Calibrating, Printing and Proofing by the G7™ Method

Version 6

August 2006

C O N T E N T S

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1 Introduction

1.1 About this document

This document describes how to calibrate a printing press, proofing system, or any CMYK imaging device to the new GRACoL 7 specifications, and how to maintain those specifications during production. The calibration process is broken into two stages. The first stage uses ISO-standard colorants and substrate, and the new G7™ method to match the NPDC (Neutral print Density Curve) and gray balance of neutral gray tones. The second stage uses ICC (International Color Consortium) or similar color management to optimize the match to a reference characterization data based on ISO-standard print conditions, such as produced by FOGRA, GRACoL, SWOP, etc.

Simply using the G7 calibration method will often be enough to match multiple devices to each other, at least in neutral gray tones. But in other cases, for example with non-standard colorants, to set up a digital proofer, or when repurposing from one print method to another, additional color management will be needed, with G7 acting as an optimized and repeatable calibration basis.

1.2 Changes to this version

Version 6 of this document corrects a number of small errors and omissions in earlier versions and adds several new items. The main changes between version 6 and versions 4 or earlier are;

- Adds new variables 'SC' (Shadow Contrast) and 'HC' (Highlight Contrast)
- Broader tolerances for ink color and press gray balance
- Minor changes to gray balance formula and NPDC curve shape
- New 'fan-type' graph paper simplifies re-drawing graphs
- Adds references to the new IDEAlink™ Curve software
- Expanded or revised illustrations, charts and glossary
- Clarifies the use of CIE-based (instead of density-based) TVI curves
- Corrected errors in some charts and formulae

1.3 What is GRACoL 7?

GRACoL 7 is the seventh edition of the GRACoL specification. GRACoL 7 differs from previous editions of the GRACoL specification by;

- Defining substrate and colorants in colorimetry rather than status T density
- Defining tonality in 'Neutral Print Density Curves' (NPDC) instead of TVI
- Defining gray balance as a primary colorimetric variable, rather than a secondary function of CMY TVI
- Defining a GRACoL 7 characterization data set that represents an ideal printed sheet

1.4 What is G7?

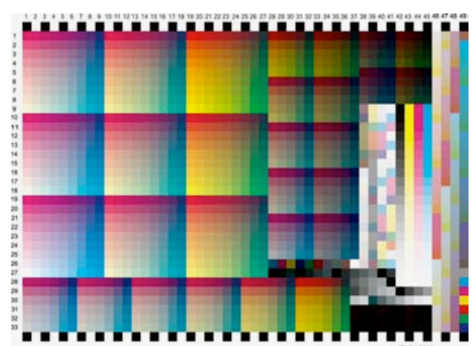
G7™ is a new calibration method developed to support the GRACoL 7 specification, and described in detail in this document. The 'G' refers to calibrating Gray values, while the '7' refers to the seven primary color values defined in the ISO 12647-2 printing standard; Cyan, Magenta, Yellow, Black (K), Red (M+Y), Green (C+Y) and Blue (C+M). Although originally intended for commercial offset printing, the G7 method is applicable to virtually any CMYK imaging process, and has been successfully tested on a wide range of processes, including coated and uncoated offset, newsprint, gravure, flexography, dye-sublimation, ink-jet, and electrophotography, as well as a wide range of AM and FM screening methods.

1.5 GRACoL 7 and ISO print standards

NOTE: GRACoL IS NOT A STANDARDS ORGANIZATION AND DOES NOT CREATE STANDARDS, however as far as possible GRACoL 7 and this document are based on existing ISO standards.

ISO is the International Standards Organization governing all industries including printing. ISO 12647-2 is a standard for "Graphic technology - Process control for the production of half-tone colour separations, proof and production prints - Part 2: Offset lithographic processes". ISO 12647-2 is remarkably valid today, but its reliance on a small number of solid ink colors and TVI (Tone Value Increase) curves limits its value in ICC workflows. The main problem is that ISO 12647-2 is ambiguous due to the use of multiple TVI curves, and the lack of a colorimetric definition for gray balance.

Today's users want a printing standard to define the 'appearance' of the final image more precisely than is guaranteed with ISO 12647-2. A good way to define print 'appearance' is with a characterization data set containing colorimetric (CIE or spectral reflectance) values from a standard characterization target like the IT8.7/4 shown here.



The IT8.7/4 characterization target (Visual)

At the time of writing, an ISO TC 130 subcommittee is working to define a characterization data set that will be acceptable by all member countries. Meanwhile, several national organizations including Germany's FOGRA, Japan Standards Institute, and USA's GRACoL and SWOP, have already produced their own characterization sets based on their own interpretations of ISO 12647-2. The question is how to interpret an ambiguous standard? Specifically, on which (if any) of the six TVI curves in ISO 12647-2 will the final data set be based? And is TVI even a sound metric in a colorimetric standard?

1.6 Solving the TVI problem

GRACoL's research indicates that TVI is a poor basis for a colorimetric standard because different TVI curves can be necessary on different devices to produce a consistent visual appearance. Part of the problem is that TVI is based on densitometry, which has no fixed relationship to colorimetry. This might be solved by a new TVI formula based on CIEXYZ or ΔE, but GRACoL 7 eliminates the TVI problem entirely by replacing ISO 12647-2's multiple TVI curves with the new concept of a single 'NPDC' (Neutral print Density Curve) that can be derived unambiguously from any characterization data, and which, if used as a basis for device calibration, eliminates much of the work normally done by ICC color management.

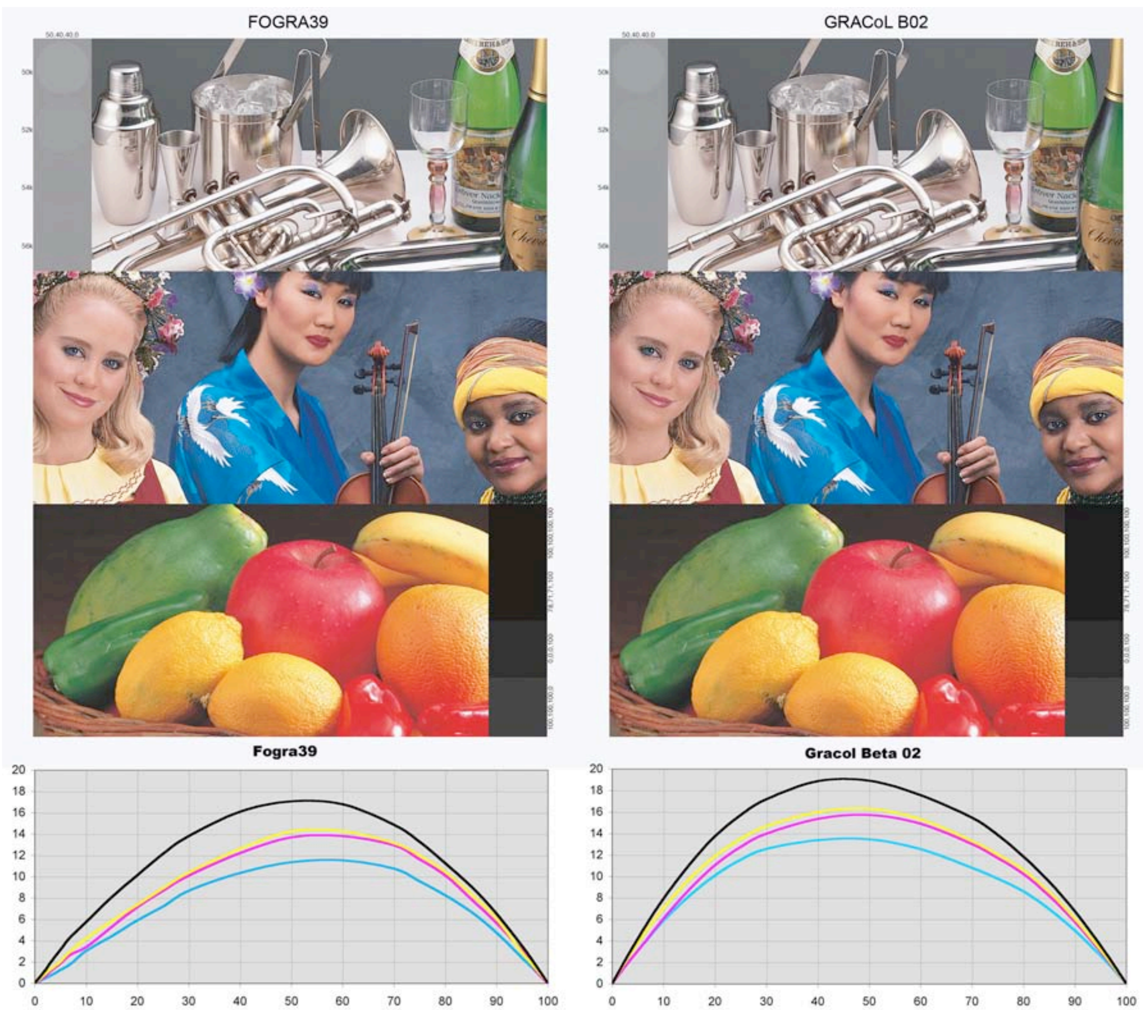
To help promote unified printing worldwide, GRACoL has attempted to represent in its characterization data and NPDC curves the 'natural' behavior of typical CtP printing, i.e. what happens with no RIP curve correction. This approximately correlates to a TVI curve shape between the legacy-positive and legacy-negative curves in ISO 12647-2 for paper type 1 coated.

1.7 In search of international unity

The two most widely-promoted characterization data sets for commercial printing come from FOGRA and GRACoL 7. The visual differences are quite small, as shown by the illustrations below, in spite of significantly different TVI curves shown below each image. This is not surprising as the GRACoL 7 Beta 02 Characterization Data was based largely on FOGRA39, but adjusted to fit the GRACoL NPDC and gray balance definitions.

The final TC 130 data *(see 1.5)* will probably be similar to both, but remember that this will then have to be ratified by all the TC 130 delegates before becoming an official ISO standard.

IMPORTANT: Although closely tied to ISO 12647-2, the GRACoL 7 Characterization Data and NPDC curves are NOT an official standard, but simply one of several possible 'appearances' allowed under ISO 12647-2. Any future ISO characterization data may lead to a change in the GRACoL 7 or FOGRA data.



Interpretations of ISO 12647-2 by the TVI method (left) and the G7 method (right) and their relative CIEXYZ-based TVI curves (below). Remember these SCID images have no 'right' or 'wrong' appearance. (Color and density may vary depending on viewing and reproduction conditions.)

NOTE: The TVI curves shown above are calculated from CIEXYZ data (see 2.9) - NOT density readings, and are intended for comparative purposes only.

2 New Variables and Definitions

This section explains some new variables introduced with the G7 method, including 'NPDC', 'HR', 'SC', and 'HC', and some new definitions or uses for old variables such as gray balance and TVI.

2.1 Neutral Print Density Curve (NPDC)

A new concept introduced with G7 is the definition of a 'Neutral Print Density Curve' (NPDC), which is the relationship between measured neutral density and original halftone percentages on a printed gray scale. Because neutral density is an absolute value, while TVI is a relative function, NPDC ensures a better contrast and density match between multiple devices.

Two NPDC curves are specified, one for a combined CMY gray scale and one for a black-ink gray scale. NPDC calibration compares a printed gray scale to a reference scale and calculates RIP correction values in dot percentage terms that force the press (or other imaging device) to the desired NPDC shape. Curve correction values are calculated either manually by plotting graphs on special graph paper *(see Appendix B)*, or automatically in the IDEAlink™ Curve software available from www.printtools.org.

2.1.1 Determining 'natural' CtP curves

To determine the 'natural' print curves of commercial CtP-based printing, the GRACoL technical committee analyzed multiple ISO-standard press runs made with a variety of plates imaged on un-calibrated CtP systems, set up to manufacturer specifications.

While every press run is unique, we believe the G7 NPDC formula represents what an average press running to ISO 12647-2 specifications would produce with typical un-calibrated CtP plates, on high quality commercial stock.

For an explanation of how the NPDC curves were mathematically smoothed, *see Appendix E.4*

REMEMBER: G7 NPDC curves are NOT an official ISO standard. Other valid interpretations of ISO 12647-2 may produce slightly different NPDC curves.

2.2 Highlight Range (HR)

HR is a single measurement that quickly tests the mid-tone density of a previously-calibrated device during production, for example while a press is running or after each proof is made. HR replaces individual TVI readings as the primary measure of overall print darkness and gray balance, however TVI is still a useful press control metric - *(see 2.8 When to Use TVI).*

HR is computed twice, once for CMY ('HR_cmy') and again for black ('HR_k'). Just two measurements are required for each, or just one each (total 2) in absolute mode *(see2.2.3),* compared to three measurements each for C, M, Y and K TVI (total 12), yet HR gives a more reliable indication of pictorial darkness and contrast because HR is absolute while TVI is only a relative measurement.

For convenience, HR is expressed in neutral density (ND), which can be measured with a densitometer set to the black channel, or 'Visual density'. ND can also be computed from CIEXYZ_Y, in fact GRACoL officially defines Neutral Density as ;

$$ND = \text{Log10}(100/Y); \quad (\text{where } Y > 0 \leq 100)$$

2.2.1 Measuring HR_cmy

HR_cmy is computed by measuring the neutral density (ND) of a combined CMY gray patch (50c, 40m, 40y) and subtracting the neutral density of paper.

$$HR\_cmy = ND(50c,40m,40y) - ND(paper) = 0.54 \text{ (typical)}$$

For devices with a dynamic range of about 1.3 ND or higher, HR_cmy is effectively a constant of 0.54. For low dynamic range devices, such as newsprint, HR_cmy may be lower. *(See Appendix A.5 for a graph of HR_cmy vs. dynamic range.)* HR_cmy is calculated automatically by IDEAlink Curve.

2.2.2 Measuring HR_k

HR_k is computed by measuring the ND of a 50k patch and subtracting the neutral density of paper.

HR_k = ND(50K) - ND(paper) = 0.50 (typical)

For devices with a dynamic range of about 1.3 ND or higher, HR_k is effectively a constant of 0.50. For low dynamic range devices, such as newsprint, HR_k may be lower. *(See Appendix A.5 for a graph of HR_k vs. dynamic range.)* HR_k is calculated automatically by IDEAlink Curve.

NOTE: Prior to February 2006 GRACoL 7 proposed that HR_k = HR_cmy, but the HR_k value was lowered in February 2006 to 0.50 to remain 'legal' to the current ISO 12647-2 TVI curves. Users who prefer to calibrate their black NPDC to match the CMY NPDC should use the HR_cmy value (0.54) instead of 0.50 for HR_k.

2.2.3 Absolute HR

Only a single measurement of the gray patch is needed to control HR if the paper density is added to HR to get the 'Absolute' HR density for that particular paper. For example,

If paper ND = 0.09, and HR = 0.54

Absolute HR = 0.09 + 0.54 = 0.63 (for that paper)

2.2.4 Absolute HR in L* units

A single Lab reading can be used to measure gray balance and lightness simultaneously if Absolute HR is expressed in L* instead of density. The Absolute L* HR values for a standard paper lightness of L* 95 and maximum darkness at 300% CMY of at least 25 L* (1.35 ND) or a maximum darkness at 100k of at least 16 L* (1.7 ND) are, (rounded to one decimal);

Absolute HR_cmy = L* 57.5

Absolute HR_k = L* 59.9

Absolute L* HR values for other papers are calculated automatically by IDEAlink Curve.

NOTE: Expressing or measuring HR in 'relative' L Is not recommended as most spectrophotometers do not allow calibration on an arbitrary base and it is not trivial to calculate a new relative L* value if the paper varies from the standard 95 L* value.*

2.3 Shadow Contrast (SC)

A new G7 variable introduced in this edition is Shadow Contrast ('SC'). SC is a, quick way of checking the NPDC in neutral shadow tones during production. SC is an optional replacement for individual CMY Print Contrast readings. SC is computed twice, once for CMY ('SC_cmy') and again for black ('SC_k').

2.3.1 Measuring SC_cmy

SC_cmy is computed by measuring the neutral density (ND) of a combined CMY gray patch (75c, 66m, 66y) and subtracting the neutral density of the paper.

SC_cmy = ND(75c,66m,66y) - ND(paper)

The value of SC_cmy depends on the dynamic range of each device, and is calculated automatically by IDEAlink Curve. *(See Appendix A.5 for a graph of SC_cmy vs. dynamic range.)*

2.3.2 Measuring SC_k

SC_k is computed by measuring the ND of a 75% Black patch and subtracting the neutral density of the paper.

SC_k = ND(75k) - ND(paper)

The value of SC_k depends on the dynamic range of each device, and is calculated automatically by IDEAlink Curve. *(See Appendix A.5 for a graph of SC_k vs. dynamic range.)*

2.3.3 Absolute SC

By adding the paper density to SC to get the 'Absolute' SC density for that particular paper, only a single measurement of the gray patch is needed to control SC. For example,

If paper ND = 0.09 and SC = 0.97

Absolute SC = 0.09 + 0.97 = 1.06 (for that paper)

2.3.4 Absolute SC in L* units

A single Lab reading can be used to measure gray balance and lightness simultaneously if Absolute SC is expressed in L* instead of density. Absolute L* SC is calculated automatically by IDEAlink Curve.

NOTE: Expressing or measuring SC in 'relative' L Is not recommended as most spectrophotometers do not allow calibration on an arbitrary base and it is not trivial to calculate a new relative L* value if the paper varies from the standard 95 L* value.*

2.4 Highlight Contrast (HC)

Another new G7 variable introduced in this edition is Highlight Contrast or 'HC'. HC is a quick way of checking the NPDC in neutral highlight tones during production. HC is computed twice, once for CMY ('HC_cmy') and again for black ('HC_k'). HC is a virtual constant for dynamic ranges above about 0.8 ND.

