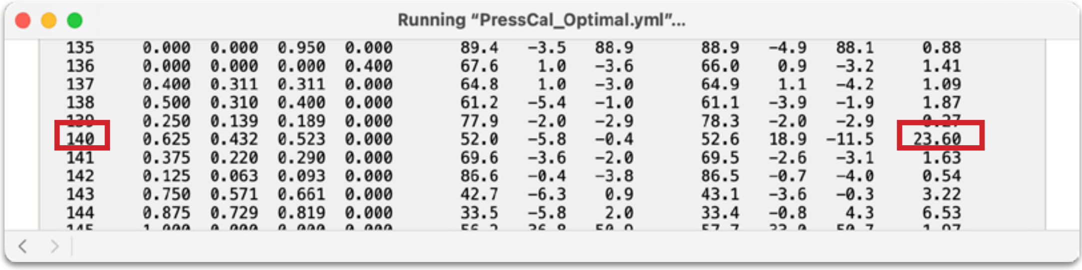
To make an ICC profile, use the **`adjust_path:`** setting. This will apply the curves to the press measurements, and save them as a file. The saved file will be named **curve_adj_press.txt** or **curve_adj_press.mxf**, depending on the measurements you provided. Build your ICC profile using these curve-adjusted measurements.

If you used the **`highlight:`** or **`shadow:`** settings, the curve-adjusted values could be less than 0% or greater than 100%, causing the profiling software to fail. Should that happen, build the ICC profile from the unadjusted press measurements, then use the **`adjust_profile_path:`** setting to apply the curves directly to the profile.

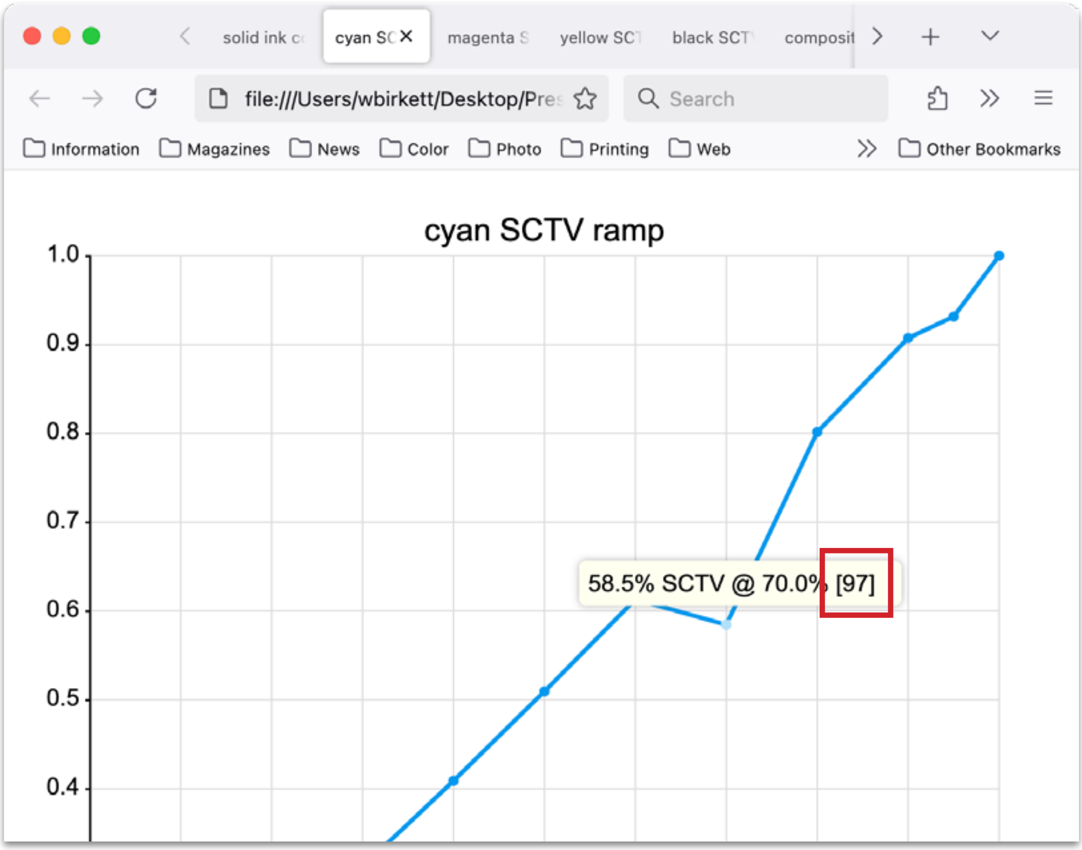
Identifying Outliers

An outlier is a sample that seems to be wrong, possibly from a bad measurement, or a flaw in the printing. You can remove outliers with the minus token. But how do you identify these samples?

If you used optimization to build the curves, look for large initial color errors. You can sort the samples by error value by adding the **`sort(error)`** token to the **`select:`** list.



If you built SCTV or TVI curves, the initial color errors are not output in the log. Instead, run the grade tool ⌘I and look at the ramp graphs. These graphs should be fairly smooth, revealing the outlying samples. If you click on a graph point, text will appear with the sample number in brackets.



Sample Selection Tokens

token	selection
`all`	all samples
`c`	cyan ramp
`m`	magenta ramp
`y`	yellow ramp
`k`	black ramp
`cmyk`	cyan, magenta, yellow, black ramps
`ramps`	all ink ramps, including spot colors
`ramps(1)`	ramp(s) by ink channel, ink 1 is normally cyan
`ramps(1, 2, 3)`	ink ramps 1, 2, 3, normally cyan, magenta, yellow
`ramps(1 .. 3)`	same, using the Perl range operator
`rt(10)`	round-trip black change ≤ 10%
`rt(10, -2)`	round-trip RMS change ≤ 10%
`gray(5)`	near-neutral cmy samples, C* (chroma) ≤ 5
`gray(5, 50)`	near-neutral cmy samples, C* (chroma) ≤ 5 and L* ≥ 50
`iso`	isometric samples (c = m = y, all others 0%)
`iso(50)`	isometric samples (c = m = y, all others 0%), ink values ≤ 50%
`g7`	gray CMY samples per TR015
`g7(50)`	gray CMY samples per TR015, cyan ink ≤ 50%
`cmy`	CMY ramps
`cmy(50)`	CMY ramps, ink values ≥ 50%
`c+m+y(200)`	CMY total ink ≤ 200%
`tac(280)`	total ink less ≤ 280%, including spot colors
`nr(33)`	chart has 33 rows (number of rows, if missing from data set)
`rows(1 .. 5, 7, 9)`	rows 1, 2, 3, 4, 5, 7, 9
`cols(1 .. 5, 7, 9)`	columns 1, 2, 3, 4, 5, 7, 9
`rect(1, 4, 3, 7)`	rectangular chart area, rows 1 – 4, columns 3 – 7
`plus(1, 2, 3)`	add samples 1 – 3
`minus(4, 5, 6)`	remove samples 4 – 6
`nosub`	remove substrate samples (all ink values 0%)
`nobin`	remove binary samples (all ink values 0% or 100%)
`nospot`	remove samples with non-CMYK inks
`nok(95)`	remove samples with K > 95%
`nocmy(240)`	remove samples with CMY total ink > 240%
`notac(300)`	remove samples with TAC > 300%
`sort(4, 3, 2, 1)`	sort by black, yellow, magenta, cyan
`sort(error)`	sort by optimization error value

Sample Selection Setting

The **select:** setting value is a list of sample selection tokens. The list may be empty,

```
select:
```

or it may contain a single token,

```
select: ramps
```

or it may contain multiple tokens,

```
select: rt(10) k nosub
```

Sample Selection Processing

Tokens from **all** to **plus** in the token table are processed first, each adding samples to the list. The list is then sorted by sample number, and any duplicates are removed. Next, the tokens **minus**, **nosub**, **nobin**, **nospot**, **nok**, **nocmy** and **notac** are processed to remove unwanted samples. Finally, if the **sort** token is present, the samples are re-sorted according to their device values, or the sample color error.

Token Parameters

Some tokens take parameters, located within parentheses **()**, immediately following the token. Multiple parameters are separated by commas. For a range of integer values, you may use **..** notation. For instance, **1 .. 100** indicates the integers from 1 to 100. Color and %-dot values may have a decimal point, for example **gray(2.5)**.

Selecting by Patch Location

The selection tokens **rows**, **cols**, and **rect** use patch location to choose samples, rather than device values. A tone ramp is often located as a row or column of patches to avoid random variations that would occur if those patches were shuffled. A chart may contain a group of samples in a certain location. For instance, the PressCalC6 chart contains realistic samples in rows 6 - 20 or columns 6 - 20.

Removing Feckless Samples

If the highlight endpoint is pinned at 0%, the color error of substrate samples is unaffected by the curves. The **nosub** token removes substrate samples, to make the optimization faster. Likewise, if the shadow endpoint is pinned at 100% and the gamut scale factor is fixed, binary samples (all device values 0% or 100%) are unaffected by the curves. For this case, the **nobin** token removes binary samples.

Removing Outliers

An outlier is a sample that seems to be wrong, possibly from a bad measurement, or a flaw in the printing. You can remove outliers with the **minus** token. Suppose samples 136 and 682 had much larger error values than similar adjacent samples. You could remove these samples by adding the token **minus(136, 682)** to your selection,

```
select: rt(10) k nosub minus(136, 682)
```

You would then re-compute the curves. Because PressCal uses optimization, removing outliers improves the accuracy of the curves without any side effects.

Curve Output Tokens

token	output format	file type	colors	steps
`apogee`	Agfa Apogee	XML	CMYK	Y
`cgats`	CGATS.17 text format	text	n-color	Y
`device_link`	ICC device link profile	binary	n-color	N
`efi`	EFI XF .vpc/.vcc	text	CMYK + 4 spot	Y
`equios`	DS Equios	text	CMYK	N
`fuji_xmf`	Fuji XMF	text	CMYK	N
`harlequin`	Harlequin-based RIP	text	CMYK	N
`heidelberg`	Prinect (CTS 2.1, measured or calibration)	text	CMYK	Y
`hybrid`	Hybrid PACKZ	JSON	n-color	Y
`indigo`	HP Indigo	text	CMYK	N
`iso_18620`	ISO 18620 (Esko .ted)	XML	n-color	Y
`navigator`	Xitron Navigator (push calibration)	Postscript	n-color	N
`onyx`	Onyx .Lin	binary	n-color	N
`photoshop`	Photoshop .acv	binary	n-color	Y
`prinergy`	Kodak Prinergy Harmony (Colorflow)	text	CMYK	N
`rampage`	Rampage curve set	text	CMYK	N
`sierra`	Xitron Sierra	text	CMYK	N
`trueflow`	Screen Trueflow	binary	CMYK	N
`text`	tab-delimited text	text	n-color	Y

Output formats with file types **Postscript**, **text** or **XML** may be opened in TextMate for examination. Curves with file type **binary** must be opened in an app that recognizes them, usually the DFE.

All output formats support **CMYK** curves. Some support additional colors.

Output formats marked with a **Y** in the **steps** column can have customized steps.

The **`device_link`** format supports the **`'desc'`** hash key.

The **`heidelberg`** format supports the **`'type'`** hash key, with values **`'measured'`** or **`'calibration'`**.

The **`iso_18620`** format supports the **`'inks'`**, **`'origin'`**, **`'Creator'`**, **`'OperatorName'`**, **`'PressName'`**, **`'MediaName'`**, **`'TransferCurveSetID'`**, **`'Side'`** hash keys.

The **`navigator`** format supports the **`'inks'`**, **`'name'`**, **`'colorspace'`** hash keys.

The **`prinergy`** format supports the **`'Comments'`**, **`'CurveSet'`**, **`'DefaultFrequency'`**, **`'DefaultMedium'`**, **`'DefaultResolution'`**, **`'DefaultSpotFunction'`**, **`'Enabled'`**,**`'FirstName'`**, **`'FreqFrom'`**, **`'FreqTo'`**, **`'ID'`**, **`'Medium'`**, **`'Resolution'`**, **`'ScreeningType'`**, **`'SpotFunction'`**, **`'SpotFunctionMode'`** hash keys.

These output tokens are methods of the **ICC::Profile::cvst** object. See the color tool kit documentation for details. If you need a curve format that's not listed, please contact us. We want to support all popular formats.

Output Setting

The **`output:`** setting value is a list of curve output tokens. The list may be empty,

```
output:
```

or it may contain a single token,

```
output: text
```

or it may contain multiple tokens,

```
output: iso_18620 photoshop device_link text
```

A curve set is output in the format of each valid token.

Tone Steps

Each output format has a default list of tone steps, e.g. (0%, 5%, 10% ... 100%). Those marked 'Y' in the token table's **steps** column may use custom tone steps. The custom steps are added as a list of parameters, for example,

```
output: iso_18620(0, 10, 25, 50, 75, 90, 100)
```

You may also use the default steps from another token, for example,

```
output: iso_18620 text('iso_18620')
```

In this example, curves are output in ISO 18620 and text formats, with the same steps.

Hash Parameters

Curve options may be passed as a hash parameter. A hash contains key-value pairs enclosed in braces **`{}`**,

```
output: iso_18620({'steps' => [0, 10, 25, 50, 75, 90, 100]})
```

This gives the same result as the prior example using the same tone steps. The difference is that the hash may contain multiple key-value pairs. Here is an example with multiple keys,

```
output: iso_18620({'PressName' => 'Komori', 'MediaName' => 'Finch opaque'})
```

The name of the saved file may be specified with the **`'base'`** key,

```
output: iso_18620({'base' => 'alto_2025.ted'})
```

All keys have default values, and extraneous keys are ignored.

Curve Channels

Curve channels correspond to those of the press measurements. Some output formats have limitations on the channels, as shown in the token table's **colors** column.

Output Folder Path Setting

The **`output_path:`** setting controls the file destination and modifications to the base file name with the **`'path'`**, **`'prefix'`**, **`'suffix'`**, **`'time'`** and **`'index'`** keys. These keys may also be used with the **`output:`** token settings and will override any values set by the **`output_path:`** setting.

Process Control Report

PressCal can generate a report containing measurements of the curve-adjusted printing process. This report provides aimpoints for the process control step of the ***FIRST*** methodology, and is useful for all printing processes, not just flexography. The aimpoints provide a basis for setting up subsequent print runs, and for quality control functions.

The process control report is a text file containing information taken from the press measurements, with or without curves applied. This information includes **L*a*b*** and **SCTV** values, and with spectral measurements, **density**, **Murray-Davies %-dot**, **TVI** and **print contrast**.

process_control.txt — Desktop

process_control.txt

```
Process Control Info / 2025-04-01, 06:27 PM GMT (1743532042)

Step   Curve                          SCTV     Density T   M-D     TVI
%-dot  %-dot           L*a*b*         %-dot    (Filter)   %-dot   %-dot

cyan ink
  0     0.00     93.5    1.4   -6.0     0.0     0.08 (R)    0.0     0.0
 10     7.33     89.1   -3.2  -12.2    12.0     0.17 (R)   19.5     9.5
 20    16.45     85.3   -6.3  -17.0    22.2     0.24 (R)   33.4    13.4
 40    37.05     77.5  -12.9  -27.0    43.0     0.42 (R)   57.9    17.9
 70    68.09     66.7  -22.4  -40.7    72.2     0.76 (R)   83.6    13.6
100   100.00     56.4  -31.7  -53.1   100.0     1.33 (R)  100.0    -0.0
print contrast (70%) =  43.4%

magenta ink
  0     0.00     93.5    1.4   -6.0     0.0     0.07 (G)    0.0     0.0
 10     5.38     88.6    8.8   -7.6     9.8     0.15 (G)   16.5     6.5
 20    13.29     83.7   15.9   -8.4    20.2     0.23 (G)   31.6    11.6
 40    31.35     74.1   30.5   -9.5    40.7     0.41 (G)   56.5    16.5
 70    60.98     60.7   52.9   -8.5    70.2     0.76 (G)   83.0    13.0
100   100.00     48.2   75.8   -2.8   100.0     1.44 (G)  100.0    -0.0
print contrast (70%) =  47.2%

yellow ink
  0     0.00     93.5    1.4   -6.0     0.0     0.04 (B)    0.0     0.0
 10     6.59     93.1   -0.5    4.0    10.4     0.11 (B)   17.1     7.1
 20    15.31     92.5   -1.7   13.0    19.8     0.18 (B)   31.2    11.2
 40    33.91     91.5   -3.6   30.6    38.4     0.33 (B)   54.7    14.7
 70    62.72     90.0   -5.0   61.0    70.0     0.63 (B)   83.5    13.5
100   100.00     88.6   -4.6   90.1   100.0     1.00 (B)  100.0     0.0
print contrast (70%) =  36.7%

black ink
  0     0.00     93.5    1.4   -6.0     0.0     0.08 (V)    0.0     0.0
 10     6.24     85.7    1.2   -5.4     9.7     0.17 (V)   20.4    10.4
 20    15.06     78.7    1.0   -5.2    18.2     0.27 (V)   36.0    16.0
 40    33.57     65.6    0.8   -4.3    34.4     0.46 (V)   59.8    19.8
 70    66.35     42.5    0.7   -2.6    62.8     0.89 (V)   86.3    16.3
100   100.00     12.7    1.1    1.3   100.0     1.82 (V)  100.0     0.0
print contrast (70%) =  50.8%
```

Process Control Report Setting

The function is activated by the **`process:`** setting. The setting is a hash and supports the **`'steps'`**, **`'curves'`**, **`'status'`**, **`'desc'`**, and **`'base'`** hash keys.

Here are some examples:

```
process: {} # use default values: curves enabled, steps 0%, 10%, 20%, 40%, 70%, 100%, status same as grading function
```

```
process: {'curves' => 0} # disable curves, process control values are 'as-measured'
```

```
process: {'steps' => [0, 2, 10, 25, 50, 75, 100]} # set the steps
```

```
process: {'status' => 'E'} # use status E density (density is also used to compute M-D %-dot, TVI, and print contrast)
```

```
process: {'desc' => 'setup for 0.5 mil poly bags'} # description string
```

```
process: {'base' => 'my_process_control.txt'} # base file name
```

Output Folder Path Setting

The **`output_path:`** setting controls the file destination and modifications to the base file name with the **`'path'`**, **`'prefix'`**, **`'suffix'`**, **`'time'`** and **'index'** keys. These keys may also be used with the **`process:`** setting and will override any values set by the **`output_path:`** setting.

Caveats

The process control values are computed from measurements of the calibration target. Normally, these measurements would be made with an X-Y spectro after the ink has dried. Press measurements are normally made of control patches located near the edge of the sheet, or an inconspicuous area of a package. Measurements are made with a pressroom instrument, and the ink may not be completely dry. There could be color variations over the area of the press sheet.

These factors may cause significant differences in corresponding measurement values. We suggest you make an initial report with the curves disabled (see the 'curves' parameter, above), and compare it with corresponding pressroom measurements.

When comparing density-based values, make sure the PressCal status setting is the same as the pressroom instrument. Be aware that some DFEs allow control strips to be printed without curves applied. If that is your practice, disable curves when making the process control report.

