

The Colour Accuracy of Expanded Gamut Printing

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Keywords: extended gamut, Pantone, color accuracy, color difference, Scope

Abstract

The purpose of this project is to determine whether using spot colours or seven colour (7/C) process colours will result in a more accurate colour reproduction. To do so, the L*a*b* values of twelve (12) spot colours from the Pantone Formula Guide and twelve (12) corresponding expanded gamut colours from the Pantone Extended Gamut Guide will be measured and compared to their appropriate reference L*a*b* values in Photoshop to determine the difference in colour (Delta E) between samples and references. The resulting CIEDE2000 values will then be compared and analyzed to determine which printing method creates the most colour accurate reproductions. Using the results of this testing, this report will provide a greater understanding of the abilities and limitations of each of these two printing methods as it relates to colour management and will make recommendations regarding the application of each going forward.

Summary

It is widely recognized within the graphic arts industry that Pantone colour books are meant solely as reference guides for spot colours, not as completely accurate reproductions of the Pantone colour libraries available in Photoshop and Illustrator. Pantone itself stated, when announcing their newest colour guides, that while “none of the printed formulas in previous guides are known to be inaccurate...it is possible that a few select colours in some guides visually appeared differently due to wider process variation based on variables in the printing process such as paper stock, base pigments, finished inks, press conditions and environmental conditions – all of which can contribute to inconsistency” (Color Alignment FAQ, 2018). With this potential for inconsistency acknowledged, this testing will be used to determine whether 7/C printing is able to more accurately reproduce colours than printing with spot colours.

Ryerson University, Harvey Levenson Undergraduate Student Paper Award Recipient

The best way to determine colour accuracy is to compare the measured L*a*b* values of a printed colour sample to its reference L*a*b* values (listed in Photoshop) to determine the difference in colour (Delta E) between the two. The lower the Delta E value, the closer the printed colour is to its reference. This test will be conducted for twelve spot colours and their corresponding expanded gamut colours to determine, overall, which method of printing is able to achieve more accurate colour reproductions.

Introduction

Spot colours are colours created without screens or dots (Color Intelligence, 2018). The most famous and widely-used set of spot colours are those found in the Pantone Matching System. Each of these spot colours is created by precisely mixing a combination of base inks (of which there are 18) according to a specified formula (Color Intelligence, 2018). Spot colours appear brighter than four colour process colours due to the gamut of the 18 base inks, and as such are commonly used for corporate logos and branding (Color Intelligence, 2018).

Expanded gamut (EG) printing, on the other hand, is the process of adding supplementary ink colours to a conventional four colour process (Smyth, 2017). While the additional inks can be a variety of different colours, the most common combination for expanded gamut printing currently is Cyan, Magenta, Yellow, Black + Orange, Green, and Violet (CMYK + OGV) (Smyth, 2017). This is the combination used by Pantone in their Extended Gamut Guide. Although this is a seven colour process, only three colourants (maximum) are ever used to create a colour (Sharma, 2018). For example, using a four colour process, a combination of cyan, magenta, and yellow would be used to create an orange colour. However, the same target colour in a seven colour process would be made from only the three nearest colourants - yellow, orange, and magenta (see Figure 1). Because the three adjacent colourants are of similar hues (as opposed to cyan, magenta, and yellow) the printing process is much easier to control, and slight misregistration of inks on press has a less jarring effect on the final colour (Sharma, 2018).



Figure 1: Pantone 150 XGC (left), a seven-colour process colour, is composed only of two adjacent colourants - Yellow and Orange.

The process as it is known today dates back to the late-1980s/early-1990s, when Harald Küppers introduced Color-Atlas a seven colour process designed to use red, green, and blue in addition to CMYK, and Davis Mills and Don Carli, sponsored by industry vendors, established the HiFi Color Project (Kasdorf, 2003). At the time, however, widespread adoption of the process was limited due to high licensing and material costs, “combined with the complexity of creating separations and process control” (Smyth, 2017).

In recent years though, expanded gamut printing has become more accessible than ever, as the costs and complexity associated with the process have decreased (Smyth, 2017). In an interview with Chris Smyth for Graphic Arts Magazine, Matthew Serwin, Graphic Arts Sales Specialist at Spicers Canada explains that “the continuing development of digital workflows and enabling technologies [have blended] together to create renewed interest [in the expanded gamut process]” (2017). Pantone’s response to this increased interest was the creation of the Extended Gamut Guide in 2015. Meant to allow printers to reproduce a wider range of colours and accurately simulate Pantone spot colours (Pantone Extended Gamut, n.d.), the Extended Gamut Guide has undoubtedly contributed to the popularity of expanded gamut printing today.

Definitions

Colour Gamut: The range or extent of colours a device can produce; most print processes use CMYK inks in a subtractive colour imaging process, and therefore in general, printers and presses have a smaller colour gamut than additive RGB colour devices such as digital cameras and flat-panel displays (Sharma, 2018).