2.4.1 Computing HC_cmy

HC_cmy is computed by measuring the ND of a combined CMY gray patch (25C, 19M, 19Y) and subtracting the neutral density of the paper. HC_cmy is calculated automatically by IDEAlink Curve. *(See Appendix A.5 for a graph of HC_k vs. dynamic range.)*

HC_cmy = ND(25c,19m,19y) - ND(paper) = 0.25

2.4.2 Computing HC_k

HC_k is computed by measuring the ND of a 25% Black patch and subtracting the neutral density of the paper. HC_cmy is calculated automatically by IDEAlink Curve. *(See Appendix A.5 for a graph of HC_k vs. dynamic range.)*

HC_k = ND(25k) - ND(paper) = 0.22

NOTE: Users who prefer to calibrate their black NPDC to match the CMY NPDC should use the HC_cmy value (0.25) instead of 0.22 for HC_k.

2.4.3 Absolute HC

By adding the paper density to HC to get the 'Absolute' HC density for that particular paper, only a single measurement of the gray patch is needed to control HC. For example,

If paper ND = 0.09 and HC = 0.25

Absolute HC = 0.09 + 0.25 = 0.34 (for that paper)

2.4.4 Absolute HC in L* units

A single Lab reading can be used to measure gray balance and lightness simultaneously if Absolute HC is expressed in L* instead of density. The Absolute L* HC values for a standard paper lightness of L* 95 and a standard dynamic range of at least 0.8 ND are, (rounded to one decimal);

Absolute HC_cmy = L* 75.7

Absolute HC_k = L* 77.7

Absolute L* HC values for other papers are calculated automatically by IDEAlink Curve.

NOTE: Expressing or measuring HC in 'relative' L Is not recommended as most spectrophotometers do not allow calibration on an arbitrary base and it is not trivial to calculate a new relative L* value if the paper varies from the standard 95 L* value.*

2.5 HR, SC and HC aim values vs. dynamic range

The graph in Appendix A.5 shows that HR and HC are effectively constants for normal offset density ranges, but SC (and to a less extent HR and HC) do vary as a function of high dynamic range.

2.6 Gray balance

GRACoL 7 breaks with tradition by raising gray balance to a more important status than TVI, but this raises the question; how do you define 'gray balance'? Gray balance was traditionally defined as the CMY percentages needed to match the color of a 50% black ink tint, or the color of paper, but these definitions are too vague for today's ICC workflows. To avoid these ambiguities GRACoL 7 defines an arbitrary table of CMY percentage 'triplets' based on the generic 50c, 40m, 40y ratio, and pre-defined a* and b* values for each triplet.

In previous versions of this document gray balance was an arbitrarily constant of 0 a*, -2 b* throughout the whole CMY gray scale, regardless of paper color. As of version 5, gray balance is now calculated by a paper-dependent formula *(see Appendix E)* based on ideas from several public forums.

CAUTION: The new paper-dependent gray balance definition means that gray tones in a CMYK file will shift in gray balance towards paper color. Separations and proofs made for one paper may therefore not exactly match a proof created for another paper type.

2.6.1 Abbreviated Gray Balance chart

The following chart lists some CMY percentage values and approximate a* b* values for a paper white of 0 a*, -2 b*. Note how the b* values converge towards zero at higher CMY percentages. *(See Appendix E for full gray balance formulae and chart of the P2P23 target gray balance.)*

C%*	M%	Y%	a*	b*
0.0	0.0	0.0	0	-2
12.5	9.0	9.0	0	-1.7
25.1	18.8	18.8	0	-1.5
37.3	29.0	29.0	0	-1.2
49.8	**40.0**	**40.0**	**0**	**-1**
62.7	52.9	52.9	0	-0.70
75.3	66.3	66.3	0	-0.5
87.5	81.2	81.2	0	-0.2
100	100	100	0	0

Nominal gray balance percentages and a,b* values for a paper white of 0 a* and -2 b**

**NOTE: For precision purposes GRACoL 7 expresses all percentage values as their nearest 8-bit fractional value. (See Appendix D.)*

2.6.2 Calibrating Gray Balance

Gray balance can be calibrated either by adjusting the device itself (for example with modified ink densities) or by creating separate CMY RIP curves *(see Section 8 'Achieving Gray Balance in RIP Curves'.)*

NOTE: Whenever possible, separate RIP curves should be AVOIDED when calibrating an offset press, as most offset gray balance errors are unstable or inconsistent. The reverse is true when calibrating a more stable device such as a proofing system or ink jet printer, where gray balance is more consistent.

2.6.3 Controlling Gray Balance in production

For process control purposes, measuring a single gray patch of (nominally) 50c, 40m, 40y is usually enough to confirm a previously - calibrated device is still 'in balance'. Measuring gray balance also on the SC patch (75c, 66m, 66y) and (optionally) on the HC patch (25c, 19m, 19y) may reveal run-specific errors due to temporary variations in performance that are difficult or impossible to correct on inherently unstable devices like an offset press. In live production a compromise may sometimes be necessary in meeting the target Lab values of HR, SC and HC patches.

2.7 Benefits and limitations of the new method

The primary advantage of the G7 calibration method and the use of HR, SC, HC and gray balance to monitor production, is that the visual appearance of neutral tones and near-neutral colors is more effectively controlled than by traditional TVI-based methods. The main disadvantage is that gray balance can be a challenge to maintain in offset lithography.

2.7.1 Benefits

- NPDC, HR and SC measure visual lightness and darkness directly, independent of SID, but TVI is a dependent variable of SID, and therefore an unreliable measure of visual lightness.
- The G7 method and values are equally valid in proofing or printing, unlike TVI-based calibration, which requires different aim values for proofing systems than for presses.
- NPDC, HR and SC are independent of screening variables, hence one specification can apply to all types of imaging system, regardless of dot type, or even if there is no dot at all.
- Reading the color of a CMY gray patch is the most efficient way to control gray balance, because the combined effects of all variables are measured at once, but gray balance cannot be defined by separate CMY TVI readings, if hue and trapping effects are not also precisely controlled.
- Press control is faster because only 2 instrument 'clicks' are needed to monitor gray balance and absolute HR - one for a CMY gray patch and one for a 50% black tint - instead of the 12 clicks needed to measure CMYK TVI.
- Separating the two critical attributes of NPDC and gray balance, allows each to be adjusted independently of the other.
- Even if ICC profiles are used, G7 calibration establishes a consistent neutral scale performance which can expand the value and extend the life of standardized device profiles.
- Even if gray balance remains hard to control on press, applying the G7 method to every proofing system (and to every 'standard' characterization data set) will yield more consistent proofs, more interchangeable CMYK files, and will ultimately make every printer's job easier.

2.7.2 Limitations

- Gray balance is generally harder to control on a typical offset press than single-ink performance, due to wet trapping and other issues *(see Appendix G.6).* But that's really the whole point - focusing on the most unstable variable helps stabilize the whole process.
- If the average job contains few gray areas, gray balance control may not be worth the effort.
- Calibrating an unstable device with different CMY curves may solve a one-time gray balance error but cause a different gray balance problem on subsequent work, if the calibration test was not typical. The use of 'smoothed' gray correction curves helps reduce this problem.

2.8 When to Use TVI

Although dot sizes and TVI are unreliable for controlling appearance, they continue to serve as valuable process control metrics for offset lithography.

- After reaching nominal solid ink levels check TVI to be sure each unit is printing normally, otherwise curve corrections may be introduced to correct for physical or chemical anomalies that should have been corrected on press *(see 6.3).*
- Whenever color problems during a run cannot be solved by simple SID adjustments, individual-ink TVI values will indicate if one or more plates are printing incorrectly.
- Individual-ink TVI values should be monitored, as well as gray balance and HR, as part of any thorough process control program.

- On very stable devices whose individual colorants and trapping effects are highly predictable, it may be possible to learn device-specific CMY TVI values that, if individually measured, will control gray balance and NPDC on that device. This will typically NOT be true in offset lithography, and offers little advantage over direct gray-patch readings.

2.9 G7 TVI curves and calculations

Because the G7 solid ink colors, NPDC curves, gray balance and characterization data are either expressed in, or based on, colorimetric values, (even the NPDC curves are derived from CIEY, not actual densitometry) it is anachronistic and problematic to include traditional Density-based TVI values in the G7 specification. However at times it is useful to show comparative TVI curves, for example to check on the relative "health" of individual plates on an offset press.

To solve this dilemma, GRACoL 7 and the IDEAlink Curve software have taken the logical (if not yet "standard") decision to calculate a modified form of TVI from CIEXYZ values, instead of from traditional densitometry. This produces slightly different TVI values and curves for C, M and Y than you may be familiar with, but makes TVI a more useful metric in an all-colorimetric specification, and eliminates the need for physical density readings of any status. (G7 TVI values or curves for neutral black ink are theoretically identical to those produced by densitometry.)

CAUTION: TVI numbers and graphs shown in this document for CMY inks are NOT the same as produced by a traditional densitometer, regardless of filtration or polarization status.

Other CIE-based TVI formulae may be equally valid, for example calculating from ΔE^*_{ab} reflectance values, and GRACoL will gladly move to such a formula when and if it becomes an official standard.

2.9.1 CIEXYZ-based TVI formulae used by G7 and IDEAlink Curve

For n = 0 to 100%;
TVI_c = (paper_X – nc_X) / (paper_X – 100c_X) x 100 – n;
TVI_m = (paper_Y – nm_Y) / (paper_Y – 100m_Y) x 100 – n;
TVI_y = (paper_Z – ny_Z) / (paper_Z – 100y_Z) x 100 – n;
TVI_k = (paper_Y – nk_Y) / (paper_Y – 100k_Y) x 100 – n;

2.9.2 Using traditional density-based TVI measurements

Printers who want to continue using traditional density-based TVI as a process control metric are perfectly able to do so while remaining faithful to the G7 specification. All you have to do is calibrate your device using G7's colorimetric aim points (NPDC, HR, gray balance, etc.) then take TVI readings on a calibrated sample with your own densitometer and the filtration and polarization status of your choice. These TVI readings can then be used as process control aims for that device/media combination, or the remainder of that production run.

3 G7 Calibration / Profiling Summary

A complete G7 calibration and profiling workflow consists of the following steps;

3.1 Prepare the equipment and materials

The first step is to make sure the device being calibrated is operating to manufacturer's specifications and using the correct consumables.

3.2 Print a Calibration target

The second step is to print a GRACoL P2P target *(see 5.2.1)* on standard paper with colorants specified for the process being calibrated, e.g. # 1 coated sheet and ISO – compliant inks. This target provides a snapshot of the natural NPDC and gray balance of the device being calibrated.

3.3 Compare 'found NPDC' to reference NPDC

The third step is to compare the NPDC of the calibration target to the pre-defined G7 NPDC curves, by measuring two gray scales from the P2P target – one printed in CMY only and another printed in black only, and either drawing graphs on special G7 graph paper *(see Appendix B)* or entering the values into IDEAlink™ Curve software.

3.4 Compare 'natural gray balance' to reference gray balance

Next the natural gray balance of the device is compared either manually, using the GrayFinder target *(see 5.2.2)*, or automatically by IDEAlink Curve and the P2P target.

3.5 Calibrate the RIP or device driver

Correction values are read from the graph, or from the Create Curves window of IDEAlink Curve software, and entered into the CtP RIP or driver as 'wanted' CMYK percentage values.

3.6 Verify the calibration

A new P2P target is printed through the newly-calibrated RIP or driver and the resulting NPDCs for CMY and black, and gray balance, are checked for accuracy.

3.7 Print a Characterization target (optional)

Once gray balance and NPDCs are calibrated, an optional ICC profile can be created, if needed. In the case of a digital proofer, an ICC profile (or equivalent color management system) is normally essential for best results, but when calibrating an actual press, if NPDC and gray balance calibration was successful and if standard inks and paper are used, a standardized characterization data set (appropriate for that printing type) should avoid the need for a custom press profile.

3.8 Verify the Characterization (optional)

The last step in a full workflow is to create a hard-copy (or soft) proof that simulates the reference characterization data via ICC or other color management, and compare it to a proof or press sheet made in step 3.7.

4 Time, Materials, and Tools

NOTE: The G7 method is applicable to any printing process, so long as the correct materials and target values are used. In the following description, emphasis is given to commercial print calibration on high quality coated paper. If calibrating another process, for example SWOP, uncoated web printing, or a proofing system, substitute the appropriate materials and colorimetric aim points as needed.

4.1 Time

The full press calibration method requires two press runs, each approximately one to two hours long, with a short break between (approximately 30 minutes to 1 hour) for plate calibration. Both runs should be scheduled for the same day, with the same equipment and press crew. Experienced users may reduce subsequent calibrations (for example for different papers or screening) to a single run, omitting the second 'qualification' or 'characterization' run.

4.2 Paper

Approximately six-to-ten thousand sheets of paper will be needed, depending on run efficiency. For commercial printing use ISO Paper type 1 with as little fluorescence as possible and a nominal white point of 95 L* (± 3), 0 a* (± 2), -2 b* (± 2) (measured with white backing). For other processes, use the appropriate paper specifications in ISO 12647-2.

4.3 Inks

Like most printing specifications, GRACoL 7 defines ink color according to ISO 2846-1, however in practice it is more important that the inks, when printed on the actual substrate being calibrated, measure as close as possible to the ISO 12647-2 values for that paper type.

4.3.1 Commercial Ink Colors

The optimum printed solid values for ISO paper grades 1 & 2 (equivalent to a US #1 sheet) are;

	Base	C	M	Y	K	MY	CY	MC	CMY
L*	95	55	48	89	16	47	50	24	23
a*	0	-37	74	-5	0	68	-68	17	0
b*	-2	-50	-3	93	0	48	25	-46	0
ΔE^*_{ab}	(See 4.2)	5	5	5	5	5	5	5	(N/A)

Solid values for ISO 12647-2 paper types 1&2 (proposed November 2005) – white backing

*NOTE: These values refer to measurements taken with no back-printing, with the sample lying on a white backing material with an approximate CIELab value of L*98, a*0, b*0.*

4.3.2 Ink Colors for other paper types

For a chart of ink colors on all ISO paper types with both white and black backing, *(see Appendix H).*

4.4 Test targets and images

A pre-assembled GRACoL 7 Calibration Press Form may be purchased from www.printtools.org, or you can assemble your own form *(see 5.2.)*

4.5 Tools for graph paper method

4.5.1 Graph paper

Several sheets of the G7 K Curve Graph Paper and several sheets of the G7 CMY Curve Graph Paper *(See Appendix B).*

4.5.3 Pocket calculator

For calculating target gray values.

4.5.4 Hand-held spectro-densitometer

For measuring the P2P target and GrayFinder target

4.6 Tools for software method

4.6.1 Curve calculating software

IDEAlink™ Curve software - available at www.printtools.org

4.6.2 Automated software for measuring the P2P target

ONE OF:

- GretagMacbeth MeasureTool - available at www.gretagmacbeth.com (free version has enough functionality for this purpose)
- X-Rite ColorPort - available at www.x-rite.com

4.6.2 Automated measuring device

ONE OF:

- GretagMacbeth Spectroscan, EyeOne Pro, EyeOne IO
- X-Rite DTP-70

4.7 Dot Meter (recommended)

A video dot meter for measuring plates.

4.8 Hand-held spectro-densitometer

A spectrophotometer or spectro-densitometer is needed to control device performance during production. If you are not familiar with CIELab, see Appendix F for a brief overview.

4.9 D-50 viewing conditions

A D50 light booth or light source conforming to ISO 3664.

5 Preparation

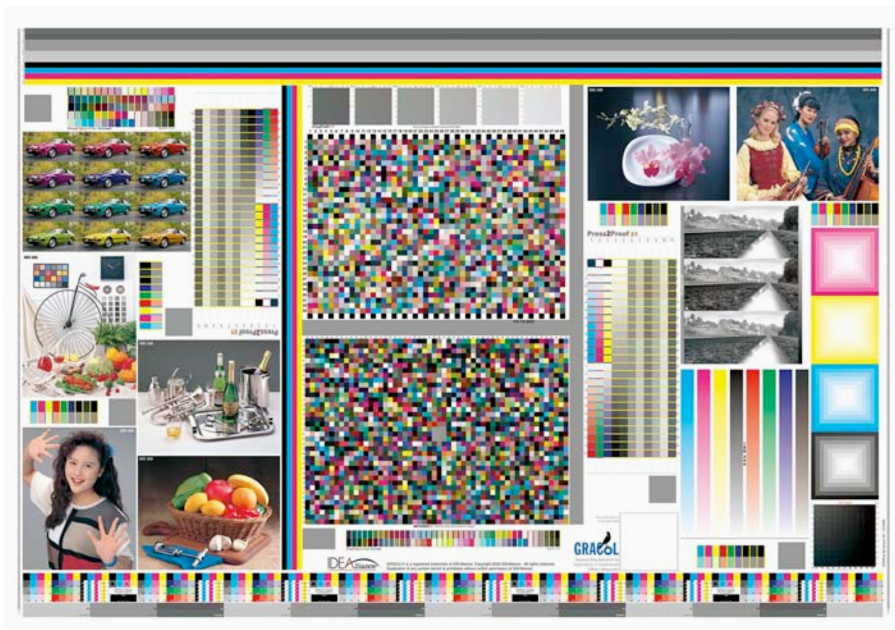
NOTE: This section refers mainly to press calibration, but is also applicable to other devices such as proofers or desktop printers

5.1 Secure all materials

Make sure all materials outlined in Section 4 are available. Remember the correct inks and paper are the most critical components to achieve the intended appearance of a GRACoL 7 commercial sheet.

5.2 Assemble the press form

A standard GRACoL 7 press form, illustrated here, can be purchased from www.printtools.org.

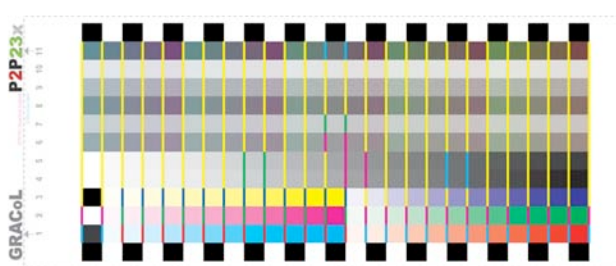


GRACoL 7 press form (be sure you have the most recent version)

If you want to make up your own form it should ideally contain;

5.2.1 P2P Target

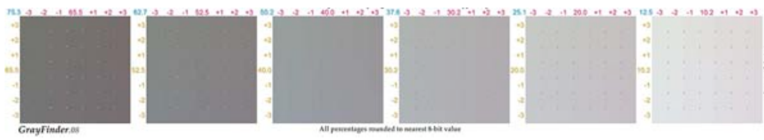
The P2P23x target or later version. On devices with uncertain evenness, for example an offset press, include two P2P targets, rotated 180° from each other, as shown in the press form above.