Rendering

The **`rendering:`** setting controls the mapping of reference profile colors. The display of solid ink colors, near the start of each log, illustrates this mapping.

```
solid ink errors:

          abs L*a*b* values   ->   ref L*a*b* values      press L*a*b* values      ΔEab     ΔE00
  paper   95.0    1.0   -4.0       95.4    1.7   -6.2     95.4    1.6   -6.2       0.03     0.02
   cyan   56.0  -37.0  -50.0       56.3  -36.8  -52.2     57.8  -32.7  -51.3       4.43     2.03
magenta   48.0   75.0   -4.0       48.2   75.8   -5.3     48.5   78.3   -2.0       4.17     1.46
 yellow   89.0   -4.0   93.0       89.4   -3.4   92.3     88.6   -4.6   92.7       1.47     0.81
    red   47.0   68.0   48.0       47.2   68.7   47.5     48.5   71.2   46.8       2.88     1.65
  green   50.0  -66.0   26.0       50.3  -65.9   25.1     50.5  -63.2   26.3       2.99     1.06
   blue   25.0   20.0  -46.0       25.2   20.4  -47.5     23.3   29.8  -46.5       9.65     6.34
    iso   23.0    0.0   -0.0       23.2    0.2   -0.8     21.8    4.5   -2.7       4.87     5.80
  black   16.0    0.0   -0.0       16.1    0.2   -0.6     15.0    1.8    2.4       3.60     3.67
   cmyk    9.0    0.2    0.4        9.1    0.4   -0.1     10.3    1.3    3.5       3.86     3.60
```

The rendering function transforms the L*a*b* values on the left (**abs**) to those in the center (**ref**). The color errors are the difference between the center values (ref) and the press measurements (**press**).

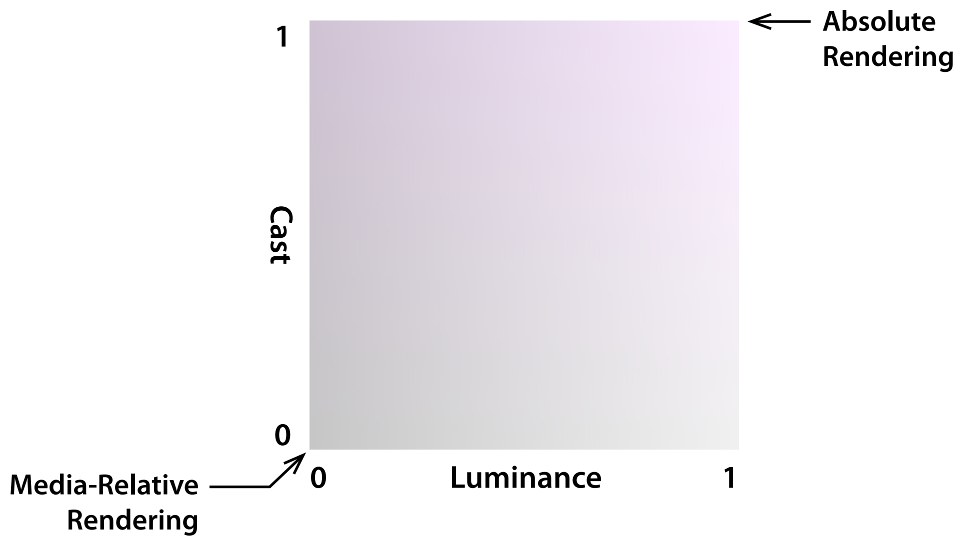
ICC Rendering Intents

The ICC specification defines four rendering intents – perceptual, saturation, media-relative colorimetric, and absolute colorimetric. An ICC printer profile contains tags for the first three rendering intents. Absolute colorimetric rendering is computed from the media-relative colorimetric tag and the media white point, using XYZ scaling. See section 6.3.2.2 of the ICC.1:2010 specification for the math.

PressCal Rendering

PressCal also computes reference values (ref) from the media-relative colorimetric tag. The tag colors are converted to XYZ values, then multiplied by constants to obtain the desired white point. These constants are determined from the media white point, the press paper color, and the **`rendering:`** setting. This setting consists of two values, **luminance** and **cast**, each ranging from **0 to 1**. When **both values are 0, rendering is media-relative**, meaning that the reference values are mapped to the press paper white. This is the default setting. When **both values are 1, rendering is absolute**, meaning that the reference values are mapped to the profile white point.

While ICC rendering is **binary** (media-relative or absolute), PressCal rendering is **completely variable**, within a unit square. This is illustrated by the image below.

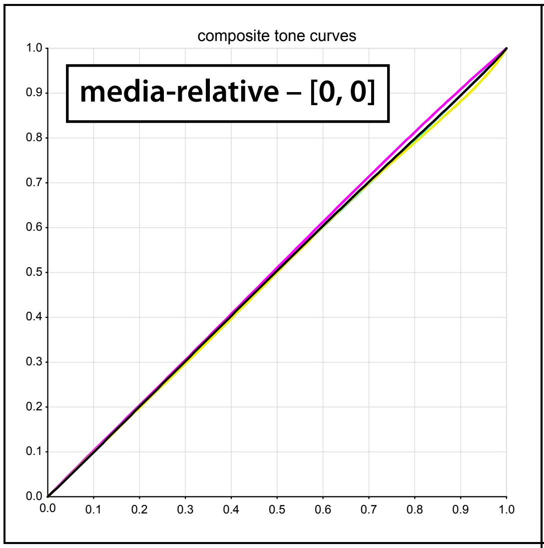


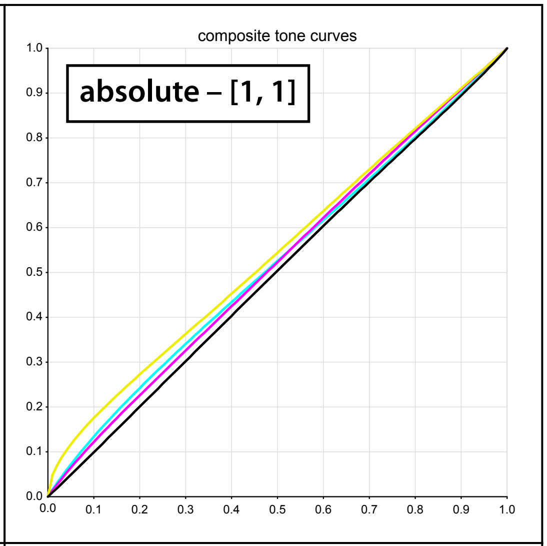
This image shows the white point reference (ref) color computed by the rendering function. The horizontal axis is the **luminance** value, and the vertical axis is the **cast** value. The L*a*b* values of the reference profile are **95, 10, -10** (purple, upper right corner). The L*a*b* values of the press paper are **80, 0, 0** (gray, lower left corner).

The luminance setting controls the L* value of the mapped white point. The cast setting controls the chroma and hue. For either setting, a value of 0 selects the press paper, a value of 1 selects the reference profile.

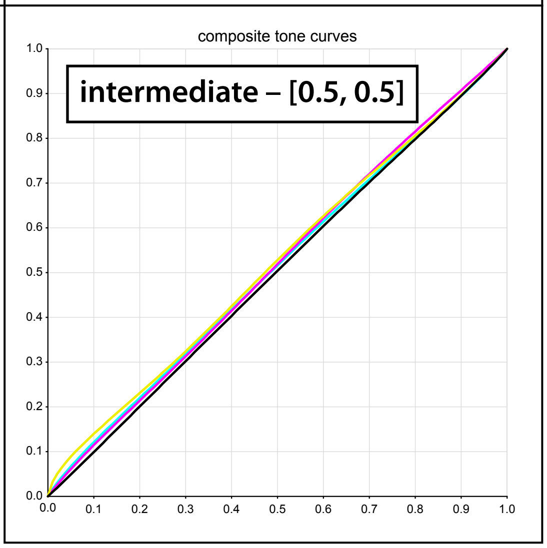
Custom Rendering

The default rendering is media-relative, meaning the white point of the reference profile is mapped to the paper color. With this setting there is no background tint, and no highlight clipping. But if the white points are significantly different, press sheets will not match proofs in a side-by-side comparison. Below, are example curves built with **CGATS21_CRPC5.icc** as the reference profile, and **CGATS21-2-CRPC6.txt** as the press measurements (to deliberately create a difference in the white points). The profile white point is L*a*b* **92, 0, 0**, and the press white point is L*a*b* **95, 1, -4**. The **`rendering:`** settings are shown on the curve graphs below.





The graph above shows media-relative rendering, and is nearly linear, as you might expect with this data. Notice that absolute rendering adds cyan and yellow to the highlights, in an effort to literally match the profile white point. The yellow curve is substantially elevated, to counter the blueness of the press paper. If this effect is too strong, it can be moderated with intermediate rendering values.
The luminance and cast settings may be set independently to obtain the desired results.



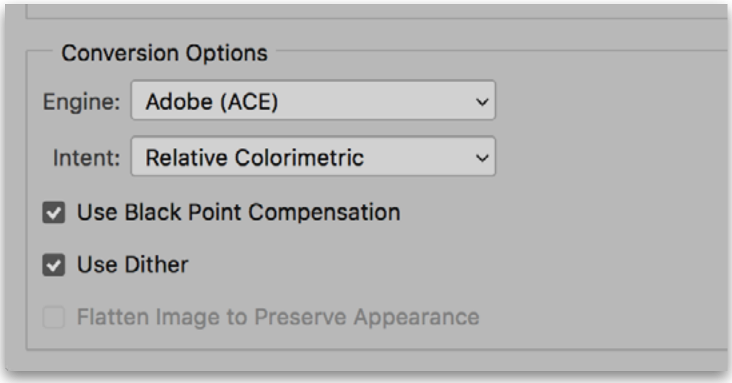
Black Point Compensation

The color reference profile is chosen for the printing process and paper (substrate). The ink densities are adjusted to match the gamut of the reference profile, as closely as possible. Curves are then built to minimize color errors.

If the endpoints are pinned (they normally are) the curves cannot affect the gamut of the printing process. If the gamut of the color reference is significantly different from the gamut of the printing process, there will be large residual color errors.

Adobe BPC

Black point compensation (**BPC**) adjusts the gamut of the color reference to align with the printing process. The term comes from color management. In Photoshop, BPC is an option in the **Convert to Profile** operation. PressCal's BPC is identical, color-wise.



Gamut Scale Factor

In PressCal, BPC is controlled by the **`gsf:`** (gamut scale factor) setting, which is the *relative size of the adjusted reference gamut*. A **`gsf:`** value of 1.1 makes the gamut 10% larger; a value of 0.9 makes the gamut 10% smaller. A **`gsf:`** value of 1 makes the gamut same-sized, effectively disabling BPC.

Optimization

The default **`gsf:`** setting is for the value to be optimized simultaneously with the curve parameters. The final value is reported in the output log. In the example below, the final gamut scale factor is 0.997.

```
621     0.000  0.000  0.000  0.600      41.9   0.5   -1.8      40.1   0.7   -0.1
622     0.400  0.400  0.700  0.600      25.4   1.0   10.4      25.5   1.9   12.1
623     1.000  0.700  0.000  0.600      17.6   3.5  -18.6      16.6   3.1  -20.6
624     0.400  1.000  0.000  0.800      14.9  15.3   -4.9      15.0  13.7   -6.3

                                                         optimized average error:

final gamut scale factor = 0.997

curve parameters:

             HLV    1/4    2/4    3/4    SHV
      cyan  0.000  0.390  0.520  0.812  1.000
   magenta  0.000  0.414  0.611  0.812  1.000
    yellow  0.000  0.411  0.608  0.902  1.000
```

If the **`shadow:`** endpoints float (are set to **`undef`**), the **`gsf:`** value must be fixed. If the **`gsf:`** setting is commented out (default), the value is automatically set to 1, and the excluded from the optimization.

OBAs and Measurement Condition

Optical Brighteners

OBAs (optical brightening agents) are chemical compounds that convert invisible UV (ultraviolet) light into visible blue light. These compounds are added to papers to increase brightness. They are a persistent problem in color management work, because their effect depends on the UV content of the illumination. When the UV content of the viewing light and the measuring device differ, color management will fail.

The OBA problem was addressed in 2009 with an update to ISO 3664, which specifies the UV content of the viewing illuminant be equivalent to CIE D50 standard illuminant (outdoor light at 5000 °K). This was a simple and obvious solution, which unfortunately, made the problem worse. Ordinary fluorescent tubes are made with UV blocking glass, and LEDs emit no UV light. It is unlikely your printed materials will be viewed with D50 levels of UV, except outdoors, or in a modern viewing booth.

Color Measurements

The ISO 13655 standard for color measurements was also updated in 2009. Four measurement conditions, **M0**, **M1**, **M2**, and **M3**, were added to better define the measuring illuminant. M1 illumination contains the equivalent UV of D50, while M2 illumination contains no UV. M0 applies to legacy instruments, which typically use tungsten lamps emitting some UV, but less than M1. M3 measurements are polarized with no UV.

Modern instruments can measure and save M0, M1, and M2 data in a single CxF3 format file. The **`condition:`** setting allows you to select the measurement condition from a CxF3 file. Your measurements should use the same condition as the reference data set/profile.

Blended Measurements

The **`condition:`** setting allows you to specify blending of the M1 and M2 measurements by entering a number between 0 and 1. A value of 0 is the same as M2 (UV cut), and a value of 1 is the same as M1 (D50). A value of 0.5 is a 50-50 blend of M1 and M2. Here are some paper measurements to illustrate blending,

Source	L*a*b* (M1)	L*a*b* (M2)
FOGA51	95, 1.5, -6	unknown
CGATS21-2-CRPC6	95, 1, -4	unknown
Veritiv Endurance Silk	94.8, 1.8, -6.4	94.5, 0.0, 0.7

If your reference is FOGRA51, the Endurance paper color is a good match. But, if your reference is CGATS21-2-CRPC6, the a* and b* values are off. A **`condition:`** setting of 0.65 adjusts the Endurance paper color to 94.7, 1.2, -4.0. You can determine the blending value by trial and error, or set the **`condition:`** to **auto** for the optimum value, in this case 0.646. You will find this blending option especially useful with premium uncoated papers, which are usually heavy with OBAs.

Caveat

Blending M1 and M2 measurements works very well in practice, but is not supported by standards, or by IDEAlliance for G7 submissions. For more information, see our TAGA presentation on the OBA effect.

Color Measurement Files

Standard File Formats

The file format most often used to store measurement data is whitespace-delimited ASCII, as saved from spreadsheet software. The data samples are rows, and the fields are columns in the spreadsheet. The spreadsheet also contains information about the test, and lines to group the field names and data. The structure of these text files, and the allowed field names are defined by parallel ANSI and ISO standards (CGATS.17 and ISO 28178).

In 2004, the CGATS group began work on an equivalent XML file format. In those days, it was believed that XML would simplify software development, and ease the integration of systems. A version of CGATS.17 was released in 2005 containing the ASCII format, and its XML equivalent. Unfortunately, this XML design was technically flawed and never used commercially. In the same time period, the Gretag-Macbeth company introduced a proprietary XML format called CxF, which was implemented in some of their color management software. Gretag-Macbeth was purchased by X-Rite, which released improved versions of CxF, known as CxF2 and CxF3. CxF3 was adopted by the ISO standards group as CxF/X (ISO 17972), and is the default file format for X-Rite's i1Profiler software.

PressCal supports both **ASCII** and **CxF/X** file formats. We use X-Rite's i1Profiler software to make measurements with their instruments. PressCal will read any of the i1Profiler file variants such as **.cxf**, **.mxf**, **.rmxf**, and **.txt**. Other manufacturers provide software that will likely save measurements in at least one of these formats.

Averaging Measurement Files

Subsequent sheets from an offset press may be slightly different due to the design of the ink train. You may wish to measure several press sheets, and average them. Place the measurement files together in a folder, and run PressCal using the folder path. PressCal will automatically average the files, providing they have the same samples and file format.

Appending Measurement Files

Measurements from different test charts may be combined, providing they have the same file format. This is done using matrix notation for the **`press_path:`** setting. Paths may be to a single measurement file, or a folder of measurements to be averaged. A common use for this capability is to combine P2P and IT8.7/4 test charts for G7 colorspace grading. Although the IT8.7/5 test chart contains both sample sets, it is much faster to read the P2P chart for the curve building steps, and append the IT8.7/4 data at the end.

Merging Measurement Files

Some PressCal functions require both M1 and M2 data. A feature of the CxF/X file format is that multiple measurement conditions (M0, M1, M2) may be stored in a single file. This simplifies file handling.

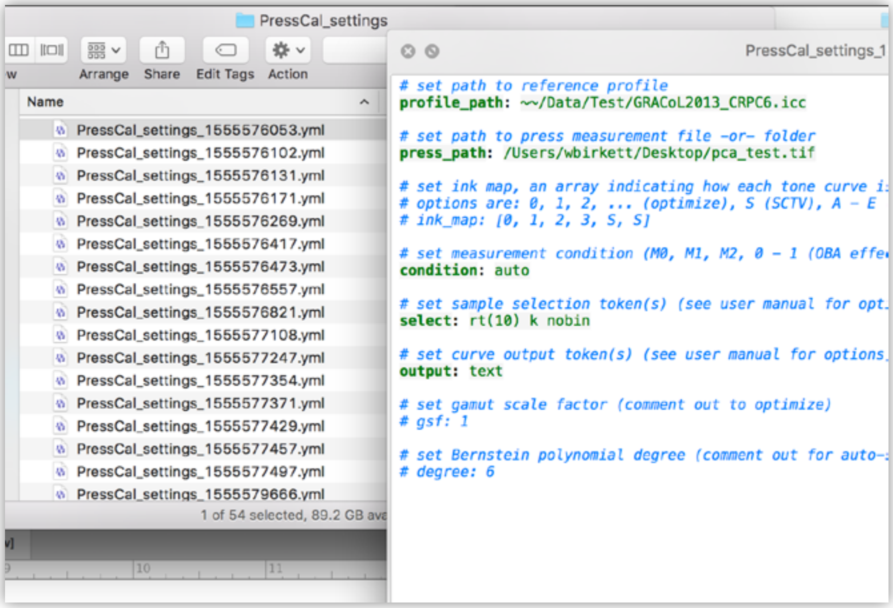
But, if you have individual ASCII files with different measurement conditions, place them together in a folder, with the file names ending like this, … M0.txt, … M1.txt, … M2.txt. When you run PressCal using the folder path, the files will be merged to a single chart object containing all of the measurement conditions.

Settings Folder

The first time you run PressCal, a folder named **PressCal_settings** will be created on your desktop. This folder will contain a text file of the current settings. The file is named **PressCal_settings_XXXXXXXXXX.yml**, where XXXXXXXXXX is the Unix time when the program was run. Each time you run PressCal with changed settings, a new settings file will be saved.

Viewing Previous Settings

You can view previous settings using TextMate. Double-click on the .yml file to open it. The settings are as they were when PressCal was run at the time indicated.



Using Previous Settings

You may edit and/or run the settings file, same as the default settings. A new settings file will be saved as it appeared in the TextMate editor. The collection of settings files is a complete record of your work with PressCal. The individual settings are very tiny files, so you don't need to worry about filling up your disk drive. You may move, copy, or delete these files without any consequence.

Settings Folder Location

The **`settings_path:`** setting allows you to specify the location of the settings folder. The default location is your Desktop.

Curve Sets

If you run the curve building tool (⌘**R**), the generated curve set will be saved in the settings folder as a file named **cvst_xxxxxxxxxx.pst**. These files may be used with the **`plate_curve_path:`** setting.