Colour Management: A way of controlling colour in digital imaging software, hardware, and systematic procedures (Sharma, 2018).

Delta E (ΔE): A metric used to calculate a numerical measure between two colours. The larger the ΔE , the more distinct the difference between the two colours (Sharma, 2018)¹.

Expanded Gamut (EG) Printing: The process of adding more colours (usually, but not always, orange, green, and violet) to a conventional four colour process setup; also referred to as extended gamut or extended/expanded colour gamut (Smyth, 2017)².

Hue Angle: The angle of the dominant wavelength of a hue (h) in the CIE colour space (Hue Angle, n.d.); starts at the +a* axis and is expressed in degrees. Hue angle is calculated using the equation: $h = \tan^{-1}(b^*/a^*)$ (“Precise Color Communication”, 2007).

Measuring Modes: defined by ISO 13655 (Graphic technology - Spectral measurement and colorimetric computation for graphic arts images), the UV component in measuring instruments is now clearly defined using four modes: M0, M1, M2, and M3 (Sharma, 2018).

M0 – legacy mode (any illumination source)

M1 – D50, UV-included mode (recommended for colour management)

M2 – UV-cut mode (removes all UV light below 400 nm from the measurement system)

M3 – polarizing mode

Testing Principles

The testing for this report will consist of twelve spot colour samples and twelve equivalent seven colour process colour samples being measured and compared to their respective reference L*a*b* values listed in Photoshop. The twelve colours tested will be mid-tone colours, roughly 30° hue angles from each other in the CIELAB 1976 colour space (see Figure 2). Each sample will be measured ten (10) times, with its L*a*b* values and the measurement mode of the spectrophotometer being populated automatically in an Excel spreadsheet. These L*a*b* values will then be averaged and compared to the reference values in Photoshop (see Figure 3) to determine the difference in colour (CIEDE2000) between them.



Figure 2: The twelve spot colours used (labelled in the diagram) compared to the GRACoL 2006 gamut in CHROMiX ColorThink, shown in a 2D colour space.

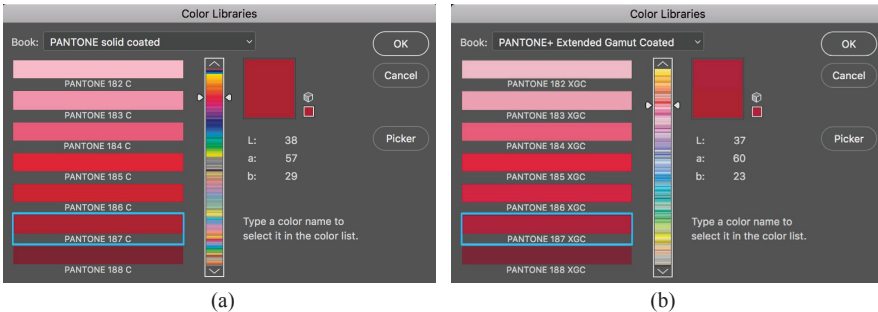


Figure 3: (a) The Photoshop reference $L^*a^*b^*$ values for Pantone 187 C.
 (b) The Photoshop reference $L^*a^*b^*$ values for Pantone 187 XGC.

With Pantone colour books being the de facto colour reference for designers and printers around the world, each colour will be measured directly from its respective colour book: the Formula Guide for the spot colours and the Extended Gamut Guide for the 7-colour process colours. Using the Pantone colour books themselves, which are held to a high standard of accuracy by the company (Falconer, 2018), will ensure print consistency between the samples.

Materials Tested

*Pantone Colour Books*³

- Pantone Formula Guide, Solid Coated (© 2016)
- Pantone Extended Gamut Guide, Coated (© 2015)

Equipment Used

Software

- Adobe Photoshop (CC 2018)
- Microsoft Excel
- PANTONE Color Manager
- TECHKON SpectroConnect

Materials

- Coated Photo Paper
- TECHKON SpectroDens (Spectro-Densitometer)

Procedure

Preparation

1. Export the Extended Gamut Guide colour book for Photoshop from Pantone Colour Manager.
2. Choose twelve (12) midtone Pantone colours at roughly 30° hue angles in the CIELAB 1976 colour space.
 - a. Use a colour difference calculator (e.g. brucelindbloom.com) and/or Excel to calculate/verify the hue angles.⁴
3. Gather the Pantone Formula Guide (Solid Coated) and Pantone Extended Gamut Guide (Coated) that will be used for testing.
4. Create an Excel spreadsheet to record the L*a*b* values and measurement mode used for testing.
5. Ensure TECHKON SpectroDens is connected to the TECHKON SpectroConnect software
 - a. Ensure the spectrophotometer measurements automatically populate in the Excel spreadsheet

Measuring Samples

1. Find the swatch for the first colour in the Formula Guide and place it on top of the coated photo paper on a hard surface (e.g. a desk).
2. Using the TECHKON SpectroDens (set to M2 mode and D50 lighting condition), measure the L*a*b* values of the sample.
3. Ensure the measurements are recorded in Excel.
4. Measure the sample an additional nine (9) times, then average the sample's L*a*b* values in Excel.