GRACoL P2P23xn Target

5.2.2 GrayFinder Target

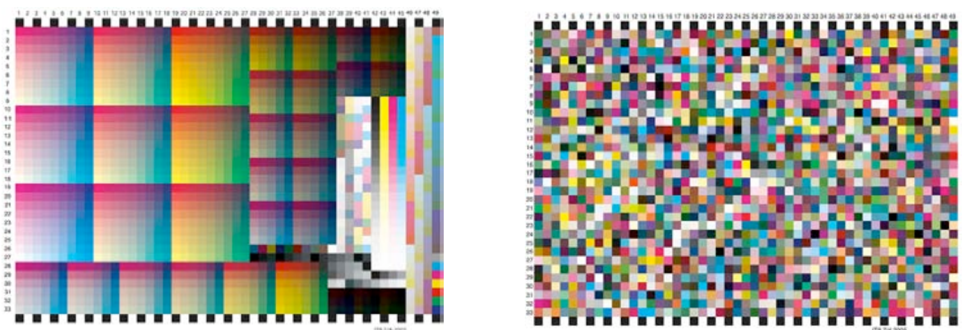
For the manual graph method, include the GrayFinder20 target (or a later version). This is not needed when using IDEAlink Curve software.



GrayFinder Target

5.2.3 IT8.7/4 Characterization Target (or equivalent)

If you plan on using the same form for characterizing or ICC-profiling the device, include at least one copy of the IT8.7/4 characterization target (or equivalent). On devices with uncertain evenness, include at least two IT8.7/4 targets rotated 180° and in line with, each other, as shown in 5.2.



IT8.7/4 Printer Characterization Target, Visual layout (Left) and Random layout (Right)

5.2.4 Gray Bars

A ½ inch (1 cm) bar of 50c, 40m, 40y across the whole sheet.

A ½ inch (1 cm) bar of 50K across the whole sheet.

5.2.5 Test Images

Some typical CMYK images, for example from the SCID image library.

5.3 Press control bars

Many existing press control bars can be adapted for use with the G7 method, or you can make up your own bar especially for G7 press control. Control bars fall into three general categories, Non-G7 complaint, Minimum G7-complaint, and Optimum G7-compliant, as follows;

5.3.1 Non G7-compliant control bars

Virtually every basic press control bar provides 100% CMYKRGB patches for solid ink measurement, and 50% CMYK patches for mid-tone dot gain (TVI) measurements. If these are the only patches available, the control bar would lack the essential 3-color gray patches necessary for G7 press control.

Basic press control bar color patches – layout may vary – (not suitable for G7 press control

NOTE: If your automated press control system or digital press does NOT permit some form of gray-balanced control, ask the supplier how this can be achieved, or add separate gray balance (HR) patches alongside the bar for manual measurement.

5.3.2 Minimum G7-compliant control bars

To make a basic press bar G7-compliant, add a mid-tone gray balance patch (HR patch) of 50c, 40m, 40y – ideally at ink-key intervals. The HR patch can replace one RGB or 50 CMY patch at each ink key. If your press control bar already has gray balance patches with slightly different values (e.g. 50c, 41m, 41y), *see 5.3.4 – Bars with non-G7 gray patches.*

Minimum G7-compliant press control bar – layout may vary – (HR_cmy patches are notched)

5.3.3 Optimum G7-compliant control bars

For maximum G7 compliance, add at least one SC (shadow contrast patch) of 75c, 66m, 66y, and at least one HC (Highlight Contrast) patch of 25C, 19M, 19Y. These patches can be added less often than the HR patch. For example after placing SID CMYK and HR patches at each ink-key, use the remaining spaces to repeat a sequence of R, G, B, 50c, 50m, 50y, SC, HC, as shown below.

Optimum G7 press control bar – layout may vary – (note SC and HC patches repeat less often than HR)

5.3.4 Bars with non-G7 gray patches

Some existing color bars already contain gray balance patches with slightly different values. For example the Brunner System Instrument Flight Colorbar uses a gray balance ratio of 50c, 41m, 41y. These control bars can be used with the G7 method so long as the target CIELab values (or target CMY density values) are modified to produce the same gray balance as if the patches were the official GRACoL 7 balance. The new target values can be determined by balancing the press on a true G7 gray patch, then measuring the non-G7 gray patch and recording it's actual CIELab or density values.

5.4 Set up the RIP

Set up the plate making RIP exactly as you would for a normal job, but clear out any values in the current calibration table, or begin with a new, empty table. The first press run is best made with 'un-calibrated' plates – i.e. no calibration values in the RIP.

IMPORTANT: Do NOT linearize the plate-setter so that measured dot values on plate exactly match original file percentages. Contrary to common belief, this may reduce accuracy of subsequent steps.

5.4.1 Screening

For commercial work, halftone screen ruling should be at least 150 lines/inch and nominally 175 lines/inch. Common screen angles are 15 C, 75 M, 0 Y, and 45 K (symmetrical dot) or 15 C, 75 M, 0 Y, and 135 K (asymmetrical dot) with K and M interchangeable.

For other printing systems check the relevant standard for suggested screen conditions.

Note that unlike TVI-based calibration, the G7 method is perfectly compatible with ANY screening system (e.g. FM or 'stochastic') without change to target values.

5.5 Check plate-making system

Check that plate-making hardware, chemistry, and RIP are within manufacturer's specs.

5.6 Exotic screening or continuous-tone systems

Exotic screening systems such as stochastic or 'FM' screening can be calibrated with the G7 method as easily as traditional AM halftone screening, but remember that color gamut is sometimes affected by screening. Continuous-tone devices can also be calibrated by the G7 NPDC method so long as separate CMYK calibration tables are available in the device RIP or driver.

5.7 Pre-adjust the plate-making system at 50% (optional)

If possible, adjust the CtP exposing unit's focus, exposure energy, or other physical parameters (including plate development) until a 50% file value measures 50% on plate. *CAUTION: Do not adjust the CtP calibration curves to achieve this condition unless delta calibration values can be added to the pre-calibration values after the calibration run. (This is easier in some RIPs than others.)*

Note that it is usually simpler to leave the CtP system in a completely un-calibrated state for the first run, even if 50% does not measure exactly 50% on plate.

5.8 Make plates for the calibration run

Produce a set of 'un-calibrated' plates of the calibration form using exactly the same workflow as you would for regular work.

5.9 Record an un-calibrated plate curve

Measure dot sizes on a test plate at 5% or 10% intervals with a video-based halftone meter, to record the baseline condition of the plate making system. These values can be used to check raw plate-maker performance any time in the future, for this particular plate type and screen ruling. Don't panic if the actual plate values Do NOT match the halftone file values at this stage. This is normal.

5.10 Check press setup

Check that the press (or whatever device you are calibrating) and its associated consumables are adjusted correctly including ink tack, ink opacity, blanket condition, blanket tension, packing, impression, fountain solution, temperature control, etc. Listing all press variables is beyond the scope of this document. Suffice it to say that the press should be in optimum physical and chemical condition.

WARNING: The G7 method will calibrate virtually any stable, repeatable device to match the pre-defined G7 NPDC and gray balance, NO MATTER WHAT IT'S CONDITION, but remember that good calibration may mask, or inadvertently encourage, 'bad' printing. For example, excessive dot gain (TVI) on one unit of a press can be compensated for by RIP curves, but the root problem will remain and may lead to poor image structure, instability, or other undesirable results.

5.11 Check measurement tools and viewing conditions

Check measuring devices are in spec and calibrated, and that press-side lighting conditions are D50. All onboard and hand-held spectrophotometers and densitometers must be calibrated and in agreement.

6 Calibration Test

NOTE: This section refers mainly to a press calibration run, but is also applicable to other devices,

6.1 Ink sequence, drying, and coating

The suggested ink sequence for offset printing is K – C – M – Y. Other sequences may cause a significant difference between your characterization data and the published GRACoL 7 Characterization Data, due to different ink trapping and opacity effects.

Presses with inter-station drying usually have better two-color saturation, but may not match characterization data created on wet-trap presses *(see Appendix G.6)*.

Aqueous coating was found to minimize drying time during the 2005 GRACoL 7 press tests. If aqueous coating is usually applied, apply the same process to the calibration run. Even if coating is only applied occasionally, calibrating and profiling with coating is usually adequate for both conditions.

6.2 Print to nominal solid ink values

Run the press up to the nominal solid ink colorimetric values (L*a*b*) or densities (SIDs) for the process being calibrated. Approximate ink CIELab values for commercial printing on coated paper are given in the table below, along with equivalent Status T densities. Devices with other Status readings can also be used in the G7 process, but will require using that device in conjunction with a spectrophotometer to determine the wet densities which produces the closest Lab value found in the table below.

NOTE: The relationship between status T ink density and Lab values shown below may not match your device, due to ink metamerism or instrument filtration. When in doubt, the Lab values take priority.

	L*	a*	b*	Approximate Density (T)	Tolerance (Density)
C	55	-37	-50	1.45	+/- 0.10
M	48	74	-3	1.45	+/- 0.10
Y	89	-5	93	1.0	+/- 0.07
*K	16	0	0	1.7	+ 0.2 – 0.05

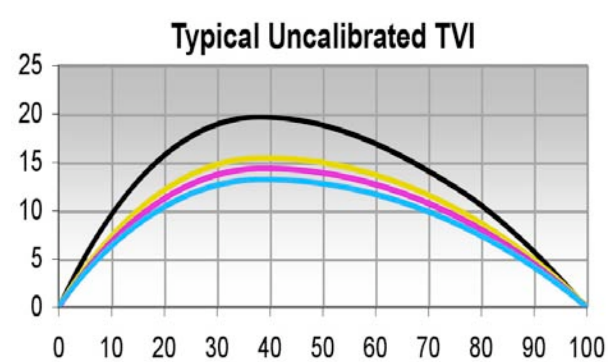
Colorimetric Values and Approximate Equivalent Status T (non-polarized) densities on a number 1 sheet (ISO paper type 1 & 2) measured with white backing

NOTE: Lower L (e.g. 12) or higher K density (e.g. 1.9) are acceptable if the k NPDC is correct.*

6.3 Check CMYK TVI

Check individual CMYK TVI values. The CMY TVIs should be within about +/- 3% of each other, with black typically about 3 – 6% higher. If possible, plot TVI curves for each ink and look for a similar curve SHAPE for each, as shown here. *NOTE: TVI values are NOT important but all inks should have relatively smooth curves.*

Right: One of many possible TVI curve sets of a healthy but un-calibrated CtP press. (NOTE: These curves are calculated by CIEXYZ and may be different from density-based TVI curves.)



6.4 Adjust device-level gray balance (optional)

With a spectrophotometer set to D50, 2°, measure gray balance at several points across the sheet on patches of 50c, 40m, 40y. The nominal gray balance for a # 1 sheet (ISO Grade 1&2 paper) is;

50c, 40m, 40y = a* 0.0 (+/- 1.0), b* -1.0 (+/- 2.0).

NOTE: At this stage the L value is relatively unimportant.*

If the 50c, 40m, 40y gray balance patch is already close to these numbers, try adjusting CMY solid ink densities (SID) within permitted tolerances to achieve the ideal CIELab gray value(s). The chart below shows how to adjust CMY ink SIDs in response to Lab error combinations. To use this chart, look for the row with the appropriate a* and b* signs, (+, -) then look in the appropriate L* column to find the suggested CMY moves, shown as up or down arrows. No arrow means no move.

a*	b*	– L*						+ L*		
–	+	▼▼	▼	▼▼▼	▼	▲	▼	▲	▲▲	▲
	+	▼▼	▼▼	▼▼▼			▼	▲▲	▲▲	▲
+	+	▼	▼▼	▼▼▼	▲	▼	▼	▲▲▲	▲	▲
+		▼	▼▼	▼▼	▲	▼		▲▲	▲	▲▲
		▼▼	▼▼	▼▼				▲▲	▲▲	▲▲
+	–	▼	▼▼			▼	▲	▲▲	▲	▲▲▲
	–	▼▼	▼▼	▼			▲	▲▲	▲▲	▲▲▲
–	–	▼▼	▼	▼	▼	▲	▲	▲	▲▲	▲▲
–		▼▼	▼	▼▼	▼	▲		▲	▲▲	▲

Chart showing how to move C, M and Y inks in response to +/- Lab errors.

If gray balance is NOT close to the target a* and b* values, or cannot be corrected with slight SID adjustments, check for excessive TVI on one or more units, improper ink hue, improper trapping (possibly due to incorrect ink tack or emulsification), or non-standard ink sequence.

If you don't want to, or cannot, adjust gray balance on press, record how the actual a* and b* values differ from the goal values (so you can check un-calibrated performance in future), and adjust gray balance via separate CMY RIP curves. *(See Section 8 'Achieving Gray Balance in RIP Curves)*

6.5 Adjust cross-sheet evenness

NOTE: This is probably the hardest part of press calibration.

Adjust the press keys until maximum solid ink density deviation at ink-key intervals across the sheet is as small as is possible, ideally no greater than +/- 0.05 deviation per solid color across the working area, and so that gray balance deviation is as small as possible, ideally no more than +/- 1.0 a* or +/- 2.0 b* across or around the working area.

Once the 50c, 40m, 40y patch measures within tolerance, use the 'Compare' feature on your Spectrophotometer (if available) or manual calculations to determine the ΔE^*_{ab} (Delta-E) difference on similar patches across the sheet. If the ΔE^*_{ab} value varies beyond 2, aim for the correct value at the 50c, 40m, 40y patch on the P2P target. If the two P2P targets on the page are more than 2 ΔE^*_{ab} different, either adjust the press to get both in tolerance or, if this is not possible, just focus on the P2P target closest to gray aims and ignore the other.

6.6 Run stabilizing speed-cycle

After achieving goal conditions, run at least 1000 sheets at typical production speed (to warm-up the press) and re-check SID, gray balance and evenness. If ink SIDs or gray balance metrics or cross-sheet evenness have decayed beyond specs, adjust the press until desired conditions are achieved, then repeat the speed cycle as needed until a 1000 sheet speed cycle produces acceptably small changes from start to finish.

6.7 Automated press control systems

If an automated ink control system is installed, it should be programmed to maintain gray balance and absolute L* of the repeating 50c, 40m, 40y gray patches in the control bar. If the system does not permit gray-based control, ask the manufacturer when it will be supported and meanwhile control gray balance manually during the calibration run, if necessary over-riding the automated system.

6.8 Record wet and dry ink values

Record the wet and dry Lab (and/or density) values of the solid (100%) CMYK inks, the CMY mid tone gray patch, and individual C, M, Y and K 50% patches. These are your target values for production work.

Remember that the ink values specified in ISO and GRACoL are DRY densities. If your dry ink values are significantly different (usually lower) than your wet densities, determine the appropriate allowance to wet values (e.g lower L* or higher density) so that the dried solid ink measurements are correct.

NOTE: Although ISO 12647-2 specifies solid ink values in CIELab units, GRACoL recognizes that many printers still find it easier to control solid ink DENSITIES. This is acceptable so long as each individual printer determines their specific density to CIELab equivalency, by measuring samples of correct CIELab values on their own specific paper and inks with their own specific measuring instrument(s).

7 Adjusting NPDC Curves

This section describes how to determine the RIP correction values from the P2P target that will force the printing device to match the specified G7 NPDC curves.

7.1 Allow sample sheets to dry

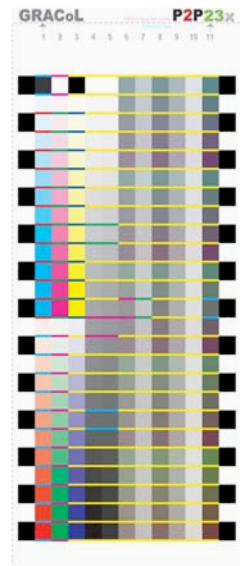
Set aside several good sheets to dry prior to measuring.

7.2 Measure the P2P target

From one or more good calibration sheets (as close to target goals as possible after drying), measure the K-only gray scale (column 4) and CMY-only (column 5) of the P2P target. The latest target (P2P23x) lets you measure manually or with an automated device such as the GretagMacbeth EyeOne Pro or X-Rite DTP70. For the graph-paper method, automated measurement files must be converted to Neutral Density values.

Measure at least two sets of scales from different parts of each sheet and average the readings.

NOTE: If taking manual readings with a hand-held densitometer, set the display to 'visual density' and zero on the substrate or paper base. If you cannot zero the densitometer on the substrate, subtract the substrate density (measured in a clear white area) from all density readings.

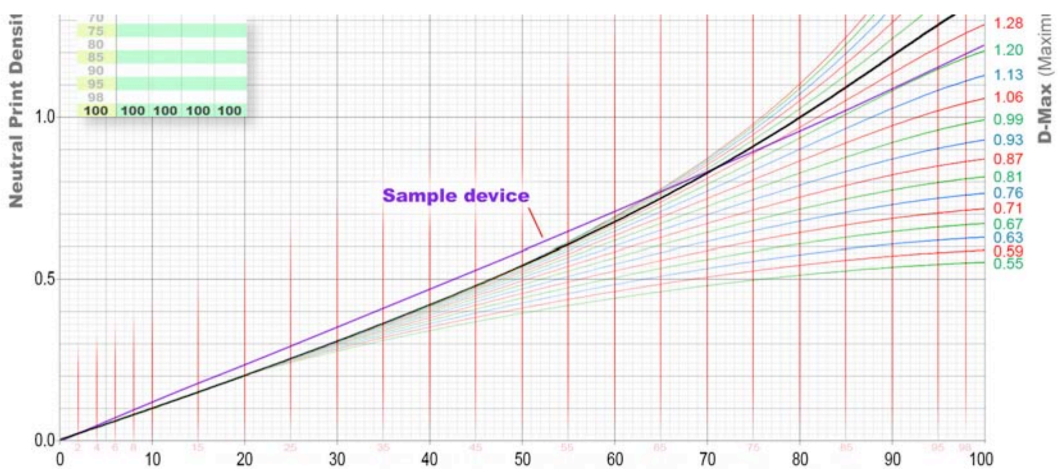


P2P23x Target

7.3 Plot the curves

NOTE: If using IDEAlink Curve proceed to step 7.7

Plot the graph of column 5 as neutral density vs-dot% on the CMY graph paper. For convenience, the red vertical lines on the graph paper correspond to each percentage step in the P2P target.