Settings Reference

Reference Profile Path

```
# set path to reference profile
profile_path: ~~/Data/Test/GRACoL2013_CRPC6.icc
```

The **profile_path:** selects the reference ICC profile which defines the desired printing result. See the section on file/folder paths. This would normally be the same profile used to make your proofs. Standard reference profiles are available from organizations like IDEAlliance and ECI.

The reference profile may also be an aggregation of multiple profiles, with varying device values. This supports a technique where an extended color gamut process is characterized by multiple profiles, each representing distinct regions of the combined color space. The notation for multiple profiles uses brackets to organize the various elements. Here is an example, which creates a virtual CMYKOGV (7/C) profile,

```
# set paths to multiple reference profiles
profile_path: [['~~/Data/FTA/FTA_CMYK.icc', 0, 1, 2, 3], ['~~/Data/
FTA/FTA_Omyk.icc', 4, 1, 2, 3], ['~~/Data/FTA/FTA_cGyk.icc', 0, 5, 2,
3], ['~~/Data/FTA/FTA_cmVk.icc', 0, 1, 6, 3]]
```

The path to each profile, followed by the ink channels it's mapped to, are enclosed in brackets. These specifications are themselves enclosed in brackets. Individual elements are separated by commas. Note the index of the first ink channel is 0 (not 1). This structure can have any number of specifications, including profiles mapped to the same ink channels. The combined virtual profile includes all ink channels from 0 to the largest map index. Note that the number of left brackets will always equal the number of right brackets in a correct expression.

Certain samples will map to more than one profile. In this case, the transformed values are averaged. It is recommended that the individual profiles be made using the same software and settings.

This is a required setting for many functions - there is no default value.

Press Measurement Path

```
# set path to press measurement file -or- folder
press_path: ~~/Data/Test/Endurance_silk_105XL.mxf
```

The **press_path:** selects the measurements of your printing process. This could be a single file, or a folder containing several data sets to be averaged. See the section on file/folder paths. Measurement file(s) may be in either CGATS (text) or CxF3 (XML) format. Plates, if used, would normally be made without tone curves, i.e. linear plates.

The press measurements may also be an aggregation of multiple measurement files, with varying device values. This supports combining different test charts on a press sheet. For instance, CMYK data might be measured as an IT8/7-4 test chart, and spot colors might be measured as individual color ramps. The setting for multiple measurement files uses brackets (**[]**) to organize the elements into a **matrix notation** like this, **[[chart1_info], [chart2_info], … [chartN_info]]**.

Here's an example,

```
# set paths to multiple press measurements
press_path: [['~/Desktop/cmyk_IT874.txt', 0, 1, 2, 3], ['~/Desktop/
red_spot.txt', 4], ['~/Desktop/blue_spot.txt', 5]]
```

The path to each test chart, followed by the ink channels it's mapped to, are enclosed in brackets. These are the elements of the matrix. This structure can have any number of elements, including files mapped to the same ink channels. Note the index of the first ink channel is 0 (not 1). The combined press measurements include all ink channels from 0 to the largest map index. Note the number of left brackets will equal the number of right brackets in a valid matrix setting. Also, note the use of commas.

Here's another example,

```
press_path: [['~/Desktop/cmyk_IT874.txt', 0, 1, 2, 3], ['~/Desktop/
cmyk_p2p51.txt', 0, 1, 2, 3]]
```

In this case, we're combining measurements of two different CMYK test charts. Paths may be to single files or folders containing multiple measurement files to be averaged.

If a folder contains multiple measurement files, by default they are averaged (assuming they all have the same structure). You can force the files to be combined (appended) by adding a **P** to the array referencing a folder,

```
press_path: [['~/Desktop/folder_of_measurements', 0, 1, 2, 3, P]]
```

CxF/X-4 files are also supported,

```
press_path: [['~/Desktop/cmyk_IT874.txt', 0, 1, 2, 3], ['~/Desktop/
red_spot.cxf', 4], ['~/Desktop/blue_spot.cxf', 5]]
```

When combining multiple test charts, they should be cut from the same press sheets, and measured with the same instrument. Otherwise there may color variations. If the paper white measurements are significantly different, the message "press data has large paper white variation ..." will appear. By adding **N** to the end of one ink channel list, the other measurements will be adjusted to have the same white point,

```
press_path: [['~/Desktop/cmyk_IT874.txt', 0, 1, 2, 3, N], ['~/Desktop/
red_spot.cxf', 4], ['~/Desktop/blue_spot.cxf', 5]]
```

When a test chart is printed without one or more inks, the missing ink(s) are indicated with an index of **undef**. For example, if a CMYKOGV test chart is printed as CMYKOV, the green ink is missing. Here is an example setting,

```
press_path = [['~/Desktop/cmykogv.txt', 0, 1, 2, 3, 4, undef, 5]]
```

This is a required setting – there is no default value.

Ink Map

```
# set ink map, an array indicating how each tone curve is derived
# options are: 0, 1, 2, ... (optimize), S (SCTV), A – F (TVI), N
(G7K), L (linear)
# ink_map: [0, 1, 2, 3, S, S]
```

The **`ink_map:`** setting controls the method used to calculate each tone curve. For each ink channel, its curve may be calculated using optimization, TVI, SCTV, NPDC, set as linear or as a copy of the plate curve. Values **A-F** are TVI tone curves per ISO 12647-2. Note these curves are different in the 2004 and 2013 editions of that standard, as selected by the 12647-2: setting. Value **S** makes a curve with linear SCTV. Value **L** makes a straight linear curve.

By default, press ink channels are mapped to profile device channels, and curves are optimized. If there are more press ink channels than profile device channels, the extra channels are linearized using SCTV. The ink map must contain an entry for each ink channel in the press measurement data set.

Measurement Condition

```
# set measurement condition (M0, M1, M2, M3, 0 – 1 (OBA effect),
auto)
condition: auto
```

The **`condition:`** setting selects the measurement condition of the **`press_path:`** data. This setting applies only to measurements in CxF3 format (.mxf files). These files may contain M0, M1, and/or M2 data. If the **`press_path:`** measurements don't include the measurement condition you specified, an error will occur. The default value is **`M0`**; therefore, you need only activate this setting to select **`M1`** or **`M2`** data. This setting may also be the OBA effect value (0 to 1), which blends the M1 and M2 data. A setting of **`auto`** will determine the OBA effect for minimum color error between the reference profile and the press substrate. **This is especially useful for substrates with heavy OBAs.**

Sample Selection Token(s)

```
# set sample selection token(s) (see user manual for options)
select: rt(10) k nosub
```

The **`select:`** setting selects a subset of the press measurement samples. This setting is a string of sample selection tokens, each of which selects a group of samples having some common property. Some tokens have parameters to control the selection. The groups are combined and duplicates are removed.

In the example above, the **`rt(10)`** token (round-trip) selects samples that are realistic, based on the reference profile. The **`k`** token (black) selects samples containing only black. The **`nosub`** token removes substrate samples, which are unnecessary when the curve highlights are pinned. This combination of tokens will produce good results in most situations. The sample selection setting is an important feature of PressCal, which allows the software to simulate other curve building methods.

The default setting is to use all samples in the data set.

Curve Output Token(s)

```
# set curve output token(s) (see user manual for options)
output: text
```

The **`output:`** setting selects the output format(s) for the optimized curves. This setting is a string of curve output tokens, which cause the curves to be output in the specified DFE format. The tokens may have optional parameters.

In the example above, the token is **`text`** (tab-delimited ASCII).

The default setting is for no output.

Gamut Scale Factor (gsf)

```
# set gamut scale factor (comment out to optimize)
gsf: 1
```

The **`gsf:`** setting controls the black point compensation applied to the reference profile color values. This setting is used to adapt the reference profile to the gamut of the press. If the **`gsf:`** setting is 1, there is no black point compensation, and the gamut size is unchanged. A value less than 1 reduces the gamut, and a value greater than 1 increases the gamut (of the reference profile).

Normally, the solid ink densities on a press are adjusted to match the reference. If this is done correctly, a **`gsf:`** setting of 1 is appropriate. But when the press gamut doesn't match the reference, black point compensation may be used to align them.

By default, the gamut scale factor will be optimized along with the curves. The final optimized **`gsf:`** value is shown at the end of the output log.

If the **`shadow:`** endpoints float (are set to **`undef`**), the **`gsf:`** value must be fixed. In this case, the default **`gsf:`** value is 1.

Linearity

```
# set tone compression linearity
linearity: 2.0
```

The **`linearity:`** setting controls tone compression contrast. The default value is 0, for linear mapping of xyz values. If the value is positive, highlight contrast is increased. If the value is negative, shadow contrast is increased. The allowable range is -5 to 5.

Rendering

```
# set rendering (luminance, cast)
rendering: [0, 1]
```

The **`rendering:`** setting controls the mapping of the reference white point to the press white point. There are two values, luminance and cast, which may vary between 0 and 1. Luminance controls the mapping of the Y-value. Cast controls the color cast. If both values are 0 (default) the rendering is media relative. If both values are 1, the rendering is absolute.

The **`rendering:`** setting may be overridden by the grading tool (**⌘I**), to obtain correct reference values for the selected grading rules (**G7** and **FOGRA PSD**).

Bernstein Polynomial Degree

```
# set Bernstein polynomial degree (comment out for auto-select)
degree: 6
```

The **degree:** setting controls the degree of the Bernstein polynomials used to model the tone curves. Lower values produce simpler curves, but with higher color errors. By default, the software determines the degree automatically, based on the sample selection and other factors. You may override the automatically determined value with this setting. Normally, this setting would be used to reduce the degree of the curves. Don't set the degree higher than the automatically determined value.

Color Error Metric (deltaE)

```
# set color error metric (dEab, dEcmc, dE94, dE99, dE00, dLCh)
deltaE: dE99
```

The **deltaE:** setting selects the function used during curve optimization to calculate color errors. All of the commonly used error metrics are supported (dEab, dEcmc, dE94, dE99, dE00), plus the L*/Ch metric used for G7 pass/fail. The default value is **dE00** (spoken as "delta E 2000").

User Defined Color Difference Function

```
# add user-defined color difference function
udf: sub mydE {return(sqrt(($_[0] - $_[3])**2 + ($_[1] - $_[4])**2 +
($_[2] - $_[5])**2))} # same as dEab
# udf: sub dEman {return(abs($_[0] - $_[3]) + abs($_[1] - $_[4]) +
abs($_[2] - $_[5]))} # manhattan distance
```

The **udf:** setting allows the user to create a custom color difference function, similar to **dEab** or **dE00**. This requires writing a Perl subroutine having two L*a*b* values as inputs, and a single output value. The user-defined function may then be selected by the **deltaE:** setting.

Colorimetry

```
# set colorimetry
color: {'illuminant' => ['~/Desktop/illum.txt', 1], 'cat' =>
'cat02'}
```

The **color:** setting allows the user to specify custom colorimetry with spectral press measurements. If enabled, this affects the conversion of spectral values to XYZ values. By default, the illuminant is D50 and the observer is 2° (CIE 1931). These are the standard graphic arts values.

A caveat is that the reference profile must be built with the same colorimetry to be strictly correct. Since most standard data sets are L*a*b*, this is not generally possible (an exception is FOGRA51). Nevertheless, by using a chromatic adaptation transform (CAT), useful results are possible.

The setting value is a Perl hash reference containing various keys. Here is documentation for the colorimetry hash. Note that within the braces, non-numeric values need to be single-quoted ('abc').

Highlight Endpoints

```
# set highlight endpoints (0 to 10 %-dot, -or- undef)
highlight: [2, 3, 4, 5]
# highlight: [undef, undef, undef, undef] # highlights floating
# highlight: [undef+, undef+, undef+, undef+] # floating, ≥ 0
```

The **highlight:** setting controls how curve endpoints (at 0 %-dot) are treated during optimization. It is an array **[]** of values corresponding to the press measurements. Each value may be a decimal number from 0 to 10 %-dot, which pins the endpoint to that value, or **undef**, which allows the endpoint to float during optimization. In addition, a **+** or **–** may be appended to **undef** to add a constraint. **undef+** forces the endpoint to always be ≥ 0 %-dot. **undef–** forces the endpoint to always be ≤ 0 %-dot. The default value for this setting is for all endpoints to be pinned at 0 %-dot.

Shadow Endpoints

```
# set shadow endpoints (90 to 100 %-dot, -or- undef)
shadow: [95, 96, 97, 98]
# shadow: [undef, undef, undef, undef] # shadows floating
# shadow: [undef-, undef-, undef-, undef-] # floating, ≤ 100
```

The **shadow:** setting controls how curve endpoints (at 100 %-dot) are treated during optimization. It is an array **[]** of values corresponding to the press measurements. Each value may be a decimal number from 90 to 100 %-dot, which pins the endpoint to that value, or **undef**, which allows the endpoint to float during optimization. In addition, a **+** or **–** may be appended to **undef** to add a constraint. **undef+** forces the endpoint to always be ≥ 100 %-dot. **undef–** forces the endpoint to always be ≤ 100 %-dot. The default value for this setting is for all endpoints to be pinned at 100 %-dot.

Natural Curve Endpoints

```
# set natural curve endpoints
natural: 1 # enable natural curve endpoints
```

The **natural:** setting applies an optimization constraint that forces curves to be straight at shadow endpoint. See Bernstein basic setting for graphs illustrating the effect.

TVI Curve Functions

```
# set ISO 12647-2 TVI standard (2004 or 2013)
tvi_std: 2004
```

The **tvi_std:** setting selects the version of the ISO 12647-2 standard used for calculating TVI curves. For example, FOGRA39 is based on the 2004 standard, whereas FOGRA51 is based on the 2013 standard. The default value is **2013**.

Gray Balance Fade

```
# set gray balance fade ([x0, x1, y0, y1])
gb_fade: [50, 100, 0, 100]
```

The **gb_fade:** setting reduces the chroma of the **CMY** press measurements to stabilize the shadow region of G7 curves. The parameters are endpoints of the fade function, as percent values. This setting should only be used when making G7 curves.

Blend SCTV Curves

```
# set curve blending
blend_sctv: {} # use default values
# blend_sctv: {'median' => 75, 'slope' => 4, 'map' => [0, 1, 2]} # same
# blend_sctv: {'map' => [0, 1, 2, 3]} # blend the black curve, too
```

The **blend_sctv:** setting calculates SCTV curves for each enabled ink channel, and blends them with the normally computed curves. Blending is controlled by a function with an S-shape, set by the **'median'** and **'slope'** values. The **'map'** value controls the ink channels affected, CMY by default.

Ink Names

```
# set ink names
inks: [cyan, magenta, yellow, black, orange, violet]
```

The **inks:** setting is a list of ink names, used in various places. The default list starts with **cyan, magenta, yellow, black**. Additional inks are named **ink5, ink6, ink7**, etc.

Settings Folder Path

```
# set path to settings folder
settings_path: ~/Clients/Acme_Printing/2018-11-11/settings
```

The **settings_path:** selects the folder where settings will be saved. If the folder doesn't already exist, it will be created. In the above example, the tilde character (~) is a shortcut for the user's home folder. The default value is the Desktop folder.

Output Folder Path

```
# set path to curve output folder
output_path: ~/Clients/Acme_Printing/2018-11-11/curves
```

The **output_path:** selects the folder where curves and other output items will be saved. If the folder doesn't already exist, it will be created. In the above example, the tilde character (~) is a shortcut for the user's home folder.

This setting has an additional function – to modify the name of the saved file by adding a prefix and/or suffix. Here are some examples of modified file names.

```
'tab_delim.txt' (default file name)
'prefix_tab_delim.txt' (add prefix)
'tab_delim_suffix.txt' (add suffix, not to be confused with the file
type extension)
'tab_delim_1644423429.txt' (add unix time, unix time is always in-
creasing, so file names will be unique and sortable)
'tab_delim_2023-10-22T11-36-49.txt' (add ISO time, as specified by ISO
8601)
'tab_delim_01.txt' (add index, find the existing file with the great-
est index and increment it, otherwise use '1')
```

We implement this capability by allowing the **output_path:** setting to optionally be a hash. A hash begins and ends with curly braces (**{}**) and contains key/value pairs. Keys and values should be single-quoted. Supported keys are **'path'**, **'prefix'**, **'suffix'**, **'time'** and **'index'**.

For example, these settings,

```
output_path: {'prefix' => 'RMGT_1060_coated', 'time' => 'unix'}
output: text
```

save a text curve file to the user's Desktop (the default path) with this name,

```
'RMGT_1060_coated_tab_delim_1644423429.txt'
```

This setting will save the file to a different location,

```
output_path: {'path' => '~/Clients/Acme', 'prefix' => 'RMGT_1060_coat-
ed', 'time' => 'unix'}
```

These settings are equivalent,

```
output_path: ~/Clients/Acme
output_path: {'path' => '~/Clients/Acme'}
```

Supported values for the **'time'** key are **'unix'** and **'iso'**. Supported values for the **'index'** key are integers between **1** and **5**, representing the width of the numeric field, which is zero filled. Any or all of the hash keys may be used. This is an optional setting – files are output to the user's Desktop without modification by default.

The default file name is generated by the setting that actually outputs the file, such as the **output:**, **adjust_path:**, **adjust_profile_path:**, **export_data:** or **stats:** settings. These settings (and others) support the **'base'** key, which allows you to override the default file name, e.g.,

```
output: text({'base' => 'my_file_name.tab'})
```

Furthermore, you may use any of the **output_path:** keys in these other settings, e.g.,

```
output_path: {'path' => '~/Clients/Midnight_Oil_Printing', 'prefix' =>
'RMGT_1060_coated'}
output: text({'base' => 'my_file_name.tab', 'prefix' => '', 'time' =>
'unix'})
```

If there are duplicate keys, the value of the actual output setting overrides the **output_path:** setting.

Plate Curve Path

```
# set path to plate curves for non-linear test plates
plate_curve_path: ~~/Data/Test/iso_18620_plate.ted # ISO 18620 format
# plate_curve_path: ~~/Data/Test/tab_delim_plate.txt # simple text
format
# plate_curve_path: ~~/Data/Test/075 LUT.txt # Curve text format
# plate_curve_path: ~~/Data/Test/Linearization.Lin # Onyx lineariza-
tion format
# plate_curve_path: ~~/Data/Test/Esko/iso_18620B_ted.icpro # Esko .ic-
pro format
```

```
# plate_curve_path: ~~/Data/Test/cvst_1738705558.pst # PressCal curve
format
```

The **plate_curve_path:** selects a file containing curves used to make the test plates. Curves may be in **ISO 18620 (.ted)**, **text**, **Onyx .Lin**, **Esko .icpro** or **PressCal curve set** formats.

Normally, test plates are made without curves, AKA linear plates. If the printing process is non-linear (e.g., flexo), plate curves are often used to print the test charts. The calculated tone curves are then combined with the plate curves using this setting. The combined curves are output, and selected in the DFE. In theory, this improves the accuracy of the calibration.

The **plate_curve_path:** setting may also be an **array of named curves**.

```
plate_curve_path: [F40] # use curve F40 for all ink channels
# plate_curve_path: [F40, F35, F45, D40] # different curves for each
channel
```

The **plate_curve_path:** setting may also be a hash containing **key/value pairs**.

```
plate_curve_path: {'path' => '~~/Data/Test/iso_18620_plate.ted'} #
hash
```

By default, tone curves are mapped directly to the plate curves. Sometimes a different mapping is needed. The **'ink_map'** key allows the tone curves to be combined with specific plate curves. The ink map is an array of ink channel indices.

```
plate_curve_path: {'path' => '~~/Data/Test/iso_18620_plate.ted', 'ink_
map' => [0, 1, 2, 3, 5]} # hash with ink map key
```

In this example, the tone curves have 5 channels and the plate curves 6 channels. The first 4 curves are combined normally, but the 5th tone curve is combined with the 6th plate curve. The numbers are the plate curve channel, starting at 0. In most cases, the **'ink_map'** key is not needed.