5. Using the reference L*a*b* values for that colour from Photoshop and the averaged L*a*b* values of the sample, calculate the CIEDE2000 for the colour.
6. Repeat steps #1-5 for the equivalent swatch of the first chosen colour in the Extended Gamut Guide.
7. Repeat steps #1-6 for the remaining eleven (11) colours.

Results and Discussion

For all twelve spot colours and all twelve expanded gamut colours, the L*a*b* values measured and the measurement mode used by the TECHKON SpecroDens were automatically populated in an Excel spreadsheet using the SpectroConnect software.

See the Appendix for the full results of the conducted testing.

The consolidated results of the testing conducted are shown in the chart below (see Figure 4).

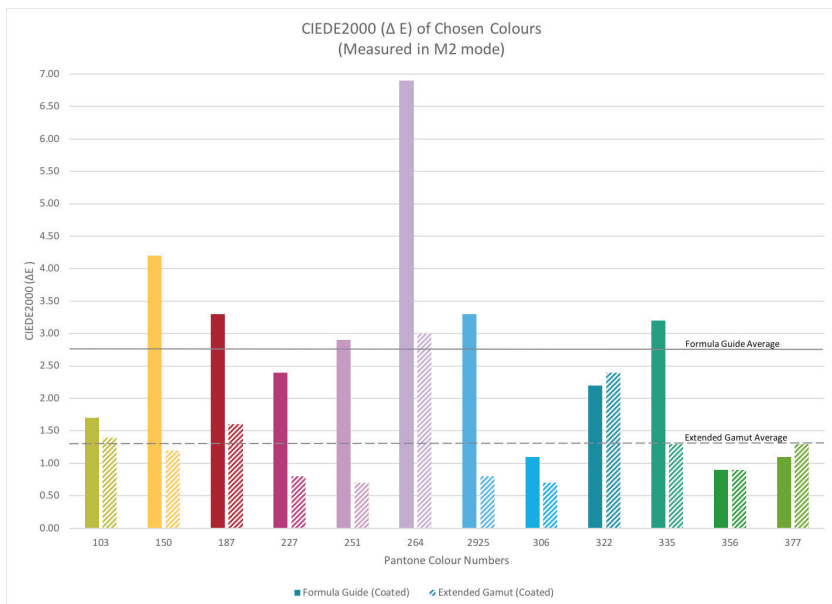


Figure 4: Consolidated results of the colour accuracy testing.⁵

For every colour sample tested (except Pantone 322 C/XGC, Pantone 356 C/XGC, and Pantone 377 C/XGC) the samples from the Extended Gamut Guide colour book had lower Delta E values when compared to their appropriate reference values⁶ than the samples from the Formula Guide colour book. The Pantone 356 XGC sample had the exact same Delta E as that of Pantone 356 C, with a value of 0.9. In the case of Pantone 322 XGC and Pantone 377 XGC, their Delta E values of 2.4 and 1.3 (respectively) are only 0.2 greater than that of their spot colour counterparts. All three of these Delta E values are still acceptable for colour reproduction commercial printing (Sharma, 2018), and two of the three meet the tighter tolerance of $2\Delta E_{2000}$ that Pantone holds for 90% of its spot colours in the Formula Guide (Color Alignment, 2018). Overall, the lower Delta E values of the 7/C samples demonstrate that printing with three adjacent colours in an expanded gamut process (specifically, CMYK + OGV) results in more accurate colour reproduction than printing with a single spot colour does.

Pantone and X-Rite (Pantone's parent company) claim that while Extended Gamut is better than CMYK at reproducing Pantone spot colours (X-Rite states that it can match 90% of spot colours compared to CMYK, which can match 55%), Pantone spot colours "are still the ideal choice for consistent, accurate colour reproduction" (Gundlach, 2018). However, if the results of this testing hold true for the majority of spot colours in the Pantone Matching System, this statement by X-Rite would be disproved, as the Extended Gamut colours have proven, thus far, to be more colour accurate than spot colours. This conclusion would have major implications not only throughout the graphic arts industry but also for companies that rely on spot colours to keep their logos and branding consistent.