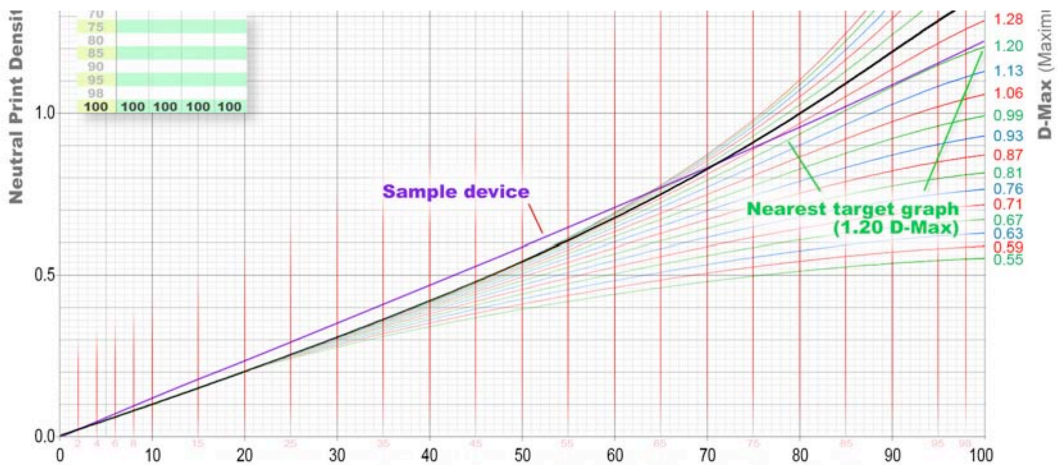


Typical sample graph compared to the G7 CMY Target graph

Repeat for K on a separate sheet of graph paper.

7.4 Find nearest target graph with same D-max

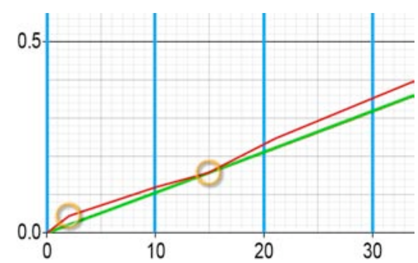
Find the target graph nearest to the D-max (Maximum Neutral density) of your graph. If your device is not close to any of the pre-printed graphs, use the two nearest graphs (higher and lower D-max) to assist in re-drawing a new reference graph that parallels its neighbors and precisely meets your device curve at 100%.



Finding the target graph that meets your sample graph at 100%

7.5 Choose the optimum curve points

Examine the graphs and decide how many 'curve points' are needed - typically wherever your curve bends significantly. For example, the curve at right requires points at 2% and 15%, and ideally at 10% and 20%, for maximum accuracy.



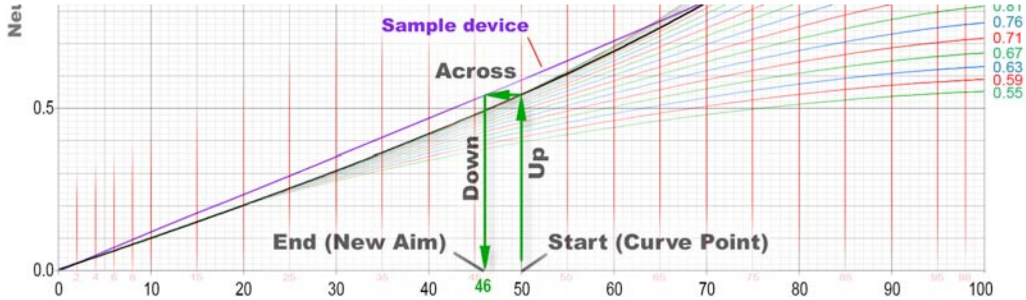
The green line shows how profiling software falsely interprets real performance (red) from 10%-spaced data (blue) unless extra curve points (circled) are added.

NOTE: Some RIPs require specific curve points. Fewer points may reduce the chance of banding, but extra precision is often needed in lighter tones.

7.6 Calculate the RIP curve correction values

For each curve point on the graph paper (or curve points for your RIP) do the following:

- Draw a vertical line *UP* to meet the target graph.
- From there draw a horizontal line *ACROSS* (left or right) to the device graph.
- From there draw a vertical line *DOWN* to the bottom axis to get the 'new aim value.' Record that in the 'new aims value' column on the graph paper.
- Repeat for each curve point except 0% and 100%, which never change.



Finding the New Aim for a 50% Curve Point by the 'Up-Across-Down' method

7.7 Correcting gray balance in RIP curves

The G7 CMY graph sheet assumes the device is already gray-balanced via SID adjustments or some other means. In this case, one common RIP curve should be calculated for CMY, with a separate curve for black. If you could NOT achieve gray balance at the device level (e.g. on the press), follow the steps in Section 8, to produce separate RIP correction values for Cyan, Magenta, and Yellow.

7.8 Apply new aim values to RIP or CtP device.

Apply the new aim values from your worksheet to the RIP or calibration utility. Note that some RIPs require you to enter 'Measured' values instead of 'Wanted' values, while other RIPs ask for delta values. This method assumes you know how to modify the New Aim values accordingly. When in doubt, remember the new aim value is what each curve point should be AFTER correction.

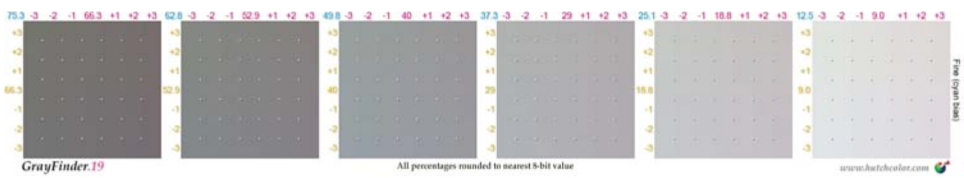
8 Achieving Gray Balance in RIP Curves

The first part of this section explains how evaluate gray balance manually using the GrayFinder target and graph paper. (*If using IDEAlink Curve, go to step 8.5 'Correcting Gray Balance in IDEAlink Curve')*

WARNING: This process requires considerable patience and attention to detail. If you do not feel comfortable attempting it, just apply one common curve to C, M and Y or use the IDEAlink Curve software to calculate gray balance corrections automatically.

8.1 Find the 'most neutral' patch in the C = 50% block

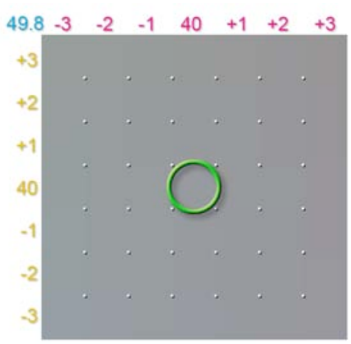
If you could not achieve gray balance on press (for example with altered SIDs) you can achieve gray balance by creating separate RIP or CtP curves for C, M and Y. The following process describes one method of doing this, using the GrayFinder target printed on the calibration run.



The GrayFinder target

With a spectrophotometer, measure the central patch in the nominal 50% (actual 49.8%*) Cyan block of the lower half of the GrayFinder Target.

*NOTE: 49.8% is the nearest true percentage to 50% in an 8 bit image - (see Appendix D)

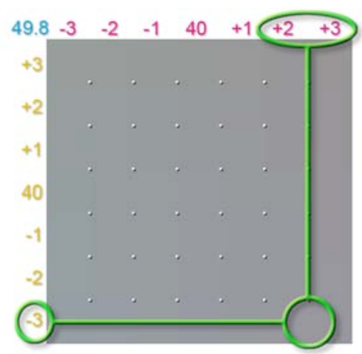


Also measure the neighboring patches and look for the one closest to the 'target gray' value (e.g. 0 a*, -1 b*). Sometimes the best reading will be found by straddling two patches with the measuring instrument. If the center patch is nearest to target gray, the device is already gray balanced (at 50% Cyan), and no corrections are needed.

Good balance: Center patch measures 'target gray'

If the patch nearest to the target a* b* values is NOT the center patch, make a note of the Magenta and Yellow percentages aligned with that patch. For example, if the best measurement was found by straddling the +2 and +3 Magenta columns on the -3 Yellow row, good gray balance requires +2.5 M and -3 Y.

Bad balance: Neutral gray requires + 2.5% M, - 3% Y



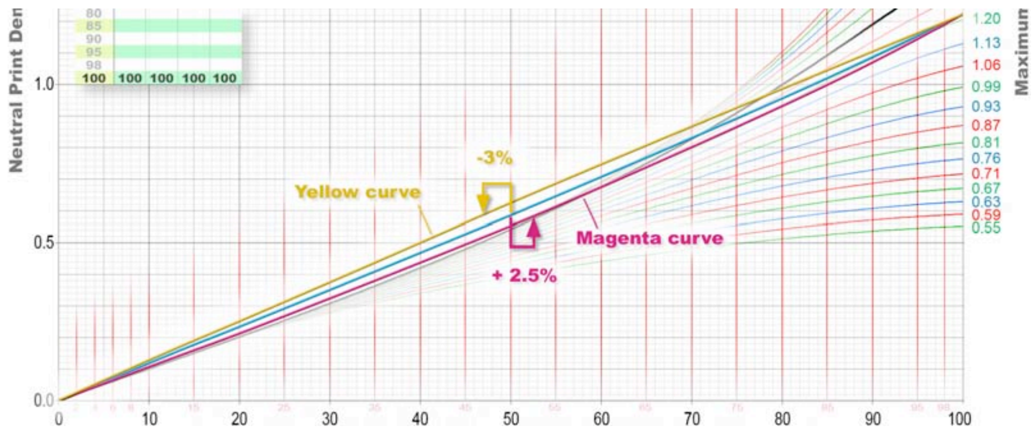
8.2 Repeat for other cyan percentages

If the gray balance error is not consistent throughout the CMY gray scale, you can make complex CMY curves with different correction ratios at different density levels, by repeating step 8.1 for the 75%, 62.5%, 37.5%, 25% and 12.5% blocks.

NOTE: It is STRONGLY RECOMMENDED that only the 50% block is used to calculate gray balance curves for offset presses, or any other device on which gray balance is inconsistent or hard to measure.

8.3 Draw new curves for Magenta and Yellow

On the CMY graph paper, draw separate M and Y curves, offset to the left or right of the original (Cyan) graph by the percentages discovered in the GrayFinder test.

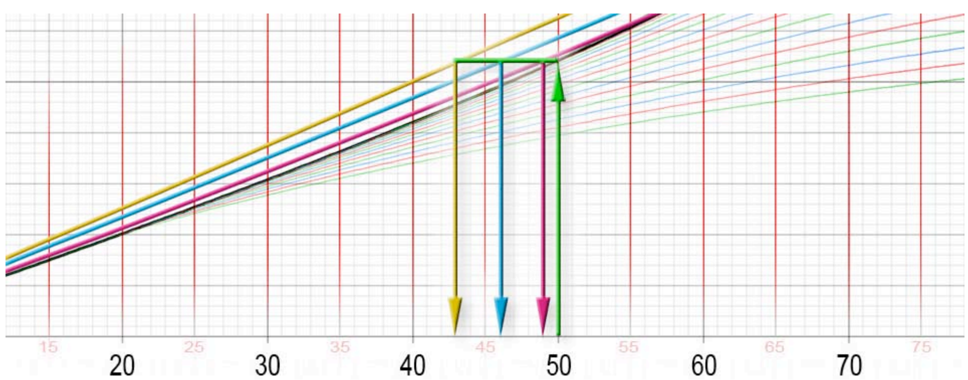


M and Y graphs offset right and left by correction values from the GrayFinder target

8.4 Find new aim values for Cyan, Magenta and Yellow

For each curve point:

- Draw a vertical line *UP* to meet the target graph.
- Draw a horizontal line *ACROSS* to intersect the C, M, and Y graphs.
- Draw *separate* vertical lines *DOWN* to get three 'new aim values', one each for C, M, and Y.
- Record the CMY aims in the 'new aims value' columns on the graph paper.
- Repeat for each curve point except 0% and 100%, which never change.



Finding separate CMY Aim Points

NOTE: Modifying the CMY graphs separately may reduce NPDC accuracy, but usually within tolerances.

8.5 Correcting Gray Balance in IDEAlink Curve

8.5.1 Switching gray balance on and off in IDEAlink Curve

Gray balance correction can be switched ON (default condition) by checking the Gray Balance button in the Create Curves window. When the Gray Balance button is checked, IDEAlink Curve calculates separate gray balance correction curves for C, M and Y.

Gray balance correction can be switched OFF by un-checking the Gray Balance button in the Create Curves window. When the Gray Balance button is un-checked, IDEAlink Curve calculates identical CMY curve values based only on the NPDC curve aims.

8.5.2 Changing the gray balance basis color

Gray Balance can be based on the color of the actual paper the P2P target was printed on by clicking Gray Options.. and checking the Paper White button. Alternately, gray balance can be based on an arbitrary paper color (for example the paper color of the characterization data you are trying to imitate) by clicking Custom White and entering the a* and b* values manually.

8.5.3 Smoothed gray balance

By default IDEAlink Curve produces 'smoothed' gray balance curves based on an averaged analysis of the whole CMY gray scale. This minimizes the possibility of unwanted side-effects on devices whose gray balance is unstable - particularly offset presses. By un-checking the Smoothed Gray Balance button you will create more complex CMY correction curves based on the separate errors discovered at 12.5%, 25%, 37.5%, 50%, 62.5% and 75% cyan values.

CAUTION: Switching off Smoothed Gray Balance is only recommended if the device has a highly stable and repeatable gray balance error. It is usually safe to switch smoothed gray balance OFF for ink jet printers and laminate-based pre-press proofing systems. It is usually best to leave Smoothed Gray Balance ON for offset presses.

8.6 Apply new aim values to RIP or CtP device

Apply the new gray-balanced aim values from your worksheet to the RIP or calibration utility. Note that some RIPs require you to enter 'Measured' values instead of 'Wanted' values, while other RIPs ask for delta values. This method assumes you know how to modify the New Aim values accordingly. When in doubt, remember the new aim value is what each curve point should be AFTER correction.

8.7 When NOT to apply gray balance in RIP curves

Gray balance should NOT be corrected in RIP curves if;

- The device is already nearly neutral.
- You feel it can be neutralized next time you print by simple adjustments, for example by modifying CMY ink quantities (usually true in offset printing).

9 Verification/Characterization Test

This section allows you to (a.) verify the calibration worked correctly, and (b.) create an optional characterization data set from your G7-calibrated device, from which a custom ICC profile can be produced. The ICC profile can be used for custom proofing purposes *(see sections 10, 11 and 12)* and/or for creating custom CMYK files that are optimized for your device.

NOTE: This section refers mainly to press calibration, but is also applicable to other devices

9.1 Make new characterization plates to G7 spec

(For non-plate devices - e.g. proofing systems - go to step 9.2.)

Create new plates of the same test form using the new RIP curves and compare the plate values on the P2P target to the un-calibrated plate curve recorded in section 5. Make sure the required changes have been achieved. For example, if the 50% Curve Point had a 55% Aim Value, check that the 50% patch on the new plate is approximately 5% heavier than the un-calibrated plate.

NOTE: Due to difficulties measuring a plate's surface, exact percentages are not necessary, so long as the values are approximately correct.

9.1.1 What if the plate values don't match the file values?

The G7 process is specifically designed to be independent of variations between requested and achieved plate values. So long as the plate making process is consistent and repeatable, the actual measured plate values DO NOT have to match the values predicted by your graph paper or IDEAlink Curve software. The G7 graphing process and IDEAlink Curve work on the original digital file values prior to plate exposure, not the actual measured plate values.

CAUTION: DO NOT adjust the graphs or IDEAlink Curve percentages to match the measured values on plate. This can actually reduce accuracy!

9.2 Print the characterization target

Print the characterization target (ideally the whole test form) using the new plates or RIP curves, and the same conditions as the calibration test. Aim for the same wet Lab values (or densities) recorded at the end of the calibration run. Pay particular attention to cross-sheet evenness and gray balance.

9.3 Characterization tolerances

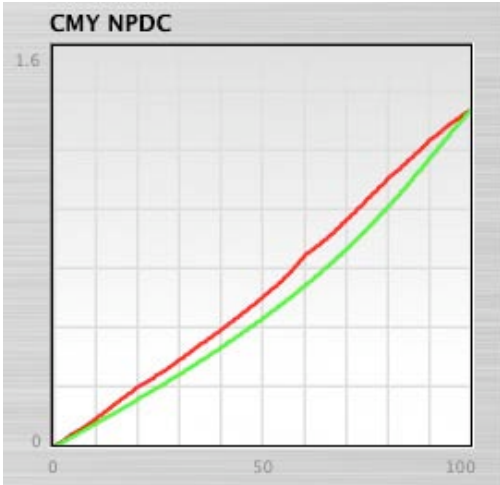
(See Appendix G for a more detailed discussion of tolerances.)

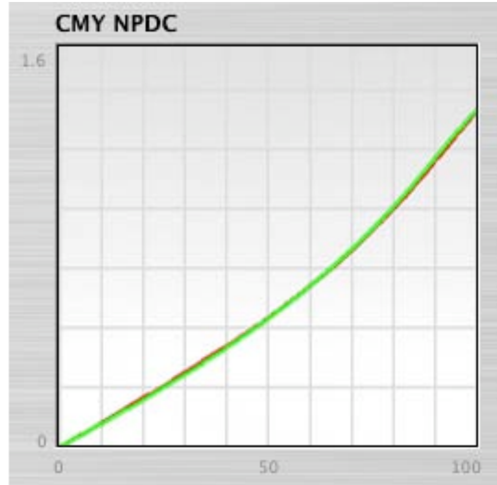
No single set of tolerances can be applied to all devices or processes due to the wide variation of inherent stability and consistency. The one universal rule is that characterization tolerances should be stricter than production tolerances, because a characterization print must represent the nearest possible thing to 'perfection' the device is capable of. In many cases this accuracy will be impossible to achieve in a single print, especially on offset presses, but may be achievable by averaging several prints made on different days or times.