This is an optional setting – plate curves are not used by default.

Adjust Measurement Path

```
# set path to curve adjusted data
adjust_path: ~/Desktop/adjusted_data
```

The **adjust_path:** setting controls the location where curve adjusted press measurements will be saved. These adjusted measurements may be used to build an ICC profile of the curved printing process. By default, no curve adjusted press measurements are computed or saved.

If the setting is a string, it is the folder path where the curve adjusted data will be saved. If it doesn't already exist, the folder will be created,

```
adjust_path: ~/Desktop/adjusted_data
```

If the setting is a hash, the **'path'** key value is the path to the same destination folder,

```
adjust_path: {'path' => '~/Desktop/adjusted_data'}
```

By default, the source data is the press data. this can be changed with the **'source'** key,

```
adjust_path: {'source' => '~/Documents/color_measurements/my_color_
data.mxf', 'path' => '~/Desktop/adjusted_profile'}
```

By default, the **'path'** value is **'~/Desktop'**. An empty hash will adjust the reference data and save it to the Desktop.

```
adjust_path: {}
```

By default, the name of the modified data file is either **'curve_adj_press.txt'** or **'curve_adj_press.mxf'**. This may be overriden with the **'base'** key,

```
adjust_path: {'base' => 'my_adjusted_data.mxf'}
```

The **output_path:** setting controls the location and naming of all saved files. The supported keys are **'path'**, **'prefix'**, **'suffix'**, **'time'** and **'index'**. These keys may also be used by the **adjust_path:** setting and those values will take precedence over the **output_path:** values for saving the **adjust_path:** file.

The optimized curves are used to adjust the data. By setting the **'combined'** flag to true, plate curves (if any) will be appended to the optimized curves, then applied to the data,

```
adjust_path: {'combined' => 1}
```

You probably don't want this behavior, but it was requested by a user.

Adjust Profile Path

```
# set path to write curve adjusted profile (comment out to disable)
adjust_profile_path: ~/Desktop/adjusted_profiles
```

The **adjust_profile_path:** setting controls the location where a curve adjusted profile will be saved. It also controls how the profile will be modified. See the section on calibrating color-managed processes for further explanation. By default, no curve adjusted profile is computed or saved.

If the setting is a string, it is the folder path where the adjusted profile will be saved. If it doesn't already exist, the folder will be created,

```
adjust_profile_path: ~/Desktop/adjusted_profiles
```

If the setting is a hash, the **'path'** key is the path to the same destination folder,

```
adjust_profile_path: {'path' => '~/Desktop/adjusted_profiles'}
```

By default, the source profile is the reference profile. This can be changed with the **'source'** key,

```
adjust_profile_path: {'source' => '/Library/ColorSync/Profiles/PSO-coated_v3.icc', 'path' => '~/Desktop/adjusted_profile'}
```

By default, the **'path'** value is **'~/Desktop'**. An empty hash will adjust the reference profile and save it to the Desktop,

```
adjust_profile_path: {}
```

By default, the name of the modified profile is **'curve_adj_profile.icc'**. This may be overriden with the **'base'** key,

```
adjust_profile_path: {'base' => 'my_adjusted_profile.icc'}
```

The **'wtpt'**, **'desc'**, **'A2B'**, **'B2A'**, and **'origin'** keys control the changes made to the source profile.

The **'wtpt'** value is a flag. If true, the white point of the press measurements will be copied to the adjusted profile.

```
adjust_profile_path: {'wtpt' => 1}
```

If the **'desc'** value is **'unix'**, the profile description will be modified by appending the unix time,

```
adjust_profile_path: {'desc' => 'unix'}
```

If the **'desc'** value is some other string, the profile description will be set to that,

```
adjust_profile_path: {'desc' => 'GRACoL_2013 modified with curves'}
```

The **'A2B'** and **'B2A'** keys may have three possible values, **-1, 0, 1**. If the value is **0**, no changes are made to that group of profile tags. If the value is **1**, the curves will be applied in the forward direction, and if the value is **-1**, the curves will be applied in the reverse direction. By default, the **'A2B'** value is **-1**, and the **'B2A'** value is **1**, to simulate the effect of applying the curves to profiling data,

```
adjust_profile_path: {'A2B' => -1, 'B2A' => 1}
```

The **'origin'** key is a flag. If true, the first entry in the profile's output curve LUT is set to 0. This is useful if the curves were generated with the **highlight:** setting. It will force paper white areas to stay white, even if the curves have a min dot.

```
adjust_profile_path: {'origin' => 1}
```

The **output_path:** setting controls the location and naming of all saved files. The supported keys are **'path'**, **'prefix'**, **'suffix'**, **'time'** and **'index'**. These keys may also be used by the **adjust_profile_path:** setting and those values will take precedence over the **output_path:** values for saving the **adjust_profile_path:** profile.

The optimized curves are used to adjust the profile. By setting the **'combined'** flag to true, plate curves (if any) will be appended to the optimized curves, then applied to the profile,

```
adjust_profile_path: {'combined' => 1}
```

You probably don't want this behavior, but it was requested by a user.

Optimal Version

```
# set Optimal version (2020)
optimal_version: 2020
```

The **optimal_version:** setting selects the version of the Optimal Method grading rules. The default value is **2020**. This setting only affects the grading function.

Optimal Level

```
# set Optimal level (offset)
optimal_level: offset
```

The **optimal_level:** setting selects the level of the Optimal Method grading rules. The default value is **offset**. This setting only affects the grading function.

G7 Pass/Fail Version

```
# set G7 pass/fail version (35, 36)
g7_version: 35
```

The **g7_version:** setting selects the version of the G7 Pass/Fail document, published by IDEAlliance. This document defines the measurements, error metrics, and tolerances for the various levels of G7 compliance. The default value is **36**. This setting only affects the grading function.

G7 Compliance Level

```
# set G7 compliance level (grayscale, targeted, colorspace_press, colorspace_proof)
# the modifier 'relative' may be added to enable SCCA
g7_level: targeted relative
```

The **g7_level:** setting selects the G7 compliance level, as explained in the G7 Pass/Fail document. The **grayscale** level grades just the gray **CMY** and **K** tone ramps. The **targeted** level adds the solid ink colors and overprints. The **colorspace_press** level adds the entire CRPC data set. The **colorspace_proof** level tightens the tolerances slightly. The default value is **targeted**. The modifier **relative** enables SCCA for targeted and colorspace levels. This setting only affects the grading function.

G7 Tone Value Parameters

```
# set G7 tone value parameters [Labp, Lcmy, Lk]
g7_tv: [95, 1, -4, 23, 16]
```

The **g7_tv:** setting controls the TR 015 tone value calculations for G7 grading. The first three parameters are the paper L*a*b* values. The fourth parameter is the **CMY** solid L* value. The fifth parameter is the K solid L* value. The press measurements are used by default. This setting only affects the grading function.

ISO 12647-2 Version

```
# set ISO 12647-2 version (2004 or 2013)
12647-2: 2004
```

The **12647-2:** setting selects the version of the ISO 12647-2 standard used for grading tolerances. The default value is **2013**. This setting only affects the grading function.

ISO 12647-6 Version

```
# set ISO 12647-6 version (2020)
12647-6: 2020
```

The **12647-6:** setting selects the version of the ISO 12647-6 standard used for grading tolerances. The default value is **2020**. This setting only affects the grading function.

ISO 12647-7 Version

```
# set ISO 12647-7 version (2013 or 2016)
12647-7: 2013
```

The **12647-7:** setting selects the version of the ISO 12647-7 standard used for grading tolerances. The 2013 version uses the dEab error metric, while the 2016 version uses dE00. The default value is **2016**. This setting only affects the grading function.

ISO 12647-7 Level

```
# set ISO 12647-7 level (control_strip, colorspace)
12647-7_level: colorspace
```

The **12647-7_level:** setting selects the compliance level. The default value is **control_strip**. The **colorspace** level adds additional requirements for IT8.7-4 test samples. This setting only affects the grading function.

ISO 12647-8 Version

```
# set ISO 12647-8 version (2021)
12647-8: 2021
```

The **12647-8:** setting selects the version of the ISO 12647-8 standard used for grading tolerances. The default value is **2021**. This setting only affects the grading function.

ISO 12647-8 Level

```
# set ISO 12647-8 level (control_strip, colorspace)
12647-8_level: colorspace
```

The **12647-8_level:** setting selects the compliance level. The default value is **control_strip**. The **colorspace** level adds additional requirements for IT8.7-4 test samples. This setting only affects the grading function.

FOGRA PSD Version

```
# set FOGRA PSD version (2018 or 2022)
psd_version: 2022
```

The **psd_version:** setting selects the version of the FOGRA PSD grading rules. The default value is **2022**. This setting only affects the grading function.

FOGRA PSD Level

```
# set FOGRA PSD level (sbs_A, sbs_B, sbs_C, rel_A, rel_B, rel_C)
# sbs = side-by-side, rel = media relative, A, B, C = quality types
psd_level: rel_A
```

The **psd_level:** setting selects the level of the FOGRA PSD grading rules. The default value is **rel_A**. This setting only affects the grading function.

Custom Grading Rules

```
# set custom grading rules
grade: {'substrate' => [[1, 'dE00', '3.5'], 1], 'cmy_ramp' => [un-
def, [1, 'dLCh', undef, '2.5'], 3], 'all_samples' => [[1, 'dE00',
'2.5'], [1, 'dE00', '4.5'], 2]}
```

The **grade:** setting selects custom grading rules, supplied as a Perl anonymous hash. See the custom grading section for a detailed explanation.

Tone Value Metric

```
# set tone value metric (SCTV, TVI)
tv_metric: TVI
```

The **tv_metric:** setting selects the metric used by the grade function to plot initial tone curves. The default value is **SCTV**. This setting does not affect the calculation of calibration curves.

Ink Sequence

```
# set ink sequence
ink_sequence: KCMY
```

The **ink_sequence:** setting specifies the sequence in which inks are printed. This setting is used by the solid ink model, and affects the ink balance calculations. The default value, **KCMY**, represents the ink sequence black, cyan, magenta, yellow.

Ink Balance Weights

```
# set ink balance weights [C, M, Y, R, G, B, ISO]
ink_weight: [1, 1, 1, 0, 0, 0, 0]
```

The **ink_weight:** setting specifies the optimization weights for the C, M, Y, R, G, B, and ISO solids. The default value is **[1, 1, 1, 1, 1, 1, 0]**, which gives equal weight to the C, M, Y, R, G, B solids.

Ink Balance Color Error Metric (deltaE)

```
# set color error metric (dEab, dEcmc, dE94, dE99, dE00, dLCh)
ink_deltaE: dE99
```

The **ink_deltaE:** setting selects the function used during ink balance optimization to calculate color errors. The default value is **dEab**.

Ink Balance Density Status

```
# set ink balance density status (T, E, I)
ink_status: T
```

The **ink_status:** setting selects the ink density calculation used to compute ink balance. This should be set to match the densitometry used in the pressroom. Status **E** is widely used in Europe, and status **T** in the US. Status **I** is narrow band, sometimes used in Europe. The default value depends on the type of curves being generated, status **E** for TVI curves, and status **T** otherwise.

Ink Reference Colors

The **ink_ref_colors:** setting selects reference solid ink colors for the **ink balance** and **grade** functions. It doesn't affect the **curve building** function. These color values normally come from the reference profile. When this is a CMYK profile, spot color data must be supplied separately. The **ink_ref_colors:** setting supports many options for entering color values.

The most direct way to specify a color is by its L*a*b* color values. For example,

```
ink_ref_colors: [[27, 17, -58, 4], [50, 72, 35, 5]]
```

Two colors are specified by this setting. The first color, L*a*b* 27, 17, -58 is applied to ink channel 4, and the second color, L*a*b* 50, 72, 35 is applied to ink channel 5. Note that the first ink channel is numbered 0, so CMYK channels are normally 0, 1, 2, 3. Also note the use of brackets **[ ]** and commas. In a correct expression, the number of left brackets **[** equals the number of right brackets **]**. Numbers are separated by commas. Ink channel numbers are integers. The L*a*b* values may be integers or decimal values. Colors may be specified in any ink channel order.

Another way to specify a color is to use a data set containing device values. Following the convention used for multiple profiles and measurements, the path to the data set is followed by a list of numbers which map the channels. For example,

```
ink_ref_colors: [['~~/Data/Test/CGATS21-2-CRPC6.txt', 0, 1, 2, 3]]
```

Four colors are specified by this setting. The solid ink colors of channels 0, 1, 2, 3 mapped to 0, 1, 2, 3. If we only wished to specify the black channel, we could use **undef** for the other channels,

```
ink_ref_colors: [['~~/Data/Test/CGATS21-2-CRPC6.txt', undef, undef,
undef, 3]]
```

Another way to specify a color from a data set is to use the sample number. In this case, the channel mapping is placed in brackets,

```
ink_ref_colors: [['~~/Data/Test/CGATS21-2-CRPC6.txt', [137 => 0, 203
=> 1]]]
```

Two colors are specified by this setting. Sample 137 is mapped to channel 0, and sample 203 is mapped to channel 1. These numbers are separated by **=>** which is the equal sign followed by the greater than sign. In this example there is no mapping for channels 2 and 3.

Some data sets contain sample names, which may be used. In this example, we access some Pantone colors by name,

```
ink_ref_colors: [['~/Documents/Pantone/Decks_v2.2.0/PANTONE Solid
Coated-V4.cxf', ['blue dark' => 4, 'red 032' => 5]]]
```

Two colors are specified by this setting. Pantone **blue dark** is mapped to channel 4 and **red 032** is mapped to channel 5. Note the sample names are enclosed by apostrophes. The sample name doesn't need to be exact. For Pantone colors, it is generally sufficient to use just the number, although this may yield multiple matches, which you can resolve by making the name more specific. If we knew the sample numbers, we could use them instead of names. Note that apostrophes are not used for sample numbers.

```
ink_ref_colors: [['~/Documents/Pantone/Decks_v2.2.0/PANTONE Solid
Coated-V4.cxf', [35 => 4, 77 => 5]]]
```

An alternative to Pantone colors is to use an Adobe Swatch Exchange (.ase) file,

```
ink_ref_colors: [['~/Desktop/test_palette.ase', ['blue' => 4, 'red' =>
5]]]
```

The CxF/X-4 format is also supported. These files are specified like this,

```
ink_ref_colors: [['~~/Data/FTA/FTA_Blue.cxf', 4], ['~~/Data/FTA/FTA_
Red.cxf', 5]]
```

A combination of several specifications may be used, in any order. For instance,

```
ink_ref_colors: [['~~/Data/Test/CGATS21-2-CRPC6.txt', 0, 1, 2, 3],
['~~/Data/FTA/FTA_Blue.cxf', 4], ['~~/Data/FTA/FTA_Red.cxf', 5]]
```

Six colors (CMYK plus two spots) are specified with this setting.

We normally assume the L*a*b* values are to be matched literally, regardless of the media white values and **rendering:** setting. However, there are times when we want the **rendering:** transform applied to the entered values. This is accomplished by adding an **A** character at the end of the specification,

```
ink_ref_colors: [['~~/Data/Test/CGATS21-2-CRPC6.txt', 0, 1, 2, 3, A]]
```

The **ink_ref_colors:** setting overrides any solid colors derived from the reference profile.

SCTV Reference

The **sctv_reference:** setting selects tone ramp data used as a reference for computing SCTV curves. Normally, SCTV curves are computed to make the SCTV values linear with respect to %-dot. This is a reasonable practice for spot colors when the desired tonality is unknown.

The ISO 17972-4 standard (CxF/X-4) describes a way to characterize the printing of a single spot color. A CxF/X-4 file contains spectral data for the solid ink, the substrate, and intermediate tone values. This data may be used as a reference for computing SCTV curves. Here is an example using CxF/X-4 files,

```
sctv_reference: [['~~/Data/Test/FTA_Blue.cxf', 4], ['~~/Data/Test/
FTA_Red.cxf', 5]]
```

Tone ramps for channels 4 and 5 are specified by this setting. Note that the first ink channel is numbered 0, so CMYK channels are normally 0, 1, 2, 3. Also note the use of brackets **[]** and commas. In a correct expression, the number of left brackets **[** equals the number of right brackets **]**. The tone ramps are specified by the CxF/X-4 file paths, enclosed by apostrophes.

It is also possible to generate SCTV curves for process colors (e.g. CMYK). In this case, the reference tone ramps are derived from a CMYK data set, rather than a CxF/X-4 file. Here is an example,

```
sctv_reference: [['~~/Data/Test/CGATS21-2-CRPC6.txt', 0, 1, 2, 3]]
```

The data set is **CGATS21-2-CRPC6.txt**, which contains CMYK device data. The numbers that follow (0, 1, 2, 3) are the ink channels the CMYK tone ramps are mapped to. If the map value is **undef**, that tone ramp is not used. In this example, only the black tone ramp is used for an SCTV curve,

```
sctv_reference: [['~~/Data/Test/CGATS21-2-CRPC6.txt', undef, undef,
undef, 3]]
```

It is possible to mix CMYK and CxF/X-4 specification. Any number of specification may be used, in any order,

```
sctv_reference: [['~~/Data/Test/CGATS21-2-CRPC6.txt', 0, 1, 2, 3],
['~~/Data/Test/FTA_Blue.cxf', 4], ['~~/Data/Test/FTA_Red.cxf', 5]]
```

The reference profile is specified by setting the file path to **'profile'**,

```
sctv_reference: [['profile', 0, 1, 2, 3]]
```

Named curves may be used as a reference. A single entry will be applied to all ink channels. Curves may be **LIN** for linear, or **undef** for no curve.

```
sctv_reference: [L44] # use 50% -> 44% curve for all inks
sctv_reference: [LIN, LIN, LIN, L44] # linear curves inks 0, 1, 2
sctv_reference: [undef, undef, undef, L44] # no curves inks 0, 1, 2
```

SCTV curves are linear, unless a reference is specified using the **SCTV_reference:** setting. Although supported, we believe using SCTV to build CMYK curves is not the best solution when a reference profile is provided.

Export Press Data

```
# export press data
export_data: ~/Desktop/data # set destination folder
# export_data: {} # use default settings
# export_data: {'select' => 'all', 'fields' => ['DEVICE', 'LAB'],
'format' => 'text'}
```

The **export_data:** setting controls the output of PressCal's internal press data. This data is formed according to the **press_path:** setting, and may be a composite of several individual data sets. The data sets may be averaged, appended, and/or mapped. The user may wish to export this "resolved data" as a single file for other uses. Data is output at the end of the curve building function (⌘**R**).

The **export_data:** setting is a hash containing optional keys and values. A hash begins and ends with braces (**{}**), and contains keys/value pairs separated by **=>**. Keys and values should be single-quoted, except for the **'fields'** value, which is an array. The supported keys are **'format'**, **'select'**, and **'fields'**.

The **'format'** key controls the data file format. **'format'** values are either **'text'** or **'cxf3'**. **'text'** format is also known as **ANSI CGATS** format. X-Rite's **.mxf** and **.rmxf** formats are **'cxf3'** format. Both formats are defined by **ISO 28178**. The default value is the format of the **press_path:** files.