A good general rule is that characterization tolerances should be roughly half as wide as normal production tolerances. For example, if gray balance tolerances for production work are +/- 1 a* and +/- 2 b*, characterization tolerances for that device should be +/- 0.5 a* and +/- 1 b*.

9.4 Confirm goal curves

During make-ready, measure the HR, SC and HC values to be sure the press is meeting the NPDC curves. If possible, also measure the P2P target and either plot columns 4 and 5 manually on a fresh sheet of G7 graph paper, or check the curve fit in IDEAlink Curve software. Your graph should overlay the target graphs almost perfectly. If not, try adjusting SIDs, or run more sheets until the press warms up.





An offset press before G7 calibration (left) and after (right) showing NPDC calibration

9.5 Verify gray balance and other parameters

Check that other parameters like gray balance, cross-sheet evenness, etc., are still in spec, then run a 'live sample' of at least 1000 sheets at high speed and check that metrics are still good at the end of this speed run.

9.6 Select samples

Select a sampling of two or more good sheets from the live sample run and allow them to dry naturally. If possible, make two or more separate press runs under similar conditions and select the best sheets from each run for subsequent averaging.

9.7 Measure characterization data

Measure characterization data from each of the selected sheets with a spectrophotometer, then build an ICC press profile from the averaged data. If possible, save the original measurement data in spectral format rather than $CIELab_{(D50)}$. With suitable software and spectral data measured from a specific light source, spectral characterization data can yield an improved ICC profile that reduces the metameric problems caused by non-standard viewing conditions, or variations between standard light sources.

9.8 Realistic expectations

Remember that the act of characterizing a device is far more significant than any normal print run. The printed sheet from which the characterization data will be measured must be as 'perfect' as possible, in all visual terms, including solid colors, gray balance, NPDC and trapping, and these characteristics should be as even as possible across the whole sheet, or at least the area of the characterization target.

Offset printing is much harder to control consistently and evenly than a typical proofing system. Even the best press operated by the most experienced workers under ideal conditions can vary considerably from run to run, due to small changes in materials, temperature, humidity, length of run, etc. The chances of a 'perfect' press sheet from any particular offset press run are very small.

If gray balance and other tolerances cannot be controlled precisely during the characterization test, aim for the best possible result but remember that the resulting characterization data will probably NOT represent the average performance of the device being characterized. In this case either use the standardized characterization data for that printing type - e.g. GRACoL 7 Characterization Data - or repeat the characterization process several times over a period of days or weeks and average the results.

10 Proofer Calibration and Profiling

This section describes how to calibrate a proofing system by the G7 method, and how to use color management (e.g. ICC profiles) to further optimize the proofer's match to an official reference characterization data set like GRACoL 7 Characterization Data, or a custom ICC profile.

NOTE: G7 proofer calibration is almost identical to G7 press calibration. This section is therefore a supplement to the preceding sections, with notes like '(see 7.1)' to save space.

10.1 What proofers are compatible with G7?

Pre-press proofing systems driven by a conventional RIP can be calibrated using a variant of the G7 press calibration procedure, and then (if necessary) color-optimized using ICC profiles or device-links for a closer match to a reference characterization data. Proprietary proofing systems with no user-accessible CMYK calibration LUTs may not be suitable for the G7 calibration, but should still be capable of a good color match to the reference characterization using ICC profiles or equivalent color management.

Your proofing system may require some modification to these instructions but the end conditions are the same for any device. If your proofing system is not compatible with these methods, ask your vendor how to match the target specifications.

10.2 Workflow summary

- Qualify the proofer
- Print the proofing targets
- Measure the Press2Proof (P2P) target
- Plot the curves or load the measured data file in IDEAlink Curve software
- Determine gray balance corrections (if needed) using the GrayFinder target. or the gray balance options in IDEAlink Curve
- Apply correction points to the proofing RIP, if necessary with three separate curves for CMY to achieve gray balance
- Test by re-printing and re-analyzing the P2P target
- Create and apply ICC profiles (if needed)
- Test color matching quality

10.3 Qualify the proofing system

Make sure the proofer;

- Is stable and repeatable
- Prints evenly across the whole image area
- Is not subject to short-term color changes or fading
- Uses a white substrate within tolerances of the target characterization or standard
- Can yield a color gamut equal to or greater than the target characterization data
- Can yield strength of black equal to or darker than the target characterization data

A good way to check color gamut and dynamic range is to create an ICC profile of the proofer with color management off and compare it to the target characterization data in a utility like CHROMiX ColorThink. If the target profile is larger than the proofer profile, some colors may not proof correctly.

10.4 Optimize the proofing system

Optimize the proofing system following the manufacturer's instructions, with the following exceptions;

- If the instructions ask you to calibrate individual CMYK scales, GRACoL recommends omitting this stage and leaving the curve tables in an uncalibrated state, EXCEPT if the proofer provides two or more calibration utilities, one for basic 'linearization' and another for user-editable curve adjustment, OR if this is an ink-jet device and the manufacturer's calibration produces ink-limiting tables.

- If multi-stage calibration utilities exist, perform the manufacturer's recommended linearization method as a base-line calibration, and use the user-editable curve adjustment to implement G7 NPDC and gray balance calibration.
- If the manufacturer's instructions involve any kind of ICC-based or custom color management, disable this function during G7 calibration.

IMPORTANT: Make sure any ICC or other color management functions are turned OFF prior to G7 calibration. (These should be re-enabled after the calibration and profiling process is completed.)

10.5 Print the proofing form target

Print either the GRACoL 7 Press Form (www.printtools.org) or your own version of it *(see 5.2 Assemble the press form)*

10.6 Measure the Press2Proof (P2P) target

Measure the K-only gray scale (column 4) and CMY-only (column 5) of the P2P target.

(see 7.2)

10.7 Plot the curves

(see 7.3)

10.8 Align end-points at 100%

(see 7.4)

10.9 Choose the optimum curve points

(see 7.5)

10.10 Calculate the RIP curve correction values

(see 7.6)

10.11 Evaluate and adjust gray balance

(See section 8)

Unlike presses, most proofers do NOT allow gray balance adjustment by physical changes. Proofer gray balance is typically achieved EITHER with three separate RIP curves for C, M and Y, OR with a 4-D transform (using ICC profiles or some other color management system).

If the proofer already requires ICC profiles (or equivalent) for color matching, there may be less advantage in calibrating the proofer to G7 gray balance and NPDC curves, but if the proofer is capable of approximating a commercial press WITHOUT a 4-D transform (true of most halftone digital proofers) then calibrating to G7 gray balance and NPDC curves should optimize quality, even without further color management.

10.11.1 Gray balance precision

When calculating gray balance corrections for a proofer (or any other stable device) by the graph paper method, every block in the GrayFinder target should be used. When using IDEAlink Curve, switch OFF ‘Smoothed Gray Balance’ under ‘Gray Options..’

10.12 Apply new aim values to RIP

(Section 8)

10.13 Evaluate accuracy in neutral gray areas

Print a qualifying proof of the same form and measure the P2P target to assure that you have made the intended corrections. Plot the NPDC curves again on fresh sheets of graph paper or load the measurements into IDEAlink Curve. Your measured data should overlay the pre-printed lines virtually perfectly from 0% to 50%. If your D-max values are different from those on the pre-printed graphs, your lines should still follow the same basic curve, but just lower or higher than the pre-printed lines.

Also check gray balance by measuring the center patches of the GrayFinder target. The most neutral patches should ideally be the center patch, or no greater than one row or column away from the center patch. So long as your qualifying proof passes the above tests, proofed images should now exhibit a very close visual match in neutral gray tones to images printed on a press using the same G7 calibration goals.

10.14 Evaluate match in colored areas

At this stage your proof's ability to match the target characterization data in colored areas will depend on how well your proofer's colorants simulate the behavior of actual offset printing inks. Colored areas will usually be different due to differences in colorant hues or saturation, or in how the proofing colorants 'trap' to each other compared to press inks. Even if the individual proofing colorants have the exact colorimetric values specified in the target characterization, two- and three-color overprints will often appear different from an actual press sheet.

One way to test this is to compare the measured IT8.7/4 characterization target from your test proof with the target characterization data in a program like CHROMiX ColorThink™, GretagMacbeth MeasureTool, or Alwan ColorPursuit™. A more visually-intuitive test is to create a profile of your proofer and assign it to an image of the CMYK profiling target in Photoshop with View - Simulate Paper Color selected, then switch between your proofer profile and a profile made from the target data*. If you cannot see a difference on screen, your proofer probably doesn't need any further color management.

**This is much easier in Photoshop CS or earlier. Photoshop CS2 requires the more tedious changing of profiles in the View - Proof Setup - Custom dialog.*

10.15 Solve remaining color errors via ICC profiles (if needed)

If you detect significant color errors, (even when gray tones are satisfactory) the most practical way to solve these errors is by creating an ICC profile of the proofer in its calibrated state, and using a profile generated from the GRACoL 7 Characterization Data as the 'source' device in a standard ICC proofing workflow or 'device link'.

For details on how to set up your proofer to use ICC profiles or device links, see the instructions that came with the proofing system, or contact the supplier.

10.16 Testing ICC profiles before installing in a RIP

Note that not all proofing RIPs use the same CMM or color 'engine', and not all produce the same result from the same ICC profiles.

Before creating an automated RIP setup, always test your profile quality by;

- Assigning the source profile (e.g. made from GRACoL 7 data) to a test form in Photoshop.
- Converting the form to your new proofer profile using absolute (or relative) intent.
- Printing the resulting converted CMYK file to the proofer with the RIP in the same state as when you printed the profiling target, i.e. with all color management disabled (off).

If the results are good, install the profiles (or a device-link profile) in the RIP and produce a second proof using in-RIP color management. The two proofs should be identical. If not, check your work or contact the RIP vendor for assistance.

11 Custom-Calibrated and Non ICC-Compatible Proofers

Ink-jet, dye-sublimation, and other non-halftone proofing systems often use proprietary software to calibrate the printing hardware, reinforced by ICC profiles or equivalent proprietary color management. These systems may not be easily adaptable to the G7 press calibration method, but a good match to GRACoL 7, or any other characterization, should still be possible so long as the system can be made to simulate an ICC profile made from the target data.

If your proofing system uses a custom color calibration system that is *incompatible* with ICC profiles, ask the supplier how to make a certified proof for that target. If the supplier cannot help, the last option is to create an ICC profile of the proofing system in its vendor-approved state, then convert incoming files from a target profile to the proofer profile in a RIP or color conversion utility up-stream of the proofing system.

An example of this 'extreme desperation' approach, which might suffice for occasional use, would be to pre-convert individual CMYK images from a target profile to your proofer profile in Photoshop, using Relative or Absolute Colorimetric Intent, then send the converted file to the proofer. Photoshop's 'Print With Preview' option can also be used for occasional, RIP-less proofing, or for testing the proofing quality of a pair of profiles *(see 10.16).*

12 Soft Proofing (Video Proofing)

12.1 Basic requirements

Today's ICC color management allows a good CRT or LCD monitor (or even a high-quality video projector) to display a very close simulation of a printed press sheet, under proper ambient lighting. But achieving an optimum soft proof is not as easy as it might seem. Minimum requirements include;

- A wide-gamut, high-contrast monitor in good condition
- An accurate ICC profile of the monitor
- A good ICC profile created from the device or characterization data to be imitated
- Software capable of converting a CMYK image from the source profile (press) to the display profile in absolute colorimetric mode – for example Adobe Photoshop
- A controlled viewing environment in which the monitor is the brightest element in the observer's field of view, and in which the ambient lighting in which the press sheet or proof is compared to the screen is the same 'color' and brightness as the monitor white point – for example a dimmable D50 viewing booth like GTI's SOFV-1e.

12.2 Soft proofing in Adobe Photoshop

With some effort, a good soft proof can be displayed in Adobe Photoshop™ 7 or later using the equipment, profiles, and conditions listed above, but Photoshop does not display CMYK files accurately by default. Simply assigning the right profile to a CMYK image in Photoshop produces a 'pleasing' image in which white and black contrast, paper color and maximum ink density may be inaccurately displayed.

The following suggestions will help you display CMYK files more accurately in Photoshop;

- For greatest soft proofing convenience use Photoshop CS, not CS2.
- Create a large white (0,0,0,0, CMYK) image and assign your target profile to it.
- In Photoshop CS select View - Proof Setup - Simulate Paper White.
- Make sure the monitor hardware is set to maximum brightness, except when matching one monitor to another alongside it, in which case set the dimmer monitor to maximum brightness and reduce the brighter one to match it.
- Adjust the dimmable viewing booth alongside the monitor so that a piece of white paper (same as used to make the CMYK profile) in the booth matches the brightness of the blank white CMYK image on screen.
- Create an ICC Version 4 monitor profile with software that allows precise manual white point adjustments, for example MonacoOPTIX Pro or ColorEyes Display.
- Calibrate the monitor white point till the white CMYK image is the same color as the paper. This is relatively easy in monitor profiling software that allows custom 'x' and y' white point adjustments, but difficult or impossible in software that provides only traditional selections like 'D50, D65' or '5000K, 5500K, 6000K, 6500K'.
- If possible, use the 'Measure' option to measure the viewing booth light source with the same sensor used to measure the monitor.
- After adjusting monitor white point, the viewing booth's intensity may have to be re-adjusted.

12.2.1 Optimizing black point

In theory, the most accurate Photoshop soft proof is achieved with 'Simulate Paper Color' (CS2) or 'Simulate Paper White' (CS) and/or 'Simulate Ink Black'. Without any of these options dark black areas may be too dark on screen, but when these options are chosen dark black areas may be too light instead. The problem is meant to be solved with Version 4 profiles but apparently not in all cases.

If your soft proof's dark areas are still too dark or to light, even with Version 4 profiles and the above settings, try adjusting the monitor's hardware contrast (black point) after creating the profile. If your profiling software allows curve editing (e.g. MonacoOPTIX Pro), try darkening the black end of the RGB video LUTs slightly while viewing with Simulate Paper White (CS) or Simulate Paper Color (CS2) selected until the displayed soft proof matches the shadow contrast of an actual proof in the accurately-dimmed viewing booth.

12.3 Remote soft proofing

'Remote soft proofing' which lets observers in different cities or buildings simultaneously view the same file in accurate color, is provided by several manufacturers, including (at the time of writing - listed alphabetically) Dalim, ICS and Kodak. These proprietary systems usually dictate the calibration and viewing conditions as part of the software / hardware package.

Appendix A: Production Press Control

NOTE: This process assumes all separations, plates and proofs have been made in an ICC workflow based on standard Characterization Data and G7 calibration.

The G7 press control method is similar to conventional press control, with CMYK solid-ink readings (in CIELab or equivalent densities) as a starting point, followed by mid-tone readings to monitor tone shape. The difference is that traditional TVI readings are replaced with absolute ND (or Lab) 'HR' readings, and traditional Print Contrast calculations are replaced with absolute ND (or Lab) 'SC' readings. This approach monitors gray balance and lightness more reliably than TVI readings, and with less chance of mid-tone density or gray balance variations, however because gray balance is typically less stable than TVI values, be prepared for wider deviations throughout the run.

Note also that this method of press control is quite new, with no well-established history of acceptable tolerances. Be prepared to experiment over time to establish the optimum tolerances for your equipment, conditions and expectations *(see Appendix G).*

A.1 Run press up to nominal ink levels

Begin by running the press to specified ink colorimetric values *(see Appendix H)* or SIDs. Remember that CIELab values take priority over density values. Once make-ready is complete, RELATIVE densitometry (based on reading a good sheet with your densitometer) remains a valid and efficient basis for run-time press control, and the same density goals can be used to make-ready future runs – at least for that specific paper/ ink/ densitometer combination.

A.2 Adjust gray balance, HR_cmy and SC_cmy

Adjust solid ink densities or other press variables within permitted tolerances till the HR_cmy patch (50c, 40m, 40y) is as close as possible to the a* and b* gray balance aim values, and ND or L* aim value. Also check that the CMY SC patch (75c, 66m, 66y) is as close as possible to the SC_cmy aim value. Some compromise will usually be necessary due to normal press variations, but try and share any error evenly between HR and SC patches.

A.3 Adjust HR_k and SC_k

Adjust black solid ink density or other press variables till the K HR patch (50k) is as close as possible to the nominal HR_k aim. Also check that the SC_k patch (75c, 66m, 66y) is as close as possible to the nominal SC_k aim value. Some compromise will usually be necessary due to normal press variations, but try and split any error evenly between HR and SC patches.

A.4 Nominal HR, SC and HC aim values

The chart below shows nominal aim values for HR, SC and HC for paper with a 95 L* value. These values assume the new G7 50k < 50,40,40cmy convention introduced in February 2006.

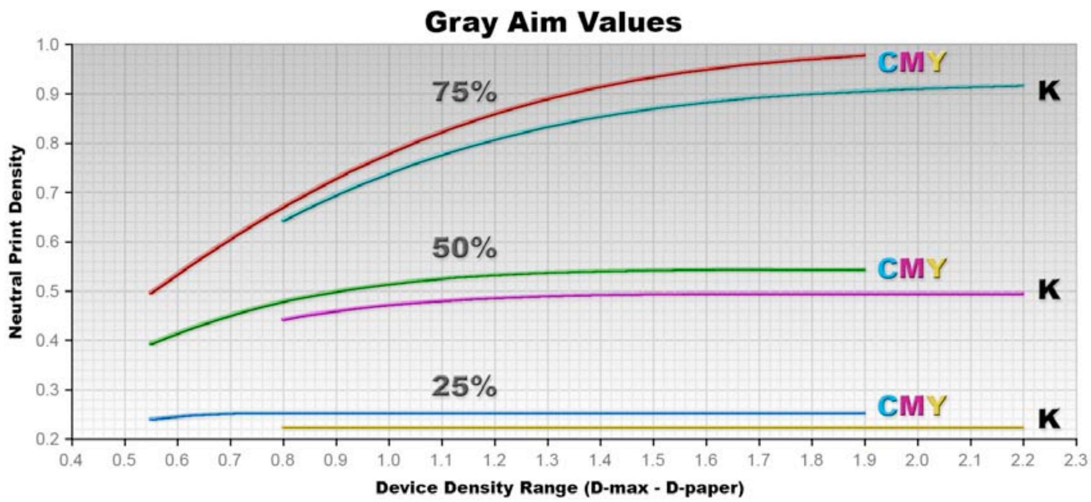
Gray Patch	Minus Paper (ND)		With Paper (ND)		With Paper (L*)	
	CMY	K	CMY	K	CMY	K
25% (HC)	0.25	0.22	0.31	0.28	75.7	77.7
50% (HR)	0.54	0.50	0.59	0.55	57.5	59.9
75% (SC)	0.90	0.90	0.96	0.96	39.5	39.7

Nominal gray patch aim densities and L values for GRACoL #1 grade (ISO Type 1 & 2) paper*

NOTE: If you prefer the 2005 G7 specification with same NPDC for K and CMY, use the CMY aim values for black, and/or the CMY graphs in A.5, but remember this is not acceptable in official GRACoL 7 or SWOP implementations, and will darken the black plate slightly more than 'normal'.

A.5 HR, SC and HC aim values for other dynamic ranges

Aim values for other printing types depend on the dynamic range of the device, as shown below. Note that while SC (75% curve) varies continuously as a function of Device Density Range, HR (50% curve) is approximately constant for typical offset Density Ranges (1.3 and higher), and HC (25% curve) is approximately constant for density ranges of 0.7 or higher.



Graph showing HR, SC, and HC aim values for devices with different dynamic ranges

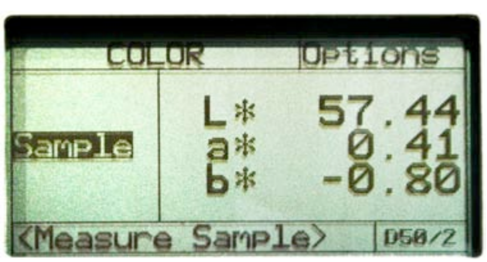
NOTE: If you prefer the same NPDC for K and CMY, take black aim values from the CMY graphs.

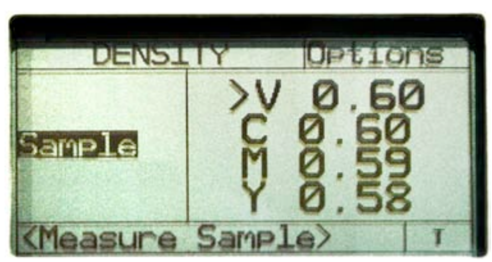
A.6 Maintaining gray balance by CIELab

Throughout the run the same L*a*b* values should be maintained on the CMY gray and 50K patches. If gray balance and SIDs move in a similar direction, small SID adjustments (see chart in 6.4) should restore gray balance.

A.7 Maintaining gray balance by CMY density

Another way to control gray balance is by recording the C, M and Y densities of a balanced CMY gray patch at make-ready, then maintain the same readings throughout the run. This approach may not be reliable for make-ready, because of densitometer variations, but it is sufficient for run-time control because ink adjustments are directly indicated by CMY density variations.





Left: A typical in-tolerance gray balance reading in Lab. Right: The same gray patch measured in CMY density mode, showing typical equivalent densities – (both with paper included).

CAUTION: The sample readings illustrated above are for illustration purposes only, and do NOT represent actual aim values.

Appendix B: G7 FanGraph Paper

The following two pages contain G7 graph paper for calibrating a wide range of presses and proofers to either the new GRACoL specifications, or the new 2006 SWOP specifications. Print several sheets of each page prior to calibrating a device. Full-sized JPEG images of these graphs are available free at www.gracol.org.

B.1 Changes since the last edition

Changes to these graphs since the last edition of this document are described below. Please destroy older versions of the graphs dated earlier than June 2006.

WARNING: Do NOT use graphs dated earlier than June 2006, or incorrect calibration may result.

B.2 NPDC FanGraphs (CMY and K)

Instead of a single curve per graph sheet, the new graphs contain 20 separate pre-printed curves in alternating red, green, and blue lines, spanning a wide range of possible D-max values. Nominal CMY and K graphs for typical commercial paper are printed in black.

The 'FanGraph' design simplifies or eliminates the process of re-drawing the target graph when the device being calibrated does not have the same D-max (neutral density at 100%) as the nominal target graph.

To use the new graphs, first draw your device graph then take corrections from whichever colored graph most closely matches your device's D-max. If your device is not close to any of the pre-printed graphs, use the two nearest graphs (higher and lower D-max) to assist in re-drawing a new reference graph that parallels its neighbors and precisely meets your device curve at 100%.

NOTE: Since the last version of this document, small changes have been made to the shape of the nominal CMY and K graphs to align them to a new mathematical model of 'natural' CtP performance. These changes are very small and should produce little or no visual difference compared to pre-June 2006 calibrations.

B.3 Possible future changes

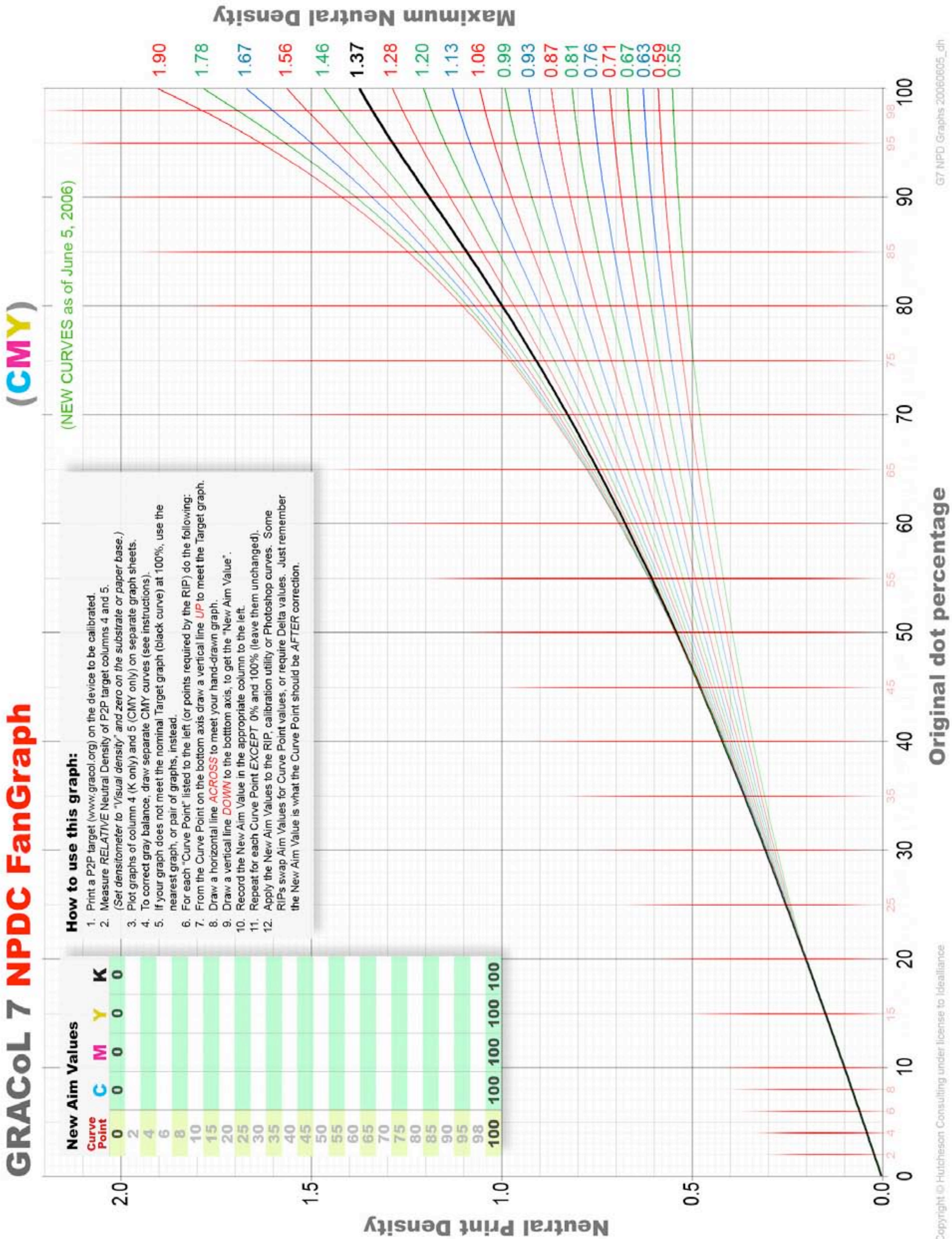
These graphs represent NPDC curves that have been carefully researched and tested by GRACoL to represent the typical average performance of CtP-based printing on a variety of papers. They are offered here for anyone to test the NPDC concept and the G7 method, but users are reminded that they are NOT an international standard.

At some time in the future these curves may be changed to agree with one or more internationally-agreed 'standard' NPDC curves or characterization data.

B.4 Matching the black NPDC to the CMY NPDC

In February 2006 the GRACoL-recommended black NPDC was lightened to conform with European and SWOP interpretations of ISO 12647-2. Users who still prefer their black NPDC to match the CMY NPDC in highlight tones should use the CMY FanGraph for the black plate.

IDEAlink Curve users should select 'K uses CMY Curve' in the Create Curves window.


GRACoL 7 NPDC FanGraph
(CMY)
(NEW CURVES as of June 5, 2006)
New Aim Values
Curve Point C M Y K
0 0 0 0 0
2
4
6
8
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
98
100 100 100 100 100
How to use this graph:
1. Print a P2P target (www.gracol.org) on the device to be calibrated.
2. Measure RELATIVE Neutral Density of P2P target columns 4 and 5.
(Set densitometer to "Visual density" and zero on the substrate or paper base.)
3. Plot graphs of column 4 (K only) and 5 (CMY only) on separate graph sheets.
4. To correct gray balance, draw separate CMY curves (see instructions).
5. If your graph does not meet the nominal Target graph (black curve) at 100%, use the nearest graph, or pair of graphs, instead.
6. For each "Curve Point" listed to the left (or points required by the RIP) do the following:
7. From the Curve Point on the bottom axis draw a vertical line UP to meet the Target graph.
8. Draw a horizontal line ACROSS to meet your hand-drawn graph.
9. Draw a vertical line DOWN to the botttom axis, to get the "New Aim Value".
10. Record the New Aim Value in the appropriate column to the left.
11. Repeat for each Curve Point EXCEPT 0% and 100% (leave them unchanged).
12. Apply the New Aim Values to the RIP, calibration utility or Photoshop curves. Some RIPs swap Aim Values for Curve Point values, or require Delta values. Just remember the New Aim Value is what the Curve Point should be AFTER correction.
Neutral Print Density
2.0
1.5
1.0
0.5
0.0
Maximum Neutral Density
1.90
1.78
1.67
1.56
1.46
1.37
1.28
1.20
1.13
1.06
0.99
0.93
0.87
0.81
0.76
0.71
0.67
0.63
0.59
0.55
0 10 20 30 40 50 60 70 80 90 100
2 4 6 8 15 25 35 45 55 65 75 85 95 98
Original dot percentage
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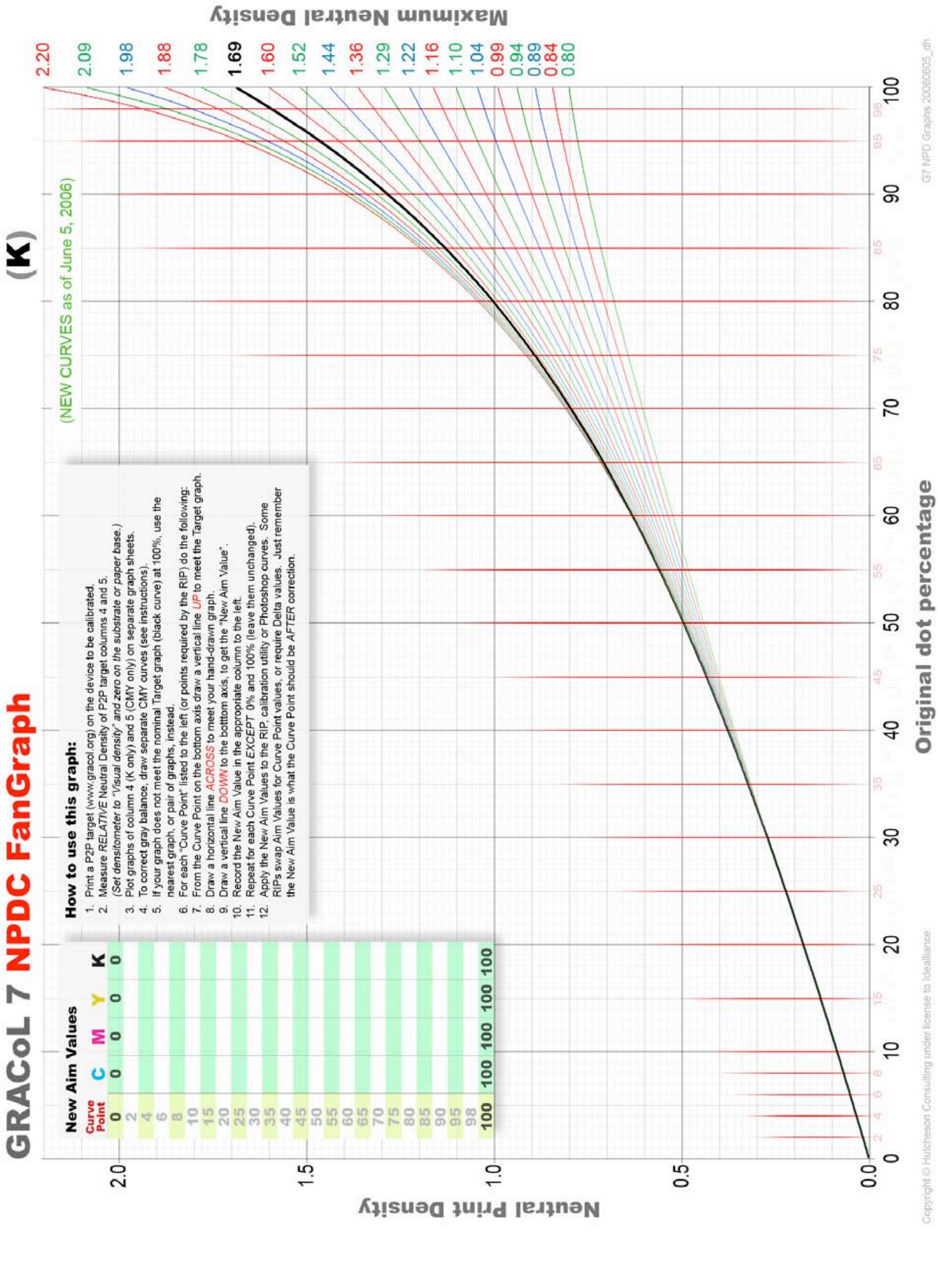
G7 NPD Graphs 20060605_dh



GRACoL 7 NPDC FanGraph
(K)
(NEW CURVES as of June 5, 2006)
New Aim Values
Curve Point
C
M
Y
K
0 0 0 0 0
2
4
6
8
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
98
100 100 100 100 100
How to use this graph:
1. Print a P2P target (www.gracol.org) on the device to be calibrated.
2. Measure RELATIVE Neutral Density of P2P target columns 4 and 5.
(Set densitometer to "Visual density" and zero on the substrate or paper base.)
3. Plot graphs of column 4 (K only) and 5 (CMY only) on separate graph sheets.
4. To correct gray balance, draw separate CMY curves (see instructions).
5. If your graph does not meet the nominal Target graph (black curve) at 100%, use the nearest graph, or pair of graphs, instead.
6. For each "Curve Point" listed to the left (or points required by the RIP) do the following:
7. From the Curve Point on the bottom axis draw a vertical line UP to meet the Target graph.
8. Draw a horizontal line ACROSS to meet your hand-drawn graph.
9. Draw a vertical line DOWN to the botttom axis, to get the "New Aim Value".
10. Record the New Aim Value in the appropriate column to the left.
11. Repeat for each Curve Point EXCEPT 0% and 100% (leave them unchanged).
12. Apply the New Aim Values to the RIP, calibration utility or Photoshop curves. Some RIPs swap Aim Values for Curve Point values, or require Delta values. Just remember the New Aim Value is what the Curve Point should be AFTER correction.
Maximum Neutral Density
2.20
2.09
1.98
1.88
1.78
1.69
1.60
1.52
1.44
1.36
1.29
1.22
1.16
1.10
1.04
0.99
0.94
0.89
0.84
0.80
Neutral Print Density
0.0
0.5
1.0
1.5
2.0
Original dot percentage
0
10
20
30
40
50
60
70
80
90
100
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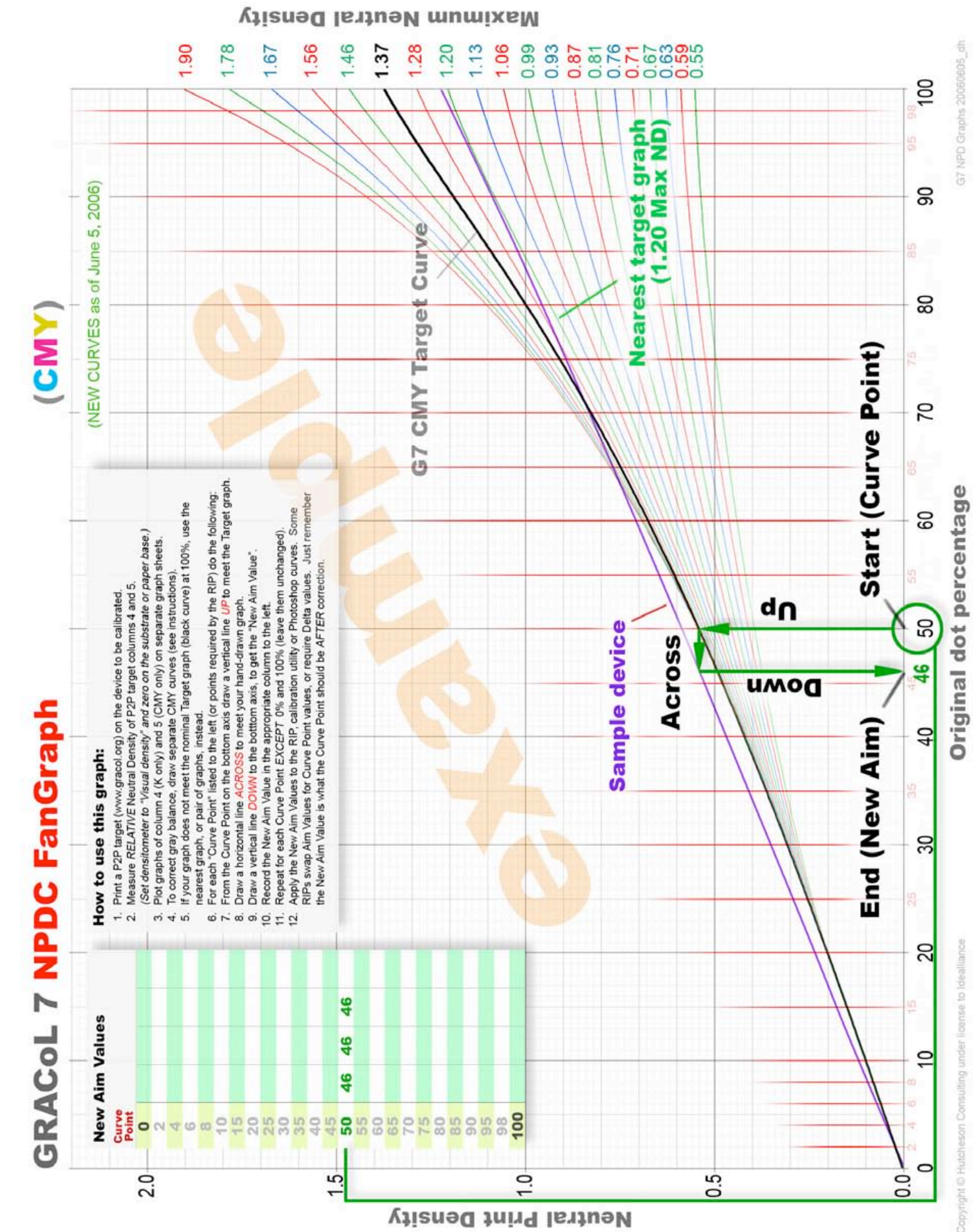
G7 NPD Graphs 20060605_dh