The **'select'** key is a string that determines which samples are saved. **'select'** values are defined in the **Sample Selection Tokens** section. A value of **'opt'** is the sample set used for optimization. The default value is all samples.

The **'fields'** key selects which data fields will be saved. This value is an array, so that multiple fields may be selected. An array begins and ends with brackets (**[]**), and contains individual single-quoted words, designating the fields in this case. Some supported field values are **'ID'**, **'DEVICE'**, **'XYZ'**, **'LAB'**, and **'SPECTRAL'**. The default value is **['ID'**, **'DEVICE'**, **'LAB'**, **'SPECTRAL']** for **'text'** format and **['DEVICE'**, **'SPECTRAL']** for **'cxf3'** format. If the data described by a field value is missing, that value will be ignored.

The **output_path:** setting controls the location and naming of all saved files. The supported keys are **'path'**, **'prefix'**, **'suffix'**, **'time'** and **'index'**. These keys may also be used by the **export_data:** setting and those values will take precedence over the **output_path:** values for saving the **export_data:** file.

PressCal computes color from spectral data based on the **color:** setting. The file name and location of the exported data is determined by the **output_path:** setting.

Statistical Output

```
# write statistical data to settings folder
stats: {'open' => 'Microsoft Excel'}
# stats: {'Rscript' => '~/Documents/R-Language/test_script.R'}
```

The **stats:** setting enables output of optimization data for statistical analysis. Output is a tab-delimited text file, which may be opened in Excel, R, MATLAB, and many other external programs. The stats file is written in the PressCal settings folder.

The setting value is a hash. Supported hash keys are **'open'**, which opens the stats file in the specified application, and **'Rscript'**, which runs a specified R script, with the stats file path as an argument.

The **output_path:** setting controls the location and naming of all saved files. The supported keys are **'path'**, **'prefix'**, **'suffix'**, **'time'** and **'index'**. These keys may also be used by the **stats:** setting and those values will take precedence over the **output_path:** values for saving the **stats:** file.

Process Control Report

```
# output process control report
process: ~/Desktop/reports # set destination folder
# process: {} # use default settings
# process: {'steps' => [0, 25, 50, 75, 100]} # output using steps
# process: {'desc' => 'RMGT1060ST - House Stock', 'time' => 'unix'}
```

The **process:** setting outputs a process control report for use in the pressroom.

The process control report is a text file containing information taken from the press measurements, with or without curves applied. This information includes **L*a*b*** and **SCTV** values, and with spectral measurements, **density**, **Murray-Davies %-dot**, **TVI** and **print contrast**.

The setting may be the path to a folder or a hash. The hash parameter supports the **'steps'**, **'curves'**, **'status'**, **'desc'**, and **'base'** hash keys.

The **output_path:** setting controls the location and naming of all saved files. The supported keys are **'path'**, **'prefix'**, **'suffix'**, **'time'** and **'index'**. These keys may also be used by the **process:** setting and those values will take precedence over the **output_path:** values for saving the **process:** report.

CED Sample Selection Token(s)

```
# set sample selection token(s) for CED plots
ced_select: rt(10) k nosub
```

The **ced_select:** setting selects samples for CED plots, before and after optimization. It uses the same logic and tokens as the regular **select:** setting. The default setting is to use the optimization selection (as specified by the **select:** setting).

CED Ink Map

```
# set ink map for CED plots
# options are: 0, 1, 2, ... (optimize), S (SCTV), A - F (TVI), N (G7K)
ced_ink_map: [0, 1, 2, 3, S, S]
```

The **ced_ink_map:** setting maps the content of each press measurement ink channel to the reference profile. It only affects the sample selection for CED plots, before and after optimization. It uses the same notation as the regular **ink_map:** setting. This setting is used in conjunction with the **ced_select:** setting. The default setting is to use the optimization ink map (as specified by the **ink_map:** setting).

CED Maximum X-Scale

```
# set maximum x-scale for CED plots
ced_xscalemax: 10
```

The **ced_xscalemax:** setting overrides the maximum x-axis value of the CED plots, which is normally determined from the quantile error data.

L*C*h Solid Ink Colors

```
# set flag to enable printing of L*C*h solid ink colors (0 or 1)
print_LCh: 1
```

The solid ink colors are printed first as L*a*b* values, then as L*C*h values, if the **print_LCh:** setting is true (1). The error values displayed for L*C*h values are ΔCh and ΔH. The default setting is to not print L*C*h colors and errors.

Settings Notation

All settings start with a key that ends with a **:** followed by space and the setting value. TextMate automatically colors the settings green.

Many settings accept a single value – either a text string or a number. Here are examples,

```
press_path: ~~/Data/Test/Endurance_silk_105XL.mxf # a text string
degree: 6 # an integer number
gsf: 0.99 # a floating point number
```

The # character indicates the rest of the line is a comment. Comments are colored blue. If a # is added at the start of a setting line, that setting is disabled or "commented out",

```
# degree: 6
```

Some settings accept an array value, which begins with a **[** and ends with a **]**. An array is a group of values. Here are examples,

```
ink_map: [0, 1, 2, 3, S, S] # CMYK + 2 spot
rendering: [0, 0] # media relative
```

Some settings accept a hash value, which begins with a **{** and ends with a **}**. Here are examples,

```
output_path: {'path' => '~/Desktop/gold_coast_printing/2025-01-09'}
export_data: {'select' => 'all', 'format' => 'text'} # selection and
format
```

A hash contains **key-value pairs**, with the **key** on the left and the **value** on the right, separated by **=>**.

A hash allows the setting to contain multiple parameters. Notice the key and value are enclosed in single quotes. Numbers may be used without quotes.

It is possible to combine arrays and hashes into a structure,

```
color: {'illuminant' => ['~/Desktop/illum.txt', 1], 'cat' => 'cat02'}
# an array value
press_path: [['~/Desktop/cmyk_IT874.txt', 0, 1, 2, 3], ['~/Desktop/
red_spot.txt', 4], ['~/Desktop/blue_spot.txt', 5]] # an array of ar-
rays
```

Note that long settings automatically wrap in TextMate. Don't add a **return** to force a line wrap.

Some settings will accept more than one type of value. For instance, the **press_path:** setting may be a string or an array, as shown above.

Gray Scale Reproduction

Many color experts believe the proper goal of print calibration is the accurate reproduction of gray scales. This idea originated long ago, in the early days of color photoengraving. It was common knowledge among tradesmen, who used gray scales to measure and guide their work.

In 1954, H. Brent Archer presented a TAGA paper titled "Reproduction of Gray with Halftones" in which he quotes the 1953 book "Principles of Color Photography" by Evans, Hanson and Brewer. They state, "*Experience has shown that one of the prime requirements which a color process must fulfill is that it reproduce a scale of neutrals approximately as neutrals.*"

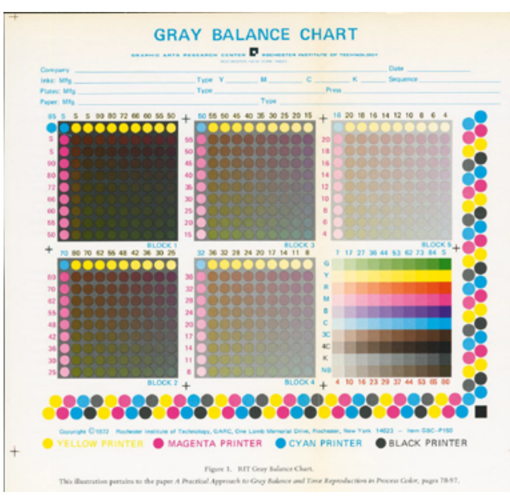
They further state, "*If such deviations occur, (that is, the neutral scale is not produced as neutral), the picture as a whole will appear to have an overcast of the predominant color. ... Owing to the appearance of the overcast of the predominant color when the neutral scale is not properly reproduced, the characteristics of the reproduction of the scale of neutrals has come to be known as color balance. For example, if the scale of neutrals is reproduced with too much magenta, the picture as a whole will appear to have a magenta overcast and the color balance is magenta.*"

TRAND Method

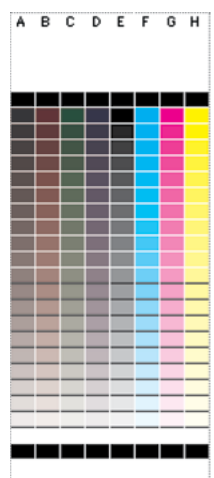
In his 1954 TAGA paper, Archer describes a method to determine the CMY values that produce gray. This work was followed in 1972 with another TAGA paper titled "A Practical Approach to Gray Balance and Tone Reproduction in Process Color." This paper describes RIT's **TRAND** method (**T**one **R**eproduction **A**nd **N**eutral **D**etermination). The TRAND method was used to calibrate drum scanners by means of gradation tables, which contain CMYK output values as a function of gray scale density.

Calibrating Presswork

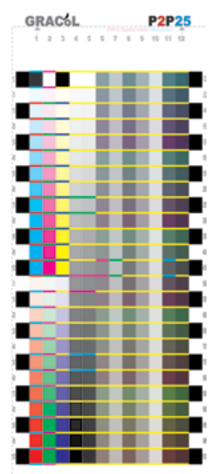
In 2003, the authors adapted the TRAND method to calibrate presswork by means of CtP tone reproduction curves. This is described in our 2004 TAGA paper, "Improving Print Standards by Specifying Isometric Tone Reproduction for the Overall Process." Our work was the basis of the "G7 Methodology", which substituted a prescribed gray scale for the simpler isometric tone scale.



TRAND (1972)



PressCal (2003)



G7 (2007)

International Print Standards

The G7 methodology caused a rift in international print standards when the German delegation to ISO/TC 130 blocked US efforts to incorporate it into ISO print standards.

In 2006, the authors completed a project for the US delegation to ISO/TC 130 to compare the "near-neutral" method (a generic name for the G7 method) to the TVI method, for presentation to the international group. We expected the near-neutral method to prove superior, but that was not the case. Instead, we found the near-neutral results had better gray balance but did not render dark colors as well as the TVI results. We attributed this to ink trapping differences between the reference GRACoL data set and actual printing. By this time, most of the US delegation was "all-in" on the near-neutral method, and our presentation revealing this weakness was not well received.

Gray Scale Table

The table on the next page shows the CMY values used by the G7 method, converted to L*a*b* values using the GRACoL2013_CRPC6 ICC profile, then back to CMYK values using the same ICC profile. You will notice the solid CMY sample has an L*a*b* value of 23, 0, 0. The G7 method prescribes the a* and b* values of this sample to always be 0. However, this is rarely the case for real printing.

Twenty-Six Shades of CMY

In 2006, FOGRA sponsored a contest among German offset printers. The challenge was to print as closely as possible to the newly adopted ISO 12647-2 standard. Below is a table of the CMY solid colors from 26 different contest entries.

ID	L*	a*	b*	ID	L*	a*	b*
01011901AK	24.26	-4.63	-0.40	19111990MR	22.56	14.14	-5.85
01011963SI	22.29	-5.37	-2.14	20012003CC	24.77	-7.63	1.74
01031991EL	20.85	-0.97	2.85	20031727IN	20.80	-1.18	1.89
04011961ES	22.82	-2.48	1.60	20121985FG	20.53	-1.93	-1.43
04041932WO	19.74	1.15	-3.61	22061985GW	19.44	6.11	4.01
05051892AH	24.13	-5.30	-8.24	24021964FM	24.10	-1.51	2.45
09031998DM	21.56	5.10	1.74	25041985DN	24.37	-2.41	0.48
11071969AK	23.50	-1.01	-1.37	26011918EH	23.83	8.94	7.09
12122004FB	25.66	-3.48	0.55	26091877HG	23.12	-3.16	-3.74
13021957GM	20.83	-0.92	-1.14	27051967JI	25.61	-5.93	0.20
14071907WP	25.29	15.01	-2.02	28061918AM	25.79	12.58	8.09
15121985WS	25.73	-9.17	2.78	30061919JR	24.21	4.14	-0.47
17041945RL	21.91	0.09	-1.92	30121928JK	21.13	2.61	-7.57

As you can see, there is great variation, and only a few measurements are close to neutral. Keep in mind, these are not just random press sheets – they are the best efforts of German pressmen to match the ISO 12647-2 standard.

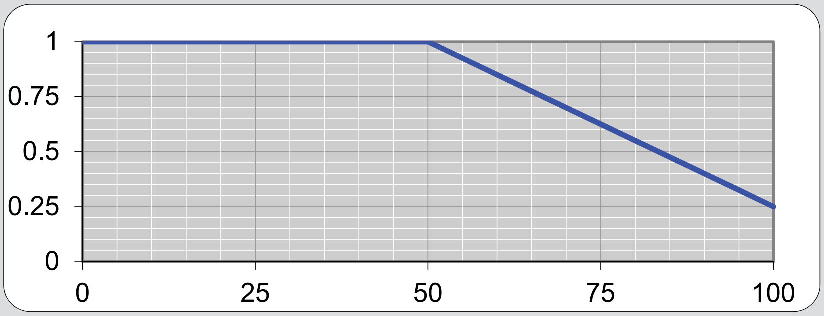
Gray Samples Round-Trip Table (CMYK ➔ GRACoL2013 L*a*b* ➔ CMYK)

C	M	Y	K	L*	a*	b*	C	M	Y	K
0	0	0	0	95.0	1.0	-4.0	0.0	0.0	0.0	0.0
2	1.5	1.5	0	93.3	1.2	-3.8	2.0	1.5	1.5	0.0
4	3	3	0	91.7	1.3	-3.7	4.0	2.9	3.0	0.0
6	4.5	4.5	0	90.1	1.2	-3.6	6.0	4.4	4.5	0.0
8	6	6	0	88.5	1.1	-3.5	8.0	5.9	6.0	0.0
10	7.5	7.5	0	86.9	1.1	-3.5	10.0	7.4	7.5	0.0
15	11.2	11.2	0	83.0	0.9	-3.2	15.0	11.2	11.2	0.0
20	15	15	0	79.1	0.8	-3.1	20.0	15.0	15.0	0.0
25	18.9	18.9	0	75.4	0.8	-2.9	24.8	18.7	18.7	0.3
30	22.8	22.8	0	71.8	0.7	-2.7	29.0	22.0	22.1	1.3
35	26.9	26.9	0	68.2	0.6	-2.6	32.7	25.1	25.2	2.9
40	31.1	31.1	0	64.6	0.6	-2.3	36.2	28.0	28.1	5.3
45	35.5	35.5	0	61.0	0.5	-2.2	39.4	30.8	30.9	8.0
50	40	40	0	57.5	0.4	-2.1	42.5	33.5	33.7	11.2
55	44.7	44.7	0	53.9	0.3	-1.9	45.6	36.3	36.5	14.7
60	49.7	49.7	0	50.3	0.2	-1.8	48.6	39.2	39.5	18.5
65	54.9	54.9	0	46.6	0.2	-1.5	51.7	42.4	42.8	22.7
70	60.4	60.4	0	43.0	0.3	-1.1	54.8	45.6	46.2	27.1
75	66.1	66.1	0	39.3	0.3	-0.7	57.7	48.8	49.6	32.3
80	72.2	72.2	0	35.7	0.3	-0.3	60.4	51.7	52.8	38.5
85	78.6	78.6	0	32.2	0.3	0.0	62.7	54.6	55.7	45.3
90	85.3	85.3	0	28.8	0.4	0.2	64.8	57.3	58.4	52.4
95	92.5	92.5	0	25.6	0.0	0.0	67.5	59.4	60.5	59.5
98	96.9	96.9	0	23.9	0.0	-0.0	68.9	60.8	61.6	63.5
100	100	100	0	23.0	0.0	-0.0	69.5	61.5	62.3	65.7
				20.0	0.0	0.0	71.6	63.9	64.1	73.0
				17.0	0.0	0.0	73.3	65.9	65.0	80.6
				14.0	0.0	0.0	75.3	68.2	65.4	88.4
				11.0	0.0	0.0	78.2	70.8	64.5	96.1

(The text is continued on the next page.)

Weighting Function

This real-world variation is acknowledged in the document "G7® Master Pass/Fail Requirements For the G7 Master Program." In section 4.0 of this document, a weighting function is introduced to reduce the significance of color errors in the darker end of the gray scale. Here is a graph of this function and an explanation of its purpose.



[8] Where $\Delta C_h = \sqrt{(a_{sample} - a_{target})^2 + (b_{sample} - b_{target})^2}$; and;

$$w\Delta C_h = \Delta C_h * (1 - \max\left(0, \frac{c\% - 50}{50} * 0.75\right))$$

The $w\Delta C_h$ formula is similar to the $w\Delta L^*$ function, reducing the significance of the ΔC_h measurement above a cyan percentage (c%) value of 50% on a linear scale beginning at 100% significance when c% = 0 through 50 and terminating at 25% significance when c% = 100. The goal of the weighting function is to minimize the significance of hard-to-control gray balance errors in very dark CMY grays that are usually covered by black ink.
$W\Delta C_h$ can be calculated using various software solutions available in the marketplace.

The weighting function has a value of 0.25 for the CMY solid, which means this sample may have a chroma of 12, and still be considered passing.

When the CMY solid is not neutral, the resulting curves will be distorted, causing dark colors to be reproduced incorrectly. To counter this problem, the widely used "Curve" software has a setting called "Gray correction feather-off", which reduces gray balance correction in the darker end of the gray scale, corresponding to the pass/fail weighting function. PressCal has a comparable setting called "gray balance fade." While these settings will smooth out wonky tone curves, they are a Band-Aid, and not a cure, for a fundamental flaw.

Fundamental Flaw

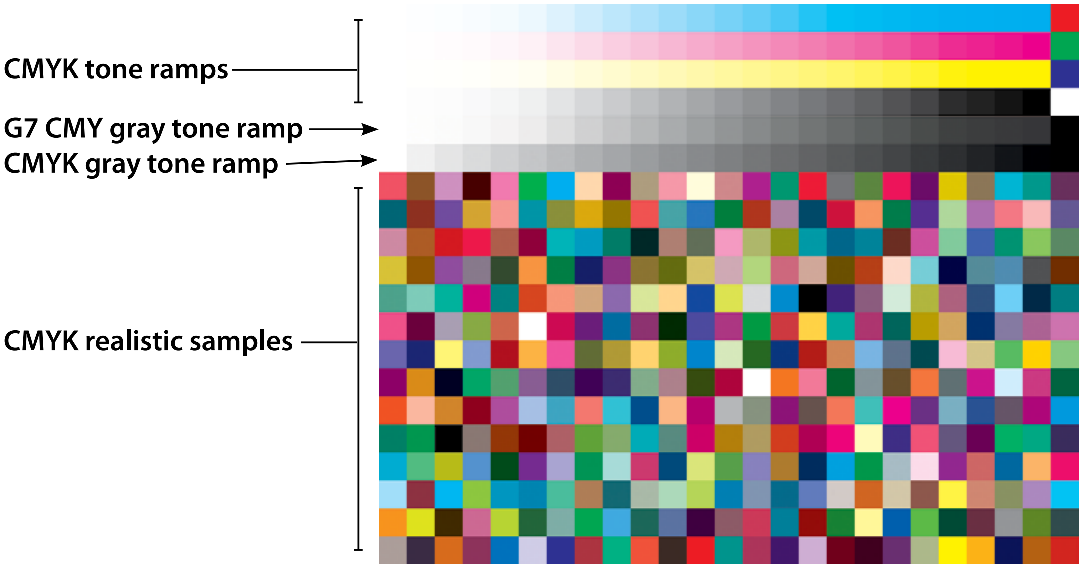
The flaw is that the darker end of the G7 CMY gray scale doesn't represent grays in an actual CMYK printing process. Returning to the gray scale table on the previous page, you will see how the darker CMYK values (right-hand side) contain significant amounts of black, as UCR/GCR reduces the CMY values. So, the near-neutral method is based on samples that will never appear in real images, which leads to unpredictable results, especially when the CMY solid strays from neutral.