Appendix C: Example Graph



Appendix D: Fractional Percentage Calculations

D.1 The problem with integer percentages

Because most integer (whole-number) percentage values have no exact equivalent in an 8-bit image, file values expressed as integer percentages will often result in slightly different values when rendered to an 8-bit/ channel image (assuming no error diffusion or 'dither' is applied). In some RIPs or software, this can lead to significant calculation errors.

To eliminate this potential error, GRACoL 7 expresses halftone dot percentages as if they had been rendered into an 8-bit/channel TIFF image without dither. The formula (1) converts integer percentage to nearest integer 8-bit (0 - 255), then (2) converts integer 8-bit back to nearest fractional percentage, with optional rounding. You can perform these conversions in Microsoft Excel using the following code;

D.2 Converting integer percentage to integer 8-bit (Excel)

```
Int_8bit = ROUND(255 - int_% * 2.55, 0);
```

D.3 Converting integer 8-bit to fractional percentage (Excel)

```
Frac_% = ROUND(100 - Int_8bit / 2.55, n);
(Where 'n' is the required number of decimal places)
```

D.4 Converting integer percentage to fractional percentage

```
Frac_% = ROUND(100 - ROUND(255 - int_% * 2.55, 0) / 2.55, n)
(Where 'n' is the required number of decimal places)
```

For an example of some common percentages converted with various levels of precision, see the chart (next page).

D.5 GRACoL fractional percentage conversion chart

Int_%	Int_8bit		Frac_%	(Decimal places)	
		(1)	(2)	(3)	(4)
0	255	0.0	0.00	0.000	0.0000
1	252	1.2	1.18	1.176	1.1765
2	250	2.0	1.96	1.961	1.9608
3	247	3.1	3.14	3.137	3.1373
4	245	3.9	3.92	3.922	3.9216
5	242	5.1	5.10	5.098	5.0980
6	240	5.9	5.88	5.882	5.8824
7	237	7.1	7.06	7.059	7.0588
8	235	7.8	7.84	7.843	7.8431
9	232	9.0	9.02	9.020	9.0196
10	230	9.8	9.80	9.804	9.8039
15	217	14.9	14.90	14.902	14.9020
20	204	20.0	20.00	20.000	20.0000
25	191	25.1	25.10	25.098	25.0980
30	179	29.8	29.80	29.804	29.8039
35	166	34.9	34.90	34.902	34.9020
40	153	40.0	40.00	40.000	40.0000
45	140	45.1	45.10	45.098	45.0980
50	128	49.8	49.80	49.804	49.8039
55	115	54.9	54.90	54.902	54.9020
60	102	60.0	60.00	60.000	60.0000
65	89	65.1	65.10	65.098	65.0980
70	77	69.8	69.80	69.804	69.8039
75	64	74.9	74.90	74.902	74.9020
80	51	80.0	80.00	80.000	80.0000
85	38	85.1	85.10	85.098	85.0980
90	26	89.8	89.80	89.804	89.8039
91	23	91.0	90.98	90.980	90.9804
92	20	92.2	92.16	92.157	92.1569
93	18	92.9	92.94	92.941	92.9412
94	15	94.1	94.12	94.118	94.1176
95	13	94.9	94.90	94.902	94.9020
96	10	96.1	96.08	96.078	96.0784
97	8	96.9	96.86	96.863	96.8627
98	5	98.0	98.04	98.039	98.0392
99	3	98.8	98.82	98.824	98.8235
100	0	100.0	100.00	100.000	100.0000

Some common percentages converted with various levels of precision

Appendix E: Gray Balance and NPDC

E.1 G7 specified gray balance

GRACoL 7 defines gray balance in two parts, (1.) CMY triplet percentages (common for all print conditions), and (2.) nominal CIELab a*, b* values for each triplet, which depend on paper color.

E.1.1 G7 gray balance percentages

The G7 gray balanced CMY 'triplet' percentages are shown in the chart below for each step of he P2P23 target. These are theoretical averages derived and smoothed from many press runs. Gray balance triplets above 75% are smoothly converged to C=M=Y=100%, because the average balance for 300% in typical CMY offset printing exhibits no clear trend. Any particular press will likely deviate from this table in higher densities (over 75%) but at these values black typically hides CMY balance.

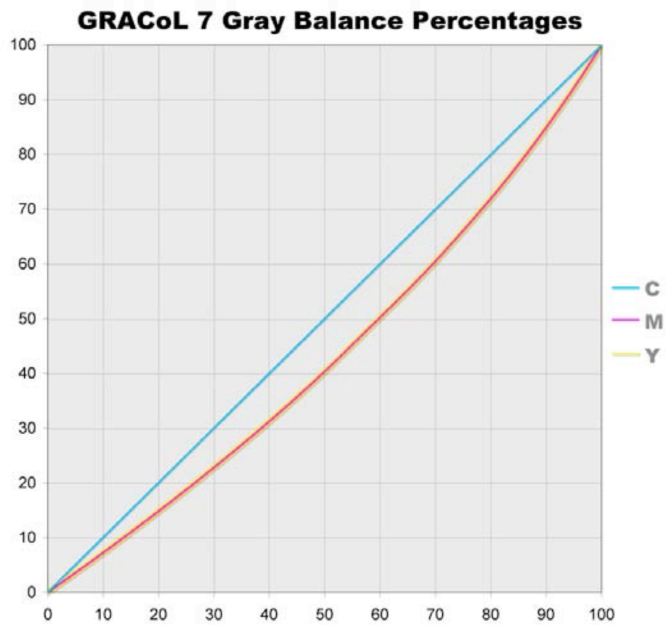
NOTE: The G7 gray balance triplet percentages are NOT an official ISO standard, but DO represent a good average of common gray balance usage.

C%	M%	Y%	ND	L*	a*	b*	X	Y	Z
0	**0**	**0**	0.06	95	0	-2	84.48	87.62	74.59
1.96	**1.18**	**1.18**	0.08	93.4	0	-1.96	80.88	83.88	71.4
3.92	**2.75**	**2.75**	0.1	91.81	0	-1.91	77.41	80.28	68.31
5.88	**4.31**	**4.31**	0.11	90.55	0	-1.87	74.72	77.5	65.93
7.84	**5.49**	**5.49**	0.13	88.99	0	-1.82	71.49	74.14	63.06
10.2	**7.45**	**7.45**	0.15	87.13	0	-1.78	67.76	70.27	59.75
14.9	**10.98**	**10.98**	0.2	83.16	0	-1.67	60.23	62.46	53.07
20	**14.9**	**14.9**	0.26	79.27	0	-1.56	53.42	55.4	47.03
25.1	**18.82**	**18.82**	0.31	75.74	0	-1.46	47.7	49.47	41.96
30.2	**23.14**	**23.14**	0.36	71.97	0	-1.36	42.05	43.61	36.97
34.9	**27.06**	**27.06**	0.42	68.24	0	-1.26	36.93	38.3	32.43
40	**31.37**	**31.37**	0.48	64.56	0	-1.15	32.3	33.5	28.33
45.1	**35.69**	**35.69**	0.53	61.18	0	-1.05	28.4	29.45	24.89
49.8	**40**	**40**	0.59	57.53	0	-0.96	24.56	25.47	21.5
54.9	**45.1**	**45.1**	0.66	53.89	0	-0.86	21.09	21.87	18.44
60	**50.2**	**50.2**	0.73	50.23	0	-0.76	17.95	18.61	15.67
65.1	**55.29**	**55.29**	0.8	46.85	0	-0.65	15.34	15.91	13.37
69.8	**60.39**	**60.39**	0.88	43.17	0	-0.56	12.8	13.27	11.13
74.9	**65.88**	**65.88**	0.96	39.47	0	-0.46	10.54	10.93	9.15
80	**71.76**	**71.76**	1.05	35.79	0	-0.36	8.58	8.9	7.43
85.1	**78.04**	**78.04**	1.14	32.43	0	-0.25	7.02	7.28	6.06
89.8	**84.31**	**84.31**	1.24	28.93	0	-0.16	5.6	5.81	4.82
94.9	**92.16**	**92.16**	1.33	25.7	0	-0.07	4.48	4.65	3.84
98.04	**96.86**	**96.86**	1.38	24.16	0	-0.03	4	4.15	3.43
100	**100**	**100**	1.42	23.01	0	0	3.67	3.8	3.14

Chart of G7 CMY Gray Balance triplet percentages vs. nominal NPDC and CIE values for grade # 1 paper (ISO paper types 1&2)

The ND and L* values in the chart above represent absolute values (paper included) of an ideal G7 NPDC curve, based on typical maximum ND values (on a 300% CMY patch with paper included) of 1.42 ND (23 L*). Note, however, that the actual maximum ND and minimum L* values at 300% can vary widely from device to device, and may result in slightly different theoretical goal values for L* and ND, but should produce a very similar appearance in normal 4-color images, if the device is G7-calibrated.

E.1.2 G7 gray balance percentage graphs



Graph of G7 CMY Gray Balance triplet percentages

E.1.3 G7 'nominal gray' a b* values for grade # 1 paper (ISO paper types 1&2)*

The CIEa*b* (and equivalent CIEXYZ) values in the chart above were calculated by the formula shown in E.2, and indicate a perfectly-balanced CMY gray scale printed on paper with a white point of 0a*, -2b*. The actual balance at higher (darker) percentages may vary considerably from device to device, but the differences will usually be masked by the black ink on well-made separations.

NOTE: The gray balance CIELab values shown in the chart are NOT an official ISO standard. Other valid interpretations of ISO 12647-2 may produce slightly different values.

E.2 Nominal target a* and b* values for standard papers

In previous versions of this document gray balance was defined as an 'arbitrarily constant' of 0 a*, -2 b* for a 50,40,40 CMY triplet, regardless of paper color. As of version 5, gray balance is defined by a paper-dependent formula suggested by G7 users and PAB (Printing Across Borders) readers.

In simple terms, the formula calculates the required a* and b* values for any CMY gray triplet *(listed in E.1.1)* by multiplying the a*, b* values of the standard paper by the relative lightness of the CMY triplet. The relative lightness of each triplet is calculated by dividing the L* value of the CMY triplet minus the L* value of the 300% CMY patch by the L* value of paper minus the L* value of the 300% CMY patch.

E.2.1 Formula for nominal target a and b* values*

a*_triplet = a*_paper * relative lightness;
b*_triplet = b*_paper * relative lightness;

where;

relative lightness = (L_ triplet - L_300) / (L_paper - L_300);
L_triplet = L* value of CMY gray triplet

L_300	=	L* value of 300% CMY triplet
L_paper	=	L* value of paper

NOTE: Further research may change this formula, but the differences should be almost invisible.

In practice the new gray balance definition produces almost no visible change compared to previous versions of this document, at least on nearly-neutral papers. The benefit of the new formula is that on less-neutral papers, for example 'warm' publication stocks, or 'cold' white papers, grays are closer to what the eye expects when the stock is used as a reference. The main disadvantage is that gray tones in a CMYK file will shift towards paper color, and a proof on one paper may not match a proof on another paper type as well as under the old “arbitrary” gray balance definition.

E.3 Printing on non-standard paper color

When printing on paper that is not exactly the color of the reference paper, for example paper with excessive brighteners that create a strong blue bias, there are three main options;

E.3.1 No gray correction

Let gray balance shift in the direction of paper color. No gray correction is common where paper color is the only reference the eye has for what is truly ‘gray’, and when the natural gray balance of the printing device is unstable or hard to determine. This option is NOT recommended for proofing.

E.3.2 Full gray correction

Use an absolute colorimetric transform (usually in the pre-press workflow) to balance the whole gray scale, including paper color simulation. Full gray correction is mainly reserved for proofing applications where (a.) the proofing substrate is a different color from the press paper, (b.) the best possible color match is needed, and (c.) a fine dot pattern can be accepted in areas representing plain white paper.

E.3.3 Partial gray correction

Use RIP curves to balance darker grays, but let lighter grays shift towards paper color, Partial gray correction is best when matching a proof or print that was made on another-colored paper, but when white areas must be free of dots or colorants.

Custom target gray balance values for partial gray correction can be calculated using the formula in E.3.4, which maintains nominal gray balance when the Cyan value is higher than a threshold (usually 30%), but otherwise shifts gray balance towards paper a* b* in proportion to relative lightness.

E.3.4 Partial correction formula for target a and b* on non-standard paper*

If C_triplet ≥ T (Threshold); /use nominal target a* and b* values (E.2.1)/

Else

ab*_triplet = ab*_paper x (L_triplet - L_300) / (L_paper - L_300) x (T - C) / T + nominal_ab* x C / T);

Example (for 25% triplet, T = 30):

Standard paper	=	95 L*, 0 a*, -2 b*
Nominal a*, b* @25%	=	0 a*, -1.46 b* (through formula in E.2.1)
Non-standard paper	=	2.5 a*, -7 b*
L_300	=	23 L*
Target a*	=	2.5 x (75.4 - 23)/(95 - 23) x (30 - 25)/30 + 0 x 25/30;
	=	**0.30;**
Target b*	=	-7 x (75.4 - 23)/(95 - 23) x (30 - 25)/30 + -1.46 x 25/30;
	=	**-2.07;**

NOTE: Results may depend on rounding

E.4 Determining 'natural' CtP curves

To determine the 'natural' print curves of commercial CtP-based printing, the GRACoL technical committee analyzed multiple ISO-standard press runs made with a variety of plates imaged on un-calibrated CtP systems, set up to manufacturer specifications. The resulting curve shape was then smoothed by the following equation;

```
        For TV (dot%)   =   0 - 100;
        NPDC ND         =   IF(SiCoY > 0, LOG10(100/SiCoY), 1000) ;
    Where
        SiCoY (cmy)     =   100 - 95.7 * SiCoTV/100;
        SiCoY (k)       =   100 - 98 * SiCoTV/100;
        SiCoTV          =   TV + SiCoTVI;
        SiCoTVI (cmy)   =   (((1 - 1/10^ SIN(TV/100)) / 0.8559448 - TV/100) * 2.744 - ((0.1
                            - 1/10^ COS(TV/100)) / - 0.1882025 - TV/100) * 0.594) * 25.2;
        SiCoTVI (k)     =   (((1 - 1/10^ SIN(TV/100)) / 0.8559448 - TV/100) * 2.2295 - ((0.1
                            - 1/10^ COS(TV/100)) / - 0.1882025 - TV/100) * 1.0395) * 20.1;
```

While every press run is unique, we believe the G7 NPDC formula represents what an average press running to ISO 12647-2 specifications would produce with typical un-calibrated CtP plates, on high quality commercial stock.

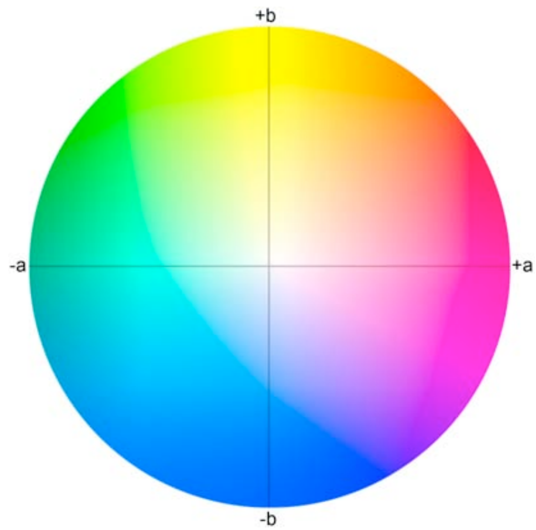
E.5 Relationship of NPDC to TVI

When correlated back to TVI curves (an inexact process) the G7 NPDC curves lie between the old positive and negative curves in ISO 12647-2, but closer to positive than negative. To further align GRACoL 7 with other interpretations of ISO 12647-2, such as FOGRA and ECI in Europe and SWOP in the USA, the G7 black curve was lightened in February 2006.

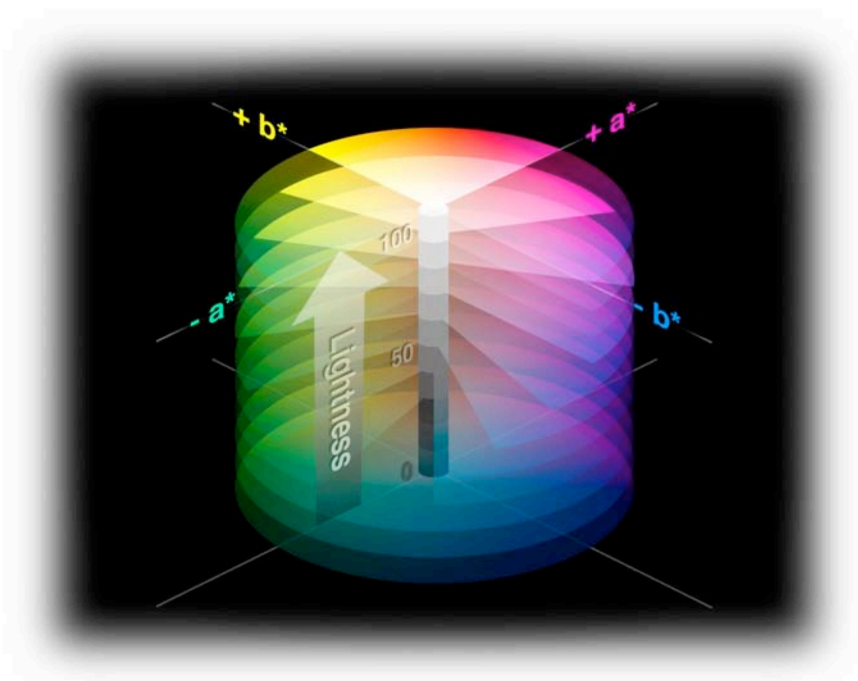
REMEMBER: G7 NPDC curves are NOT an official ISO standard. Other valid interpretations of ISO 12647-2 may produce slightly different NPDC curves.

Appendix F: Introduction to CIELab

CIELab is the preferred color space for measuring gray balance and ink color, because CIELab is 'device-independent', meaning two samples on different materials with the same CIELab value will look identical under standard D50 lighting. CIELab is therefore ideal for matching devices in different locations, or with different inks, to a standard 'appearance'.



This CIELab a, b* chart helps translate a* b* values into CMY or RGB terms. Note that when a* and b* are both zero (center) a theoretically perfect neutral (white, gray or black) is produced*



This 3-D CIELab diagram shows how every a, b* value also has a full range of L* values*

Appendix G: Tolerance Notes

G.1 Introduction

One of the most difficult things to define in a printing specification is the allowable tolerance for each parameter - partly because acceptable tolerances for one user may be unacceptable to another, and partly because realistic tolerances often depend on the type and condition of the printing system in use. A single set of color performance tolerances cannot be applied (fairly) to all devices or processes, if for no other reason than the wide variation of native stability and consistency between devices.

Obviously more stable devices or processes have an advantage when high accuracy and repeatability are needed, but frequently this higher stability is paid for in slower production or higher material costs, often negating the original advantage. For example, a typical pre-press proofing system or wide-format ink-jet printer is typically much more stable than offset lithography, and will usually score higher over time against a rigid set of tolerances, but the relative efficiency of offset printing, combined with the use of standard materials, proper operator training and automated press control, regularly satisfies the vast majority of print buyers.

G.2 When tight pressroom tolerances are NOT appropriate

The overwhelming success of offset printing in relatively high-quality imaging applications, in spite of relatively low predictability, indicates that rigid measurable tolerances may not be a great advantage in certain traditional workflows where either the proof is not a reliable constant, or press conditions or customer requirements are uncertain. While the ultimate pressroom guide is a customer-supplied 'proof' of unknown origin or quality, pressroom tolerances should be tight enough to get the press close to the aim point, but loose enough to allow room for traditional skill-based proof matching.

Having said this, any printer serious about quality and economy should attempt to reduce or eliminate uncertainties from the pressroom, which is probably why you are reading this.

G.3 When tight pressroom tolerances ARE appropriate

Tighter pressroom tolerances are not only appropriate, but essential for efficient, automated printing, but will only produce optimum results when ALL the following conditions are met;

- The press uses standard media (paper, ink, blankets, fountain, etc.)
- Plates have been calibrated with the G7 method
- Every proof submitted to the pressroom has been created using color management to match EITHER the standard characterization data to which the press was calibrated OR a custom profile of that particular press
- All CMYK files are separated with an ICC profile from the same characterization data referred to in the previous point
- The press is equipped with effective automated ink control systems that have been tested to work with G7 gray balance and NPDC target values

G.4 GRACoL 7 tolerances vs. custom user tolerances

Where possible, GRACoL 7 uses the tolerances suggested in ISO 12647-2, for example on solid ink Lab values and paper color. For new parameters like gray balance, NPDC, or characterization data - where no official ISO tolerance currently exists - GRACoL 7 provides, or is working on, SUGGESTED tolerances as a starting point, but until these are tested and proven in practice, they should be interpreted (and if necessary adjusted) to fit the capability and expectations of each individual user.

NOTE: Print buyers should remember that tighter tolerances equate to higher costs.

One way to determine realistic custom tolerances for an individual user or process is to calculate the standard deviation of each parameter over time, when process control is tightly maintained.

G.5 Characterization vs. production tolerances

Characterization tolerances should be stricter than production tolerances because a characterization print must be as near to 'perfection' as the device is capable of. This accuracy will usually not be achieved in a single press run, but may be achieved by averaging several prints made on different days.

A good general rule is that characterization tolerances should be roughly half as large as production tolerances, or at least as strict as the most stringent production aims. For example, if gray balance tolerances for production work are +/- 1 a* and +/- 2 b*, characterization tolerances for that device should be +/- 0.5 a* and +/- 1 b*.

If gray balance (and other parameters) cannot be controlled to these tolerances on the characterization print, the resulting characterization will probably NOT represent the average capability of that press.

G.6 Printing vs. proofing tolerances

Most pre-press proofing systems are much more stable and often have a higher color gamut than the typical offset press, partly by avoiding wet-trapping issues (see G.6.1). This alone makes it reasonable to apply higher tolerances to proofing systems than to production offset presses, but another more important reason is that in most pressrooms the proof is still the ultimate 'target' (regardless of measured values), and a 'moving target' will obviously lead to less consistent printing.

GRACoL 7 recommends that proofing tolerances be as fine as possible, regardless of pressroom capabilities, to minimize proof-to-proof variations. Anything less would make the proofing system a moving target. Actual local proofing tolerances should be determined by trial-and-error or statistical analysis, along with an understanding of local process, control capabilities, and limitations. Wider tolerances may be necessary on coarser grades of paper.

G.6.1 Wet-trapping - the bane of offset lithography

Modern offset presses print all four (or more) inks in rapid succession, 'wet-on-wet'. The first inks down usually adhere to the paper better than later inks, which are partially repelled by the still-wet earlier inks. But in some cases the later inks actually remove some of the earlier inks, depending on the relative tack (stickiness) of each ink in the sequence. Either way, the amount of one or more inks remaining on paper is usually less than would be achieved on a 'dry trapping' press, (printing one color at a time, or with a drying system between each unit), and the visual effects are typically unpredictable and unstable - often varying as the press warms up over the course of a run.

'Wet-trapping' introduces two problems that are largely absent in slower, single-color presses - namely reduced color gamut and unstable performance in darker tones - in each case due to the loss of some wanted ink. In fact the relative instability of wet trapping in 3-color and 4-color areas is one of the main problems in matching multiple presses to a standard characterization data set, even when each press uses the same paper and ink.

Another trapping-related problem with many offset presses is that gray balance is often seriously affected by micro register changes from sheet to sheet, which create microscopic area wet trapping differences from sheet to sheet within the halftone pattern itself, and consequent short-term gray balance errors. This makes it dangerous to demand tight gray balance tolerances on an offset press - at least on any single sheet. To measure gray balance reliably on an offset press, or to calculate separate RIP correction curves for CM and Y, be sure to average several sheets in succession.

G.6.2 Solving or minimizing wet-trapping issues

Most trapping solutions work on the concept of drying each ink (at least partially) before subsequent inks are laid down. This is usually accomplished by some form of inter-station drying system, such as IR (Infra-Red) heat for conventional inks, or UV (Ultra-Violet) light for UV-curable inks. A less practical (but highly effective) solution is to print one ink at a time in 4 passes through the press. By the time the paper is ready for each new ink, the earlier inks have dried naturally, ensuring much better trapping. One-color-at-a-time printing is obviously slower, and REALLY needs tight tolerances!

Appendix H: ISO 12647-2 Solid Ink Values

The following chart lists the CIELab values for solid inks on standard ISO paper types 1, 2, 3, 4 and 5, as proposed in November 2005. Note that measurements are officially given with black backing. White-backed measurements are shown (in brackets).

Paper type	1 & 2			3			4			5		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
K	16	0	0	20	0	0	31	1	1	31	1	2
	(16)	(0)	(0)	(20)	(0)	(0)	(31)	(1)	(1)	(31)	(1)	(3)
C	54	-36	-49	55	-36	-44	58	-25	-43	59	-27	-36
	(55)	(-37)	(-50)	(58)	(-38)	(-44)	(60)	(-26)	(-44)	(60)	(-28)	(-36)
M	46	72	-5	46	70	-3	54	58	-2	52	57	2
	(48)	(74)	(-3)	(49)	(75)	(0)	(56)	(61)	(-1)	(54)	(60)	(4)
Y	87	-6	90	84	-5	88	86	-4	75	86	-3	77
	(89)	(-5)	(93)	(89)	(-4)	(94)	(89)	(-4)	(78)	(89)	(-3)	(81)
M+Y	46	67	47	45	62	39	52	53	25	51	55	34
	(47)	(68)	(48)	(47)	(67)	(43)	(54)	(55)	(26)	(53)	(58)	(37)
C+Y	49	-66	24	47	-60	25	53	-42	13	49	-44	16
	(50)	(-68)	(25)	(50)	(-64)	(27)	(54)	(-44)	(14)	(50)	(-46)	(17)
C+M	24	16	-45	24	18	-41	37	8	-30	33	12	-29
	(24)	(17)	(-46)	(25)	(20)	(-44)	(38)	(8)	(-31)	(34)	(12)	(-29)
C+M+Y	22	0	0	22	0	0	32	0	0	31	0	0
	(23)	(0)	(0)	(23)	(0)	(0)	(33)	(0)	(0)	(32)	(0)	(0)

Solid ink values for ISO 12647-2 paper types 1 through 5. Lighter rows show white-backed readings (with numbers in brackets)

Glossary

calibration, printer	Adjusting a printing device to a known and repeatable condition - typically by using consistent substrate and colorants, and by adjusting tonality, gray balance and other metrics to a constant measurable state
Characterization data	A file of CIELab or CIEXYZ or spectral measurements of a printed target from which, if the corresponding colorant values of each patch (e.g. CMYK percentages) are also known, an ICC profile can be created
CIE	(Commission Internationale de l'Eclairage) an international group formed in the early 20th century (still active) to study and numerically define human color vision. Described as follows at www.cie.co.at/cie; *"..an organization devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting. The CIE is a technical, scientific and cultural, non-profit autonomous organization. It has grown out of the interests of individuals working in illumination. Since its inception 90 years ago, the CIE has become a professional organization and has been accepted as representing the best authority on the subject and as such is recognized by ISO as an international standardization body."*
CIEXYZ	A standard CIE color space expressed in variables X, Y and Z, corresponding to the 'visual matching functions' derived from the original CIE color vision experiments
CIELab (CIEL*a*b*; Lab)	A standard CIE color space derived from CIEXYZ where L* = Lightness, a* = the green-red vector and b* = the blue-yellow vector in a mathematically cubic space
CIELCH (LCH)	A more visually-intuitive interpretation of he standard CIELab color space in which a* and b* values are replaced by the radial vector C (Chroma or saturation) and the angular measure H (Hue)
CMY	Cyan, Magenta and Yellow
CMYK	Cyan, Magenta, Yellow and Black
Colorimetric	Based on CIE color science (as opposed to densitometry)
CtP	Computer to Plate - a plate making system which eliminates the need for intermediate positive or negative films
D-50	Industry - standard viewing light color expressed as a complete spectral energy distribution curve
Delta-E (Delta-E*, ΔE^*_{ab})	Standard CIE formula for expressing a color difference between CIELab readings. Several improvements exist, including ΔE^*_{94}, ΔE^*_{CMC} and ΔE^*_{2000}, but the original formula; $\Delta E^*_{ab} = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{0.5}$ is simplest to calculate and adequate for the purposes of this document.
Density	Log_{10} (1 / reflectance)
Dot Gain	See 'Tone Value Increase'
Fogra	www.fogra.org- German Graphic Technology Research Association whose purpose is to promote research into, and the development and application of printing technology, and to make the results available to the printing industry.
G7	The GRACoL7 calibration and press control method. 'G' denotes the focus on 'Grays', while '7' refers to the seven colorimetric ink values of Cyan (C), Magenta (M), Yellow (Y), Black (K), Red (M+Y), Green (C+Y), and Blue (C+M).
GATF	Graphic Arts Technical Foundation - provides (amongst other services) ISO 2846 laboratory ink testing
GRACoL	www.gracol.org- Subsidiary group under IDEALliance - stands for General Recommendations for Applications in Offset Lithography
GRACoL 7	Seventh edition of the GRACoL document and specifications
Gray (Grey)	A tone or image element without any visual chroma or color. The universally-accepted spelling 'Gray' is adopted in preference to the equally-acceptable 'Grey' due to simple phonetic logic. (Samuel Johnson has a lot to answer for!)

Gray Balance	1. The relationship of C, M and Y percentages or necessary to make a theoretically neutral gray - usually defined for C = 50, (e.g. 50c, 40m, 40y) but also given for other gray scale steps in this document - (see Appendix E: Gray Balance) 2. The colorimetric definition of gray in CIE units - (typically zero a* and zero b* but depends on lighting conditions and personal preference) 3. The condition in which a color or image is said to be 'neutral' or uniformly gray (with no apparent coloration) when viewed under standard lighting
GrayFinder target	A target of various different near-neutral patches from which the natural gray balance of a printing system can be determined
HC	See Highlight Contrast
Highlight Contrast (HC)	A quick process control check of NPDC in lighter tones. Density of a 25% patch minus paper density.
Highlight Range (HR)	A quick process control check of NPDC in mid-tones. Density of a 50% patch minus paper density.
HR	see 'Highlight Range'
ICC profile	A device-specific translation table between the PCS (profile Connection Space - e.g. CIELab) and the device's native color units, e.g. CMYK or RGB, and saved in the standard file format defined by the ICC
ICC	International Color Consortium - the organization responsible for defining standard file structures and rules of modern color management
IDEAlliance	www.idealliance.org- International Digital Enterprise Alliance - US graphic industry organization that has been developing, educating and validating best practices in publishing and information technology for 40 years
IDEAlink™ Curve	A software utility to simplify G7 calibration without the tedium and uncertainty of manual curve drawing. Using measurements from the P2P target calculates aim values that can be applied to the calibration tables of any RIP or software driver to simulate the G7 NPDC and Gray Balance condition.
ISO	International Standards Organization
ISO 12647-2	A standard for "Graphic technology - Process control for the production of half-tone colour separations, proof and production prints - Part 2: Offset lithographic processes".
ISO 2846-1	ISO ink standard based on laboratory measurement of samples of a specific ink-film thickness measured on a specific substrate
ISO 3664	ISO viewing and lighting standards
IT8.7/4	Most recent version in a series of standard CMYK characterization targets - available in randomized and visual layouts
Lab (CIELab)	See CIELab
LCH (CIELCH)	See CIELCH
ND	Neutral Density, or the density of a neutral gray (colorless) sample (see 'Density'). Calculated in GRACoL 7 as Log_{10} (1 / CIEXYZ_Y) where 0 < Y < 1.0, or as Log_{10} (100 / CIEXYZ_Y) where 0 < Y < 100.
NPDC	The relationship between measured neutral density and original halftone percentages on a gray scale.
Number 1 sheet	High quality coated white commercial offset paper having nominal colorimetry values of 95 L*, 0 a* and -2 b*
P2P Target	See 'Press2Proof Target'
Press2Proof Target	(Also known as 'P2P Target') - a compact target used for analyzing NPDC and other variables during the calibration process
Reference characterization	A characterization data set (see Characterization data) representing the desired appearance of a device after applying G7 calibration and / or color management
RGB	Red, Green and Blue - the so-called 'primary colors' of light. Also the abbreviations given to two-color solid ink patches, namely R = Magenta and yellow, G = Cyan and Yellow, B = Cyan and Magenta.
RIP	Raster Image Processor

RIT	Rochester Institute of Technology - provides (amongst other services) ISO 2846 laboratory ink testing
SC	See Shadow Contrast
Shadow Contrast (SC)	A quick process control check of NPDC in neutral shadow tones. Optional replacement for Print Contrast measurement. Density of a 75% patch minus paper density.
SiCo	Abbreviation of the Sin / Cosine formula used to calculate basic G7 NPDC curves
Spectro-densitometer	A combination Spectrophotometer and Densitometer convenient for measuring the quality of press sheets and/or proofs
Target	The specification, metric, device or characterization which is being imitated or aimed for
Tone Value	Percentage dot area or halftone value on a scale of 0% (no ink printing) to 100% (maximum ink printing)
Tone Value Increase	Tone Value Increase (formerly known as 'Dot Gain') - the reflection halftone percentage measured on a printed sample minus the original halftone percentage file value that produced it
TV	See Tone Value
TVI	See 'Tone Value Increase'
Un-calibrated	Without any curves or look-up-tables (LUTs). A LUT or RIP in which input digital values are the same as output digital values