Realistic Samples

Unlike other calibration methods, the Optimal method works with any sample set. So, you may replace these false CMY gray samples with realistic ones. The CMYK gray samples on the right-hand side of this table qualify, as they represent the true gray scale, with UCR/GCR and black. But none of these samples have CMY values in the shadow region. So, we need additional samples to properly define the shadow end of the CMY curves. We believe the best sample set contains a full assortment of grays and colors, generated by your reference profile. We call these "realistic" samples, since they may appear in real images.

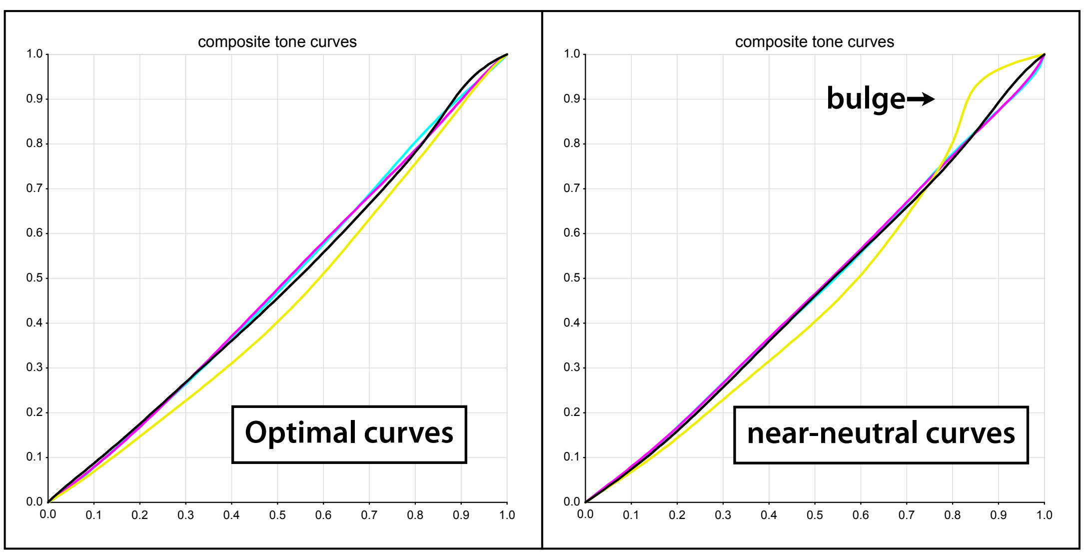
PressCal Test Chart

The PressCalC6TS test chart contains realistic samples from the GRACoL2013_CRPC6 profile, along with G7 gray samples.



Optimal vs Near-Neutral Curves

Using a data set made from this chart, we can compare the Optimal and near-neutral methods. Here are composite tone curves. The Optimal curves are on the left, and the near-neutral curves on the right.

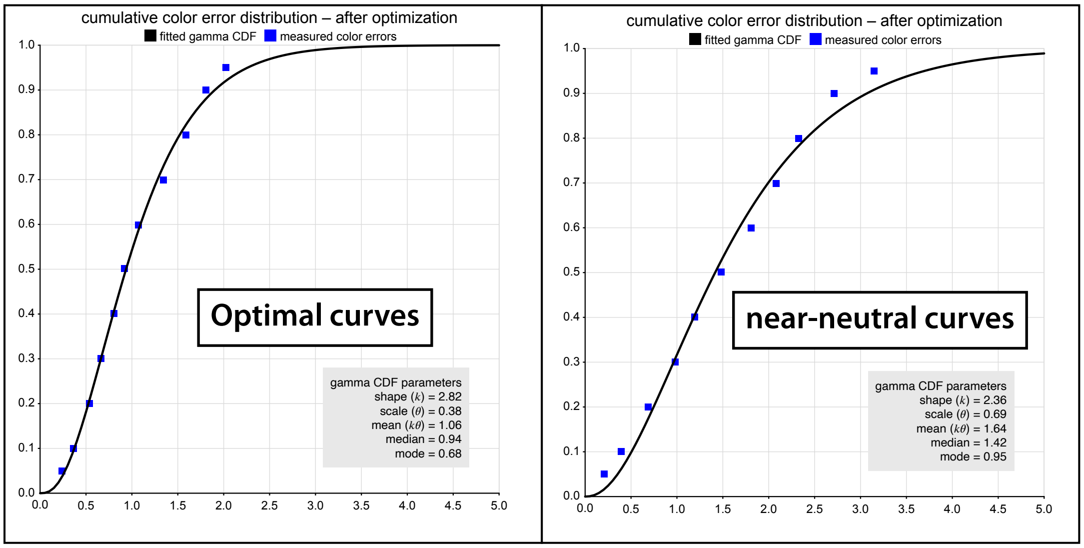


The curves are quite similar from 0% to 50% tone value. Above 50%, the yellow near-neutral curve begins to veer upward, and then flattens out, creating an odd bulge. This bulge is caused by the CMY overprint color (L*a*b* 24.2, 0.3, -4.2), which is well within the G7 chroma limit of 12. The yellow curve is trying to make this patch neutral, but is pinned at 100%, causing the bulge.

The darker gray CMY samples causing this distortion are not used to compute Optimal curves. Instead, many colored samples containing darker CMY values are used. These are realistic colors that will appear in images made with the GRACoL2013_CRPC6 profile. The shadow end of the Optimal curves will render these colors correctly.

Residual Color Errors

Here are the cumulative error distribution graphs, after the curves are applied. The Optimal errors are on the left, and the near-neutral errors on the right.



The median residual color error for the Optimal method is 0.94 ΔE_{00}, while the error for the near-neutral method is 1.42 ΔE_{00}. A lower value indicates a better match to the reference profile.

Good Properties of Optimal Curves

We like to say that Optimal curves have the good properties of near-neutral curves in the highlights, combined with the good properties of TVI/SCTV curves in the shadows. Because they are computed to have the lowest possible residual error, they will give the best visual match to the reference profile. With CRPC reference profiles, press sheets made using Optimal curves will generally pass G7 certification, thanks to the pass/fail weight function.

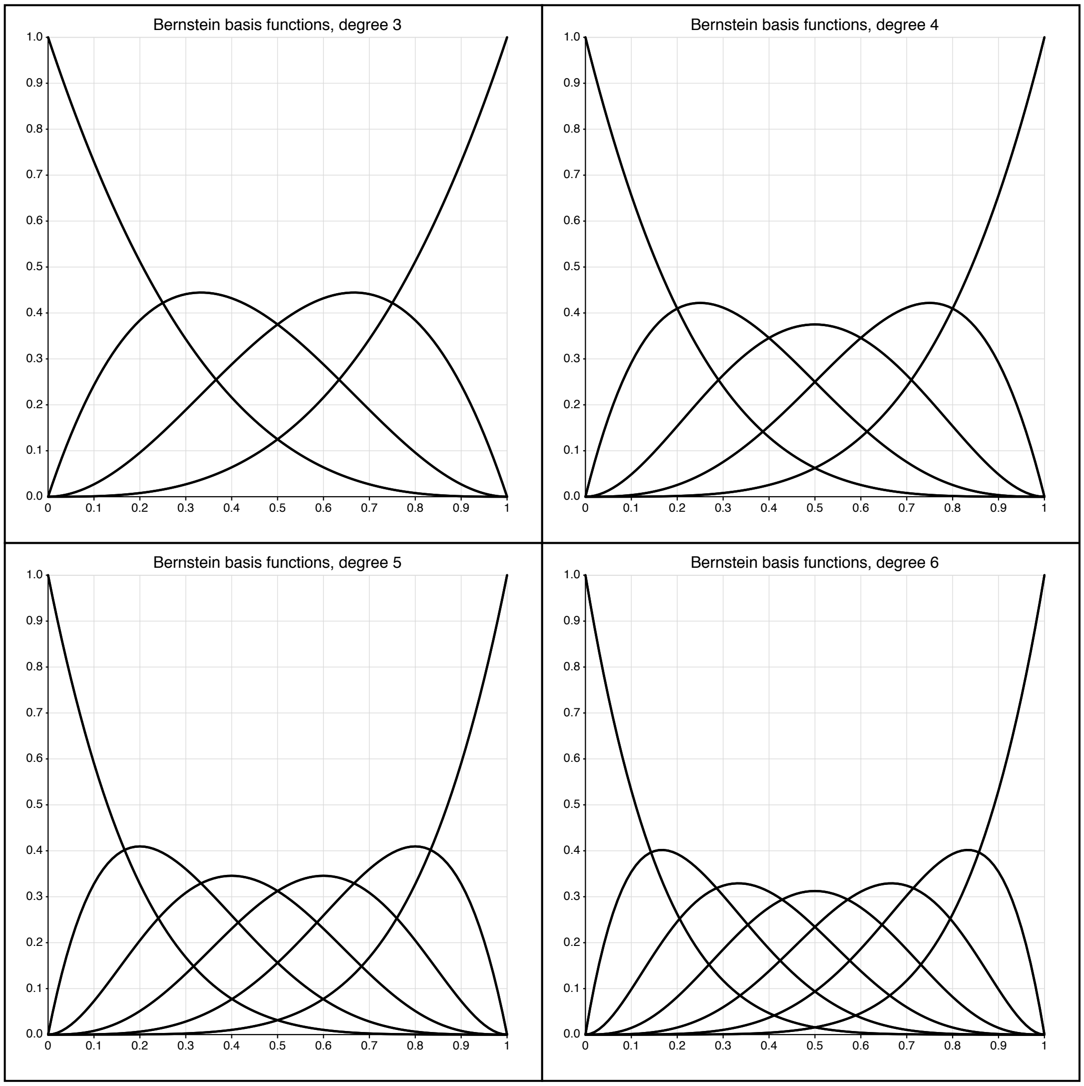
In conclusion, we agree that a good calibration will reproduce grays correctly. But that alone does not guarantee a good overall result. By using a full range of realistic samples, both grays and colors, the Optimal method achieves the best possible color match. It also provides flexibility to match any printing process, with any number of inks, and any gray balance.

Parametric Curves

PressCal curves are mathematical functions known as **Bernstein polynomials**. These functions have a property called the **degree**, which is an integer number controlling the possible complexity of the curves. We'll leave the details to the mathematicians, and try to explain this visually.

Bernstein Basis Functions

Bernstein polynomials are weighted combinations of **Bernstein basis functions**. For each degree **n** (1, 2, 3, etc.) there is a set of **n + 1** basis functions. Here are graphs of Bernstein basis functions, degrees 3, 4, 5, and 6.

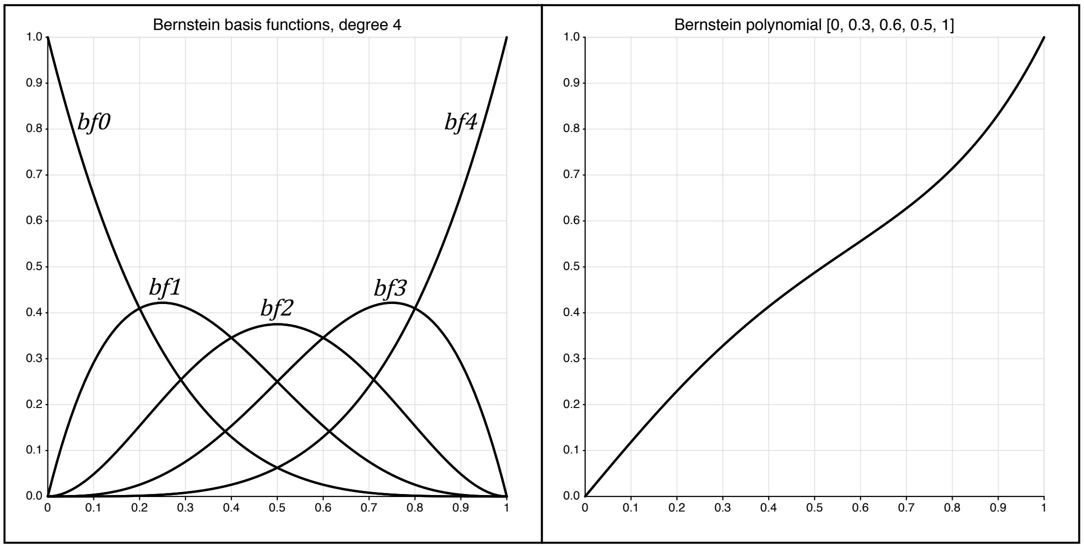


The **`degree:`** setting selects the set of basis functions used by PressCal. Each function dominates its own region of the curve. The number of basis functions limits the detail that can be rendered by the curves, a property we call complexity.

Bernstein Polynomials

PressCal curves are a weighted combination of these Bernstein basis functions, known mathematically as a polynomial. The weights are known as coefficients. Despite the math talk, this is a really simple idea. Each basis function is multiplied by its weight (coefficient), then these weighted functions are added together to form the curve. For example, the curve [0, 0.3, 0.6, 0.5, 1] and its basis functions are shown below. The numbers inside the brackets are the polynomial coefficients. We know this curve has a degree of 4, since there are 5 coefficients (weights). The curve function (*f*) is the sum of the basis functions (*bf0 - bf4*), multiplied by their coefficients:

$$f = 0 \times bf0 + 0.3 \times bf1 + 0.6 \times bf2 + 0.5 \times bf3 + 1 \times bf4$$



Parametric Curves

We call these parametric curves because they are completely described by their coefficients (parameters). You could also call them vector curves. They are perfectly smooth, and can be computed exactly at any level of resolution.

Optimization

When we compute curves by optimization, we are adjusting their parameters to minimize color errors. When the optimization is complete, PressCal displays the final parameters. In the example below, the curves are degree 4, so there are 5 parameters. The first parameter is labeled HLV which stands for highlight value. Likewise, the last

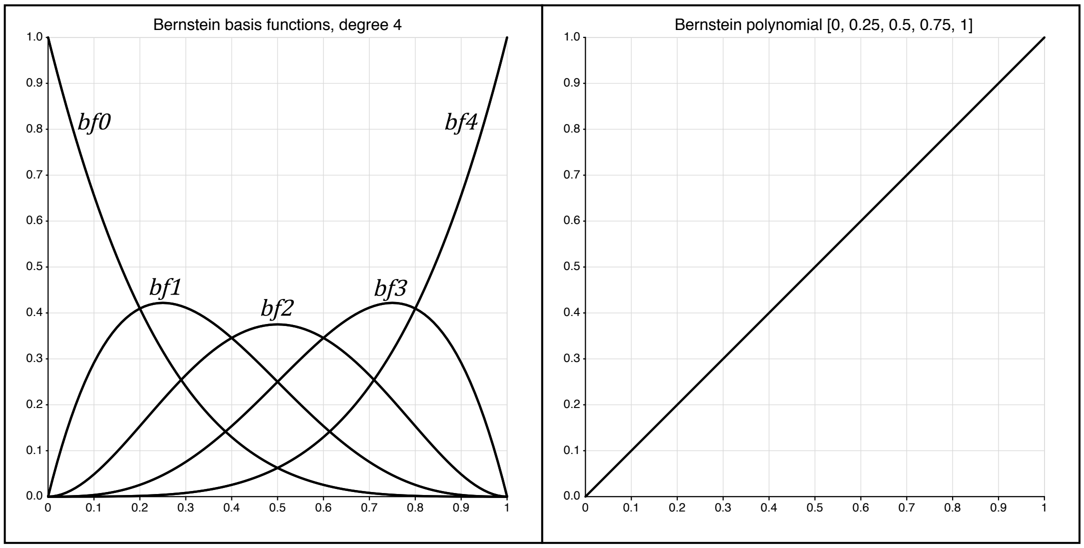
```
curve parameters:

            HLV    1/4    2/4    3/4    SHV
   cyan    0.000  0.390  0.520  0.812  1.000
magenta    0.000  0.414  0.611  0.812  1.000
 yellow    0.000  0.411  0.608  0.902  1.000
  black    0.000  0.393  0.744  0.832  1.000

writing curves in 'text'       format to /Users/wbirkett/Desktop/tab_delim.txt

Program exited with code #0 after 8.47 seconds.
```

parameter is labeled SHV for shadow value. These two parameters are also the end-point values of the curve. Keep in mind that **these curves are the inverse of the final tone curves** (see the flowchart).

Identity (Linear) Curves

If the parameters are equally spaced from 0 to 1, the resulting curve is perfectly linear, connecting the corner points (0, 0) to (1, 1). We call this the identity function. This is true for curves of any degree. PressCal curves are linear before optimization.

$$f = 0 \text{ x } bf0 \; + \; 1/4 \text{ x } bf1 \; + \; 2/4 \text{ x } bf2 \; + \; 3/4 \text{ x } bf3 \; + \; 1 \text{ x } bf4$$



Maximum Degree

The maximum degree of the curves is determined by the sample set. There needs to be sufficient information in the samples to clearly define the coefficients for each basis function. By default, the degree is set automatically by the software using appropriate (and complex) math. You can override this value manually. Decreasing the degree will produce smoother curves with larger color errors. But, increasing the degree beyond the software determined value is not recommended.

Technical Notes

PressCal software runs on modern **Macs**. This section covers some technical details of the software and hardware.

macOS and Perl Versions

PressCal is written in the **Perl** programming language, which is built into macOS. PressCal adds C-language extensions which only work with a particular version of Perl. Here is a table of macOS releases and the built-in Perl version(s).

macOS	Perl version(s)
Big Sur	5.18, 5.30
Monterey	5.18, 5.30
Ventura	5.30, 5.34
Sonoma	5.30, 5.34
Sequoia	5.34
Tahoe	5.34

Currently, there are two versions of PressCal – version **17UV** works with P**erl 5.30**, and version **17US** works with **Perl 5.34**. The XML::LibXML modules are missing for Perl 5.34 on Ventura. So, we use PressCal version **17UV** for **Big Sur** through **Ventura**, and version **17US** for **Sonoma** through **Tahoe**.

ARM and Intel Processors

In November, 2020, Apple introduced Mac computers with **ARM** processors, replacing the **Intel** processors used previously. At the time, most Mac software was written for Intel processors, so Apple provided **Rosetta 2**, to translate Intel programs into ARM code.

Universal Programs

To ease the processor transition, Apple added support for universal programs, which contain both Intel and ARM code. PressCal's extensions are now universal, compiled as **x86_64** and **arm64e** architectures. If you're using a newer Mac with an Apple processor, the arm64e code is used, otherwise the x86_64 code is used. When you run PressCal, a tiny text string is displayed in the upper right corner of the log indicating the Perl version and architecture, e.g., Perl v5.30, arm64e.

TextMate and Rosetta

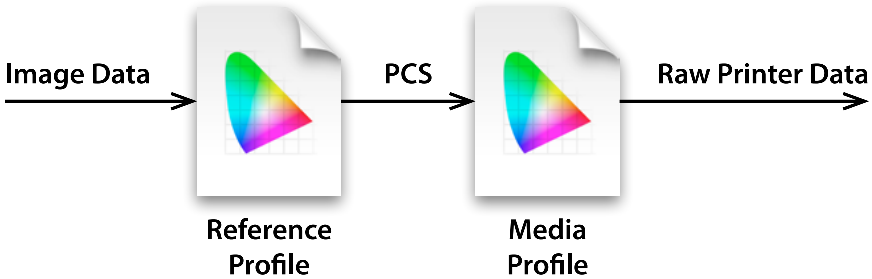
TextMate is a universal program, but uses an Intel version of the Ruby programming language. If Rosetta 2 isn't yet installed, you will get an error message when running PressCal. If this happens, open the TextMate **Get Info** window and check the **Open with Rosetta** box. Then run TextMate again. This will install Rosetta 2. You can then uncheck the **Open with Rosetta** box.

Calibrating Color-Managed Processes

PressCal may be used to calibrate color-managed printing and proofing processes. In conventional printing, curves are applied in the platemaking step by the DFE. But, digital presses, wide format printers, and proofers may lack the capability to utilize tone curves. For these processes, the **`adjust_profile_path:`** setting and function provide a solution by applying the curves to an ICC printer profile.

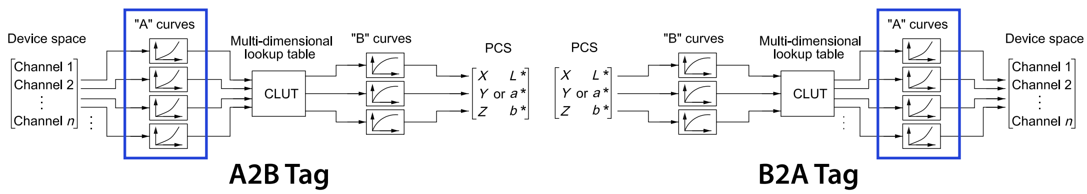
Modifying ICC Profiles

In its most basic configuration, a color-managed device employs a **reference profile** and a **media profile**, connected to form a chain, as in this illustration,



The **image data** is converted to the **PCS** (profile connection space), using the reference profile, then to **raw printer data**, using the media profile. The reference profile is typically a standard working space, such as GRACoL2013 or FOGRA51. The media profile represents the characteristics of the printer/media combination.

Internally, printer profiles contain six color transform tags – A2B0, A2B1, A2B2, B2A0, B2A1, and B2A2. The **A2B** tags transform device values (e.g., **RGB**, **CMYK**) to PCS values (e.g., XYZ, L*a*b*). The **B2A** tags do the opposite, transforming PCS values to device values. The last digit of the tag ID indicates the rendering intent – 0 is perceptual, 1 is colorimetric, and 2 is saturation. These tags contain curve elements ("A" curves) that transform the device values.



PressCal combines its curves with these curve elements to create a modified profile. The **A2B** tags of a **reference profile** or the **B2A** tags of a **media profile** are modified. This is done for all three rendering intents (perceptual, colorimetric, and saturation).

Printer profiles also contain a **media white point** tag, used to compute absolute color rendering. If the media color drifts (e.g., a new lot of material), color errors are introduced. PressCal will optionally update the media white point tag to the media color of the press measurements.

Media Profiles

If your printer drifts out of calibration, it is most likely due to changes in materials (media or inks), environment, or perhaps the printer itself, such as cleaning or replacing a print head. These changes can be countered by modifying the media profile. The **`adjust_profile_path:`** setting and function are configured to do this by default.

The procedure is similar to making a new media profile, in that a test chart is printed with **color management turned off**. The test chart is typically a control strip or media wedge, such as the **IDEAlliance ISO 12647-7 control wedge**, or the **UGRA/FOGRA media wedge**. These charts contain sufficient information, and are easy to print and measure. They are commonly used to verify proofs.

The Basic Settings file, **PressCal_Media_Profile.yml**, provides a template for adjusting your media profiles. The start of that file is shown below.

PressCal_Media_Profile.yml — PressCal_Basic_Settings

PressCal_Media_Profile.yml

```
# settings to calibrate a media profile

# see 'Calibrating Color-Managed Processes' section of the user manual

# set path to media profile
profile_path: ~/Data/Test/P9000_CMYK.icc

# set path to press measurement file -or- folder
# note: test chart must be printed with color management turned off!!
press_path: ~/Data/Test/ISO_12647-7_control_wedge_2013_NCMA.mxf

# set ink map, an array indicating how each tone curve is derived
# options are: 0, 1, 2, ... (optimize), S (SCTV), A - F (TVI), N (G7K), L (linear)
# ink_map: [0, 1, 2, 3, S, S]

# set measurement condition (M0, M1, M2, M3, 0 - 1 (OBA effect), auto)
# note: should be the same as the original media profile measurements
condition: M0

```

The **`profile_path:`** setting is the path to your media profile. We recommend you copy the profile to a safe, convenient folder, and use that path, so the adjusted profile may be written directly to your RIP. PressCal will not overwrite the profile selected by this setting.

The **`press_path:`** setting is the path to your measurements. Remember to print the test chart with **color management turned off**. The measurements should be made with the same measurement condition (M0, M1, M2) as the media profile.

Use the **`condition:`** setting to select the measurement condition from CxF3 format files (e.g., .mxf or .rmxf suffix).

```

# set sample selection token(s) (see user manual for options)
select: all sort(error)

# set curve output token(s) (see user manual for options)
output: text

# set gamut scale factor (comment out to optimize)
gsf: 1

# set shadow endpoints (unpin)
# shadow: [undef, undef, undef, undef]

# set Bernstein polynomial degree (comment out for auto-select)
# degree: 6

```

The **`select:`** setting is all samples in the control wedge. The magic of the [Optimal method]() is to construct perfect correction curves from the small errors of each sample. The **`gsf: 1`** setting disables black point compensation. The **`shadow:`** setting could be used to unpin the endpoints, without much risk of clipping, since the gamut of the media profile is larger than the reference profile.

Making Modified Profiles

When you press the ⌘**R** key combination, PressCal will generate calibration curves, per the settings on the previous page. The **`adjust_profile_path:`** setting causes these curves to be applied to the media profile, and the modified profile written to the location (path) specified by the setting.

```
# set adjust profile path — apply curves to the reference profile, equivalent to adding curves after
  color management
adjust_profile_path: {'path' => '~/Desktop/profiles', 'base' => 'P9000_CMYK_adjusted.icc', 'time' =>
'unix', 'A2B' => 0, 'B2A' => -1}
```

In the example above, that location is **~/Desktop/profiles**, which is a folder designated by the **`'path'`** key. When you run PressCal (⌘**R**) with these settings, a profile named like this, **P9000_CMYK_adjusted_1743430373.icc**, will appear in this folder. The 10-digit number is the Unix time when the profile was created. You will need to locate and select this modified profile in your printing software.

You can simplify these steps by setting **`'path'`** value to the location where media profiles are kept by your RIP software. When PressCal is run, the modified profile will be saved there. As a precaution, PressCal will not overwrite the profile selected by the **`profile_path:`** setting. It may be necessary to share the RIP's media profile folder, and make that folder writable.

Calibrating vs. Profiling

The steps for calibrating a media profile are similar to making a new one. Calibration is quick and simple, but color accuracy might not be as good as a new media profile. If your color has drifted, we suggest you try calibration first. If the residual color errors are too large, make a new media profile. These residual color errors are displayed in the PressCal log,

```
75    0.400  0.100  0.400  0.000    73.4  -24.7   11.6    73.7  -23.6   10.5    0.80
62    0.750  0.661  0.661  0.000    33.5   -3.7   -4.4    32.8   -4.1   -4.1    0.81
35    1.000  0.000  1.000  0.000    37.7  -74.1   29.0    38.1  -71.3   29.3    0.84
45    0.700  0.000  0.400  0.400    47.0  -37.9    1.0    46.5  -36.7   -0.1    0.97
64    0.000  0.000  0.000  0.900    28.4   -0.3    7.4    29.5   -0.3    6.6    1.07
81    1.000  0.000  0.400  0.000    45.1  -59.9  -27.3    45.2  -56.7  -27.8    1.14
69    0.700  0.400  0.700  0.000    45.8  -27.4   12.5    45.9  -24.2   11.5    1.53
38    0.750  0.000  0.750  0.000    58.2  -59.6   25.3    58.4  -54.6   22.3    1.57

                                             optimized average error:   0.45
```

Keep in mind these errors include measurement and spatial variations, so the average error will have a minimum value, depending on the printing process. In this example, the average error is less than 0.5, which is considered good for an ink jet printer. You should also check the individual color errors.

This calibration procedure can be done quickly, especially when the modified profiles are written directly to the RIP. It is simple enough that production operators can be trained to do it, which could minimize downtime and waste. If your RIP software has generic profiles, you may be able to get custom-profiled results with just calibration.

Electrophotographic printing is notorious for environmental variation. Media profile calibration makes it practical to stabilize these processes, and adapt them for different paper stocks.

Advanced Setting Syntax

The **`adjust_profile_path:`** setting supports using a hash for advanced options. Here is an example,

```
adjust_profile_path: {'path' => '~/Clients/ABC_Printing'}
```

A hash begins with { and ends with }. The settings are key-value pairs, and the text elements are single-quoted. In this example, the key is **`'path'`** and the value is **`'~/Clients/ABC_Printing'`**. This is equivalent to this notation,

```
adjust_profile_path: ~/Clients/ABC_Printing
```

The other supported keys are **`'wtpt'`**, **`'desc'`**, **`'A2B'`**, **`'B2A'`** and **`'origin'`**. These are explained here.

Reference Profiles

To calibrate a reference profile, use the advanced setting syntax to select the **A2B** tags, and disable updating the media white point,

```
adjust_profile_path: {'A2B' => 1, 'B2A' => 0, 'wtpt' => 0}
```

The test chart should be printed normally, with **color management turned on**. Be sure to name modified reference profiles so they won't be confused with the originals.

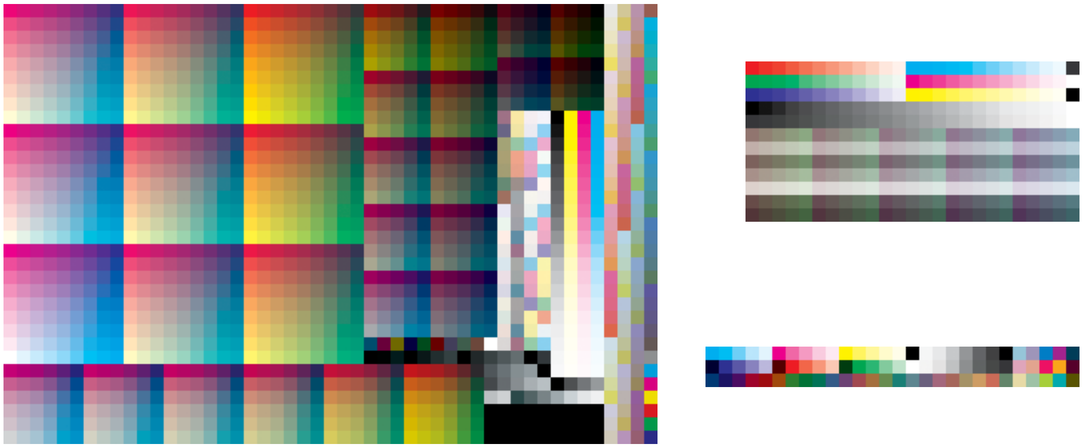
Modified reference profiles are equivalent to applying the curves at the start of the color management chain. If you cannot change the media profiles, this may be your only option. However, reference profiles are normally considered invariant, and we are uneasy modifying them. The capability is there, and it works correctly, but things could go wrong. Use with care.

RGB and Multicolor Processes

PressCal will also calibrate **RGB** and **CMYK+N** (multicolor) processes. You will need a control strip with the correct number of channels, and sufficient samples to characterize the printing process. FOGRA offers multicolor versions of their media wedge. Another option is to use the **PressCal_realistic_n-color_charts.plx** utility from our ECG Tools.

Test Charts

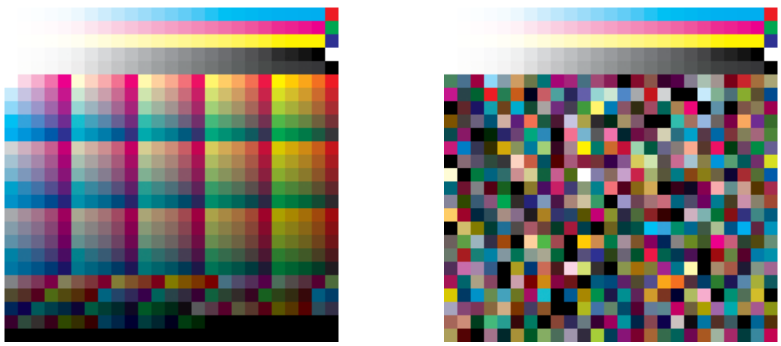
PressCal can build curves from any test chart. This includes charts designed to make profiles, curves, and even those for verifying proofs.



Of course, a test chart might not contain the ideal sample set. If possible, you should consider using one of the PressCal charts, below. These charts have been engineered for specific purposes and circumstances.

PressCalP

The PressCalP test chart is meant **for making curves and/or ICC profiles.**



The first four rows contain process color ramps. The fifth row contains a "gray" **CMY** ramp. Rows 6 - 25 contain a subset of the IT8.7/4 test chart.

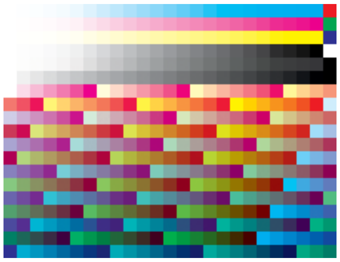
PressCalC6

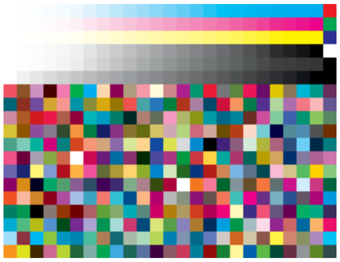
The PressCalC6 test chart is meant **for making curves (US).**

The first five rows are identical to the PressCalP test chart. Rows 6 - 20 contain a gray axis ramp and a 7x7x7 array of **CMYK** values generated from the **GRACoL2013_ CRPC6.icc** reference profile.

PressCalF51

The PressCalF51 test chart is meant **for making curves (Europe).**





The first five rows are identical to the PressCalP test chart. Rows 6 - 20 contain a gray axis ramp and a 7x7x7 array of **CMYK** values generated from the **PSOcoated_v3.icc** reference profile.

Tone Ramps

The process color tone ramps in the PressCalP, PressCalC6, and PressCalF51 test charts are identical. The step values are 8-bit binary fractions, to avoid round-off errors in the DFE. There are 24 steps. Here is the tone progression (0 - 1):

```
0, 1/255, 2/255, 4/255, 8/255, 15/255, 30/255, 45/255, ...
210/255, 225/255, 240/255, 245/255, 250/255, 1
```

You will notice the steps in the highlight and shadow regions are more closely spaced. These steps allow us to **determine highlight and shadow dot retention**, which is an important issue in flexography, and sometimes in offset.

The gray ramp (row 5) has the same cyan step values as the process color ramps. The magenta and yellow values are computed using the TR 015 (G7) gray formula.

ICC Profiling Array

The PressCalP test chart contains a 500 sample subset of the IT8.7/4 test chart. This test chart will produce good press profiles. For a simple **CMYK** process, there is little benefit from a larger test chart. You should enable smoothing in your profiling app to suppress ink variations. i1Profiler has a smoothing slider, which should be set to 100%.

Realistic Colors Array

The 7x7x7 **CMYK** array in the PressCalC6 and PressCalF51 test charts contains equally spaced **CMYK** samples of the entire print gamut. The gray axis ramp contains 25 equally spaced **CMYK** samples from paper white to the darkest black. The **CMYK** values are derived from a reference profile, GRACoL2013_CRPC6.icc for the US, and PSOcoated_v3.icc for Europe.

We call these "realistic colors" because they're the ones you're likely to print, if the **CMYK** images were converted using that ICC profile. These samples will generally contain some black, as determined by the black generation built into the ICC profile. The %-dot values in the 7x7x7 array align with the degree 6 Bernstein basis functions. We recommend building curves with this sample set, if possible.

Dithered Patches

Because most DFEs process color as 8-bit values, our test charts are created as 8-bit TIFFs. When the %-dot value cannot be represented exactly as an 8-bit value, we dither that patch. A dithered patch is composed of pixels greater and less than the desired value, to produce that value, on average. In theory, dithering improves the accuracy of measurements. These raw TIFF files are supplied, along with PDF versions. The PDF versions were built using InDesign, with the TIFFs as placed images.

Shuffled Charts

You will notice there are two versions of each PressCal chart illustrated. The samples in rows 7 and up are shuffled in the right-hand chart. They are the same samples, just arranged differently. Sometimes these are called *random* charts. The reason for shuffling the samples is to distribute the inking variation over the entire color gamut. The least squares optimization used by PressCal will effectively suppress these variations, and produce accurate curves for the underlying process.

The tone ramp samples in rows 1 - 5 are not shuffled. This preserves monotonicity of the tone ramp data. Test charts should be oriented so the tone ramps wrap around the cylinder.

Naming Convention

Each chart has four variations, which are distinguished by letters appended to the name. A test chart name may end with **T** and/or **S** (e.g. PressCalC6**TS**). **T** stands for transposed; **S** stands for shuffled. The charts illustrated in this section are the transposed versions.

Sample Selection

Samples may be selected by device values, color, or location, using sample selection tokens. If you want to match proofs, we recommend you choose realistic samples. For PressCalC6 or PressCalF51, use **`rows(4, 6 .. 20)`** or **`cols(4, 6 .. 20)`**, depending on the chart rotation. For PressCalP use **`rt(10) k`**.

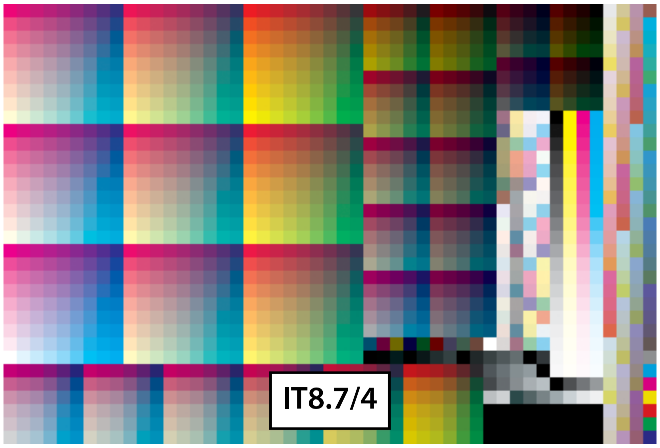
Curve types **A** - **F** (TVI), **S** (SCTV), and **N** (NPDC) do not require a sample selection. The samples are selected automatically as each curve is computed.

Abbreviated Measurements

Abbreviated measurement references are provided for the PressCalC6, PressCalF51 and PressCalP charts. These references measure the first few rows of the chart, which are sufficient for the grading and ink balance functions. This saves time, which is important when adjusting ink balance. The abbreviated references have an 'A' in their name, e.g. PressCalC6TA_i1iO_3.txf. The i1iO charts have the first and second corner points marked with thin black lines.

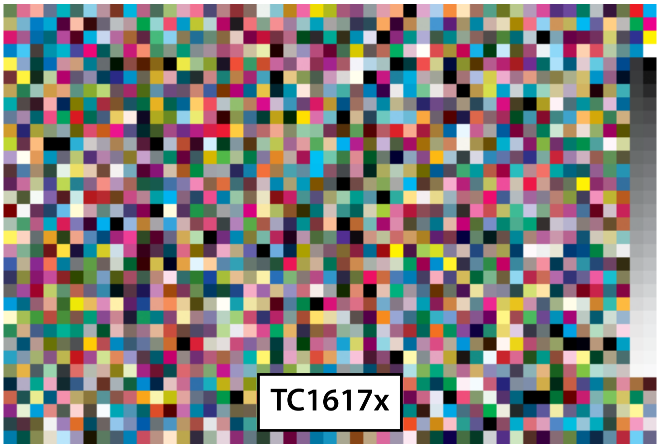
ICC Profiles

A full range of color samples are needed to make an ICC profile. Charts designed for making curves, such as the **P2P51** and **PressCalC6**, lack needed samples. The **IT8.7/4** test chart has 1617 patches, and is widely used for **CMYK** profiling. For non-digital printing processes, such as offset and flexo, good results are obtained with test charts having 400 - 600 patches, such as the **TC3.5**.



Hybrid Charts

IDEAlliance developed a hybrid test chart, the **TC1617x** (ANSI CGATS **IT8.7/5**), which combines the IT8.7/4 samples with the G7 gray samples. The **PressCalP** is our hybrid chart, carefully designed for press curves and profiles.



Single Press Run

If you're building tone curves, and wish to make an ICC profile of the curved printing process, you would normally make the curves first, then a new set of curved plates to print the profiling chart. With PressCal, this second press run is unnecessary. There is an option to apply the tone curves to your profiling chart measurements.

The **`adjust_path:`** setting selects these measurements. The adjusted measurements are saved on the desktop in a file named **curve_adj_press.txt** or **curve_adj_press.mxf**, depending on the format you supplied. Note, the **CMYK** %-dot values are adjusted, not the color values.

Custom Grading

The tests and limits used by PressCal's grade tool are accessed from a database, using keys derived from the settings. For instance, the ISO 12647-7 standard is selected using the **`12647-7:`** (version) and **`12647-7_level:`** (level) settings. Many commonly used grading standards are contained in this database.

Nevertheless, you may wish to use your own custom grading rules. The **`grade:`** setting makes this possible. The value for this setting is a Perl hash, supplied as a text string in serialized format. This format, while familiar to Perl programmers, is somewhat daunting. So, we've added a utility to dump the grading database, with the idea that an existing **`grade:`** hash would serve as a starting point. With a basic setting file (YAML) opened in TextMate, enter the ⌘K key combination. A log window will open listing all of the grade entries contained in the database.

Running "Dump Grade Database"...

```
12647-2/2004
grade: {'cmy_ramp' => [[0, 'dLCh', '1.5', '1.5'], [0, 'dLCh', 3, 3], 21], 'substrate' => [[1, 'dLab',
3, 2, 2], 17], 'cmyk_solids2' => [[1, 'dH', '2.5'], [1, 'dH', '2.5'], [1, 'dH', '2.5'], 19],
'cmyk_solids' => [[1, 'dEab', 5], [1, 'dEab', 5], [1, 'dEab', 5], [1, 'dEab', 5], 18], 'cmyk_tvi' =>
[[1, 'dT', 4, 40, 50], [1, 'dT', 3, 75, 80], [1, 'dTs', 5], 20]}

12647-2/2013
grade: {'cmy_ramp' => [[0, 'dLCh', '1.5', '1.5'], [0, 'dLCh', 3, 3], 26], 'cmyk_tvi' => [[1, 'dT', 3,
0, 30], [1, 'dT', 4, 30, 60], [1, 'dT', 3, 60, 100], [1, 'dTs', 5], 25], 'cmyk_solids' => [[1, 'dEab',
5], [1, 'dEab', 5], [1, 'dEab', 5], [1, 'dEab', 5], 23], 'substrate' => [[1, 'dLab', 3, 2, 2], 22],
'cmyk_solids2' => [[1, 'dH', 3], [1, 'dH', 3], [1, 'dH', 3], 24]}
```

Each text block contains an **ID string** followed by the corresponding **`grade:`** text. The ID string consists of the database keys separated by the **/** character. This identifies the grade settings. The first key is the **standard** value, and the second key is the **version** value. The remaining key(s) are the grading **level**, if defined for that standard. For instance, locate the ID string **g7/36/targeted**,

```
g7/36/targeted
grade: {'cmy_ramp' => [[1, 'dLCh', '1.5', '1.5'], [1, 'dLCh', 3, 3], 4], 'k_ramp' => [[1, 'dLCh',
'1.5'], [1, 'dLCh', 3], 5], 'cmyk_solids' => [[1, 'dE00', '3.5'], [1, 'dE00', '3.5'], [1, 'dE00',
'3.5'], [1, 'dE00', 5], 7], 'substrate' => [[1, 'dE00', 3], 6], 'rgb_solids' => [[1, 'dE00', '4.2'],
[1, 'dE00', '4.2'], [1, 'dE00', '4.2'], [1, 'dLCh', 12, 12], 8]}
```

Immediately below the ID string is the corresponding **`grade:`** text. This is a single line, which may wrap on-screen into several lines, due to its length. Copy and paste this line into your currently open settings file, then run the grade tool (⌘**I**).

```
standard: custom, version: settings, level: base

CMY gray ramp color errors using reference profile

     average ΔL: 1.57 ✘ [1.50]
     maximum ΔL: 2.74 ✔ [3.00]
    average ΔCh: 2.46 ✘ [1.50]
    maximum ΔCh: 4.59 ✘ [3.00]
```

The grading is now **custom**, but same as the standard G7, version 36, targeted tests.

Customizing Test Tolerances

The **`grade:`** text is a Perl hash with keys corresponding to the functions that perform the test(s). The hash values contain the parameters for the test(s), usually the pass/fail tolerances.

Suppose you want to tighten the standard G7 tolerances, to be sure your submitted sheets pass, when measured with a different instrument. Locate the **cmy_ramp** key, which points to some text in brackets.

```
# set Optimal level (offset)
optimal_level: offset

grade: {'cmy_ramp' => [[1, 'dLCh', '1.5', '1.5'], [1, 'dLCh', 3, 3], 4], 'k_ramp' => [[1, 'dLCh', '1.5'],
[1, 'dLCh', 3], 5], 'cmyk_solids' => [[1, 'dE00', '3.5'], [1, 'dE00', '3.5'], [1, 'dE00', '3.5'], [1,
'dE00', 5], 7], 'substrate' => [[1, 'dE00', 3], 6], 'rgb_solids' => [[1, 'dE00', '4.2'], [1, 'dE00',
'4.2'], [1, 'dE00', '4.2'], [1, 'dLCh', 12, 12], 8]}
```

Edit this group to look like this,

```
# set Optimal level (offset)
optimal_level: offset

grade: {'cmy_ramp' => [[1, 'dLCh', 1.2, 1.3], [1, 'dLCh', 2.5, 2.6], 4], 'k_ramp' => [[1, 'dLCh', '1.5'],
[1, 'dLCh', 3], 5], 'cmyk_solids' => [[1, 'dE00', '3.5'], [1, 'dE00', '3.5'], [1, 'dE00', '3.5'], [1,
'dE00', 5], 7], 'substrate' => [[1, 'dE00', 3], 6], 'rgb_solids' => [[1, 'dE00', '4.2'], [1, 'dE00',
'4.2'], [1, 'dE00', '4.2'], [1, 'dLCh', 12, 12], 8]}
```

and run the grade tool (⌘**l**) again. You will see the tolerances for the **cmy_ramp** test have changed. Note the correspondence between these parameters, and the measures they apply to. Using this approach, it is easy to customize tolerances, without changing the basic test framework.

Adding and/or Deleting Tests

Adding and/or deleting tests is just slightly more difficult than changing tolerances. For this you need to understand the basic structure of a hash,

```
grade: {key1 => value1, key2 => value2, key3 => value3, ... }
```

For the grade hash, the keys are the names of the Perl functions called to perform the tests. The values are arrays containing the appropriate test parameters, enclosed with brackets (`[]`), e.g.,

```
'all_samples' => [[1, 'dE00', '1.5'], [1, 'dE00', 3],
      [1, 'dE00', 5], 'it874_keys.sto', 10],
```

If you paste this string just after the first curly bracket in the grade hash, you will add this test. Check this by running the grade tool (⌘**l**) again.

Likewise, you can remove a test by deleting its key and value (and trailing comma, if any). So, it easy to add and/or delete tests, by cutting, copying, and pasting key/value pairs from existing grade strings.

Grading Functions

Each grading function has its own set of parameters. Where possible, the parameters are arranged in a consistent pattern. For example, consider the 'all_samples' function,

```
'all_samples' => [[1, 'dE00', '1.5'], [1, 'dE00', 3],
      [1, 'dE00', 5], 'it874_keys.sto', 10],
```

This function evaluates the color errors of unique IT8.7/4 samples, and tests them three ways. The first sub-test is the average color error, and its parameters are `[1, 'dE00', '1.5']`. This first parameter is a boolean value indicating whether the test is informative (`0`) or normative (`1`). The second parameter is the color error function, ΔE_{00}. The third parameter is the tolerance, `1.5`. The second sub-test is the 95th percentile color error, and the third sub-test is the maximum color error. The individual parameters have the same meaning as in the first sub-test. The string `it874_keys.sto` is a list of the unique IT8.7/4 samples. The last value (`10`) is the test order. The arrangement of keys in a Perl hash is completely random, so we sort the tests by these values to determine the order in which they are performed.

Grading Function Reference

The parameters for the grading functions have this general form,

```
'key' => [[test_1_parameters], [test_2_parameters], ... ,
      test_order],
```

The individual test parameter blocks have this form,

```
[norm_flag, error_function, limit_1, limit_2, ...]
```

The norm_flag indicates whether the test is informative (0), or normative (1). The error_function computes the error value(s) from the reference and measurement data. The error_function will return one or more values, which are compared against the limit(s) that follow. If any of the values exceed their limit, the test fails.

The test_order is a number used to determine the order in which grading tests are performed. Tests are sorted by these numbers, low to high. The first test has the lowest number, while the last test has the highest. The numbers are not necessarily sequential.

Here is a list of the grading function keys and parameters.

```
key: 'substrate'
parameters: [[substrate_test_params], abs_flag, test_order]
```

note 1: if the error_function is 'dLab', there are three limit values
note 2: if the optional abs_flag is true, use the reference profile white point

```
key: 'cmyk_solids'
parameters: [[cyan_solid_test_params], [magenta_solid_test_params],
[yellow_solid_test_params], [black_solid_test_params], test_order]
```

```
key: 'rgb_solids'
parameters: [[red_solid_test_params], [green_solid_test_params],
[blue_solid_test_params], [isometric_solid_test_params],
test_order]
```

note 1: isometric means equal amounts of **CMY**, isometric solid is the **CMY** overprint
note 2: isometric parameters are only used by the a*/b* plot, not for grading

```
key: 'cmy_ramp'
parameters: [[ramp_average_test_params], [ramp_maximum_test_
params], test_order]
```

note 1: if the error_function is 'dLCh', there are two limit values
note 2: if g7 grading is specified, the weight factor is applied

```
key: 'k_ramp'
parameters: [[ramp_average_test_params], [ramp_maximum_test_
params], test_order]
```

note 1: only the L* error is tested, there is just one limit value
note 2: if g7 grading is specified, the weight factor is applied

```
key: 'all_samples'
parameters: [[average_test_params], [95th_percentile_test_params],
[maximum_test_params], test_order]
```

```
key: 'cmyk_tvi'  (as used in ISO 12647-2:2013)
parameters: [[tvi_test_parameters_1], [tvi_test_parameters_2], ...
test_order]
```

note 1: the error_function is either 'dT' for TVI error, or 'dTs' for TVI spread
note 2: the test parameters for 'dT' are [norm_flag, 'dT', max_TVI_error_value, low_%-dot, high_%-dot]
note 3: the test parameters for 'dTs' are [norm_flag, 'dTs', max_TVI_spread]

```
key: 'black_point'  (as used in FOGRA PSD)
parameters: [black_solid_test_params, test_order]
```

```
key: 'gray_axis'  (as used in Optimal)
parameters: [[ramp_average_test_params], [ramp_maximum_test_
params], test_order]
```

note 1: the gray axis test requires a **CMYK** gray ramp made using the reference profile

Command-Line Interface (CLI)

PressCal is a Perl script and module collection, supplied as a bundle for the **TextMate editor**. TextMate provides the user interface, which is an opened **YAML** file. This non-graphical text interface is somewhat crude, but adequate.

An upside of this crude interface is that PressCal may be run from the command-line. This allows it to be used in automated workflows, or incorporated into other software tools, or even accessed on-line, with an appropriate web interface. Furthermore, since PressCal is a Perl script, it is easily modified to suit your needs.

Terminal App

On macOS, the Terminal app provides a command-line interface. This app is located in the Utilities folder. When you run the Terminal app, a window will open with some text and a cursor, awaiting your input.

Running Perl

Type **`perl -h`** into the Terminal window, followed by **return**. Perl will respond to your input with a usage summary, which includes a list of **switches**. These switches set various preferences, and in some cases, identify other input. This is the Perl command-line interface (CLI).

Running PressCal

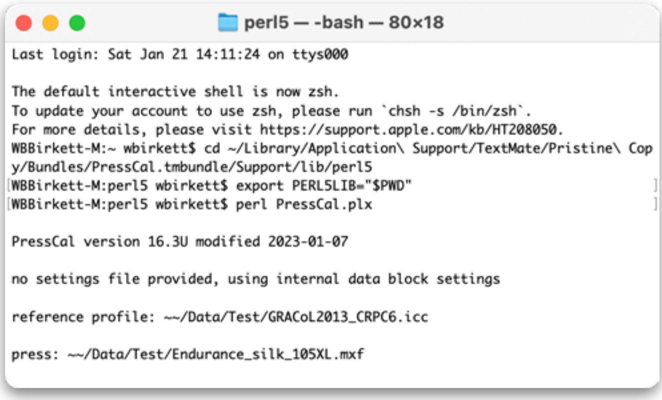
When installed as a TextMate bundle, PressCal is located in the user's **Application Support** folder. Enter the following commands to help Perl locate the bundle,

```
cd ~/Library/Application\ Support/TextMate/Pristine\ Copy/Bundles/
PressCal.tmbundle/Support/lib/perl5
```

```
export PERL5LIB="$PWD"
```

Then, enter this command to run PressCal,

```
perl PressCal.plx
```



PressCal will run, generating curves with the default settings, which are built-in. You may need to widen the Terminal window to see the results, which would normally be displayed in TextMate.

You will, of course, want to use your own settings. PressCal has over 40 settings, some of which are quite complex. It isn't feasible to put these on the command-line, as Perl does. Instead, the settings are provided as a YAML file. For example, if your settings file is on the Desktop,

```
perl PressCal.plx ~/Desktop/my_settings.yml
```

An additional command-line parameter selects the PressCal tool:
0 - curves (default), **1** - ink balance, **2** - grade. For example, this command runs the grade tool,

```
perl PressCal.plx ~/Desktop/my_settings.yml 2
```

You may redirect the PressCal log output to a file, using the **>** operator. For example,

```
perl PressCal.plx ~/Desktop/my_settings.yml 2 > ~/Desktop/my_grade_
output.txt
```

If you want to dispose of the PressCal log output, redirect to the null device,

```
perl PressCal.plx ~/Desktop/my_settings.yml 2 > /dev/null
```

PressCal Output

Most likely, you will use the PressCal output as input to some other process. All of the normal output functions, except for opening the graphs in your web browser, work as in TextMate. So, the settings and statistics will be written to the **`settings_path:`** folder, curves will be written to the **`output_path:`** folder, and so on. You may set these paths in your settings file, as well as the paths to your reference profile, and measurement data.

PressCal also generates HTML files of various graphs. When run from TextMate, the graphs are opened in your default web browser. When run from the command-line, the files are created, but not opened. You can do that manually with additional command lines. For example,

```
open ~/Desktop/PressCal_graphs/ab_plot.html
```

Settings File

Settings are saved as a YAML text file, which is processed by PressCal into a Perl hash. Comments are stripped out, and certain Perl notations are interpreted. The order of the individual settings is not important – you may arrange them as you see fit. The entire settings file is processed before any action is taken.

If you enter an invalid setting key (perhaps by mistake), it will be ignored, and there will be no indication of an error. The setting you intended will use its default value. If the setting key is valid, but its value is not, PressCal will let you know with either a warning or an error. If your settings file contains more than one instance of a key, the last instance will be used.

Warnings and Errors

When PressCal encounters a problem, it will print a warning and continue running, or terminate with an error message. Warnings and errors are printed to the **STDERR** device. PressCal returns a value on exit – **0 for a normal exit, and 1 if an error was encountered.**

Troubleshooting

PressCal's text-based interface is simple, extensible, and concise. It's also very easy to enter invalid settings. When that happens, the software will print warning or error messages. The software will continue running with a warning, or will terminate with an error.

PressCal settings files are written in the YAML language. Each individual setting has a key and a value. This is explained in the Settings Notation section.

Warnings

If a setting's syntax is wrong, the warning will tell you which setting failed. If the setting has multiple values, the warning may indicate which one is incorrect.

If you've modified a Basic Setting, check what you've added or changed. We test each basic setting to run correctly before releasing a new PressCal version. So, the problem is most likely with the new or modified settings.

Each setting has examples in the **Settings Reference** section of this user manual. A PDF search (**⌘F**) for the setting will locate examples and helpful information.

Errors

An error will cause PressCal to terminate. A bad setting could be at fault, or possibly something more serious, like a programming bug. The error message should give you a good idea where to look for the problem. If you've found a bug, please let us know. We'll try to fix it right away.

Common Issues

1. Keys are case sensitive. **`Press:`** is not the same as **`press:`** and **`{'PATH' => '~/Desktop'}`** is not the same as **`{'path' => '~/Desktop'}`**.

2. Each setting must be entirely on its own single line, ending with return. Don't add returns to wrap long lines. **TextMate** has a setting in the **View** menu to automatically wrap long lines.

3. The **#** character begins a comment that runs to the end of the line. If you have a path containing an **#**, it will be truncated. This may be fixed by adding a **** before the **#** in your path, e.g.,

```
press_path: ~/Desktop/trapping_potion_#9.txt # fails, path truncated to ~/Desktop/trapping_potion_
press_path: ~/Desktop/trapping_potion_\#9.txt # ok
```

4. Within a hash setting, enclose string values in single quotes, e.g.,

```
output_path: {'prefix' => first pull} # fails
output_path: {'prefix' => 'first pull'} # ok
```

5. Each **`(`**, **`[`**, or **`{`** in a setting should have a matching **`}`**, **`]`**, or **`)`**.

6. TextMate requires Rosetta 2 be installed on Macs using Apple silicon (M1, M2, etc.).

Debug Setting

The **debug:** setting causes PressCal to display more detailed information for warnings and errors. This is useful when debugging the software. If you've encountered a bug, please report it to us. Your settings, any referenced files, and a screenshot of the debug printout are helpful.

```
debug: 1 # enable debugging mode
```

Suggestions

If you have an idea for improving PressCal, we'd be glad to hear it. This could be a very specific change. Or, it could be an unusual calibration problem you'd like to solve. Many of the improvements we've made were suggested or inspired by our users.