Recommendations

Printability

Printability is an important consideration when printing with a seven colour process. Traditionally, four colour process inks are screened on press (AM screening), although stochastic printing (FM screening) has gained popularity in recent years (Jayaraman, 2015). Utilizing different screen angles for each ink allows printers to avoid moiré, an undesirable print artifact that occurs in halftone reproductions as a result of an interference pattern caused by incorrect screen angles (Moiré, n.d.). FM screening, which uses a random dot pattern instead of screen angles, can also be used to avoid this problem (Hershey, 2006). The inks used in a seven colour process are generally screened similarly to those in the four colour process. However, opposite colours (e.g. magenta and green), which will not overlap due to the three nearest-colourant system used in expanded gamut printing, are often printed at the same screen angle to avoid moiré (Politis et al., 2015). As with 4/C printing, FM screening is often used in expanded gamut printing for the same reason (Politis et al., 2015).

Runnability

There are several factors that contribute to the ease with which the expanded gamut printing process can be executed. The first (seemingly obvious) factor associated with the runnability of expanded gamut printing is having the capacity to print seven colours. For smaller printers who may only have a 4 or 5/C press, printing a seven colour process in one pass is impossible. As such, these smaller printers will not be able to compete in the expanded gamut market until the demand for the process becomes great enough to warrant upgrading to a larger press that is better suited to the process (should they have the resources and physical space available to do so).

For printers with the capacity to print seven colours, specialized software and workflows are required for re-separating files intended for expanded gamut printing (unlike conventional process files with spot colours) and proofing before jobs go to print (The Printer's Guide, 2017). The software required for expanded gamut printing can be both expensive for printers to purchase and difficult to learn, requiring extra training for those directly working with it (The Printer's Guide, 2017). As a result, while offering expanded gamut printing may have long-term benefits for shops, especially as the demand for the process grows, these barriers to entry can discourage printers from initially adopting the process.

Additionally, maintaining registration on press becomes more of an issue when printing three process inks than it is when printing with just one spot colour (Smyth, 2017). As stated previously, slight misregistration on press is less of an issue when printing with three adjacent colourants (as done in expanded gamut printing) than it is when printing with CMYK. Although this misregistration may seem negligible in comparison to that of conventional printing, it remains an ongoing issue in which printers could avoid by utilizing a single spot colour. For example, "smaller knockout copy that would have conventionally run as a single colour spot can pose a registration challenge for printers when it is made of screens of three different colours" (Smyth, 2017). As a result, printers looking to replace spot colours in jobs by printing with a seven colour process need to have good control of their press registration to ensure quality work is produced.

Finally, printing with expanded gamut requires greater process control than conventional printing (with or without spot colours). Conventional printing has established standards that can be followed, such as G7 calibration and GRACoL or SWOP profiles, to ensure accurate and consistent work is produced on press. Expanded gamut printing, however, has yet to have standards developed to the same extent as conventional printing (The Printer's Guide, 2017). Standardization has begun to expand as the process gains popularity within the graphic arts industry and among clients. To address the additional challenges presented by the expanded gamut process, "new ISO standards are being developed and released which help support a more open workflow for ECG ... includ[ing] ISO 17972 CxF/X-4

Spot colour characterization data for exchanging colour information as spectral data, ISO 20654 – Spot Colour Tone Value for calculating tone value increase for spot colours, and ISO 20677-1 iccMAX a new format for ICC profiles that better supports tints and overprints” (Smyth, 2017). As adoption rates increase, establishing standards to guide the expanded gamut process will become critical to the ability to successfully produce jobs according to customer specification.

End Use

Expanded gamut printing, as the name suggests, increases the range of colours a device can produce. As such, many colours that are out of gamut for conventional CMYK printing can be produced with the addition of colourants such as orange, green, and violet. As a result, EG printing can produce more vibrant, eye-catching colours than 4/C printing can (Baldwin, 2016). The ability to produce colours more vibrant than those of a 4/C process and more accurate than spot colours provides expanded gamut printing with a unique and competitive advantage in the print market.

Pantone estimates that 15-20% of packaging is printed using EG, and that number “is expected to increase more than 50% within the next decade” (Smyth, 2017). Being able to produce brighter, more vivid colours is of great benefit to brand owners, with “90% of snap judgments [being] made about products are based on colour alone” (Smyth, 2017). However, the rise of EG printing in packaging may be driven more by printers than by brand owners (Smyth, 2017). As a process, expanded gamut printing is more time and resource efficient than conventional printing. It saves money on ink and materials, as ink inventories can be reduced and less substrate is wasted on proofing (Baldwin, 2016). As well, printing all jobs using the same seven colours means that jobs can be ganged and fewer wash-ups are required between them (Baldwin, 2016). The efficiency and savings associated with EG printing will contribute to its growth in packaging in the coming years.

While it has many applications for packaging, the main end use for expanded gamut printing, based on the testing conducted for this report, is for brand colours and logos. Colour is used by brands to differentiate themselves from their competitors and increase recognition in the minds of consumers (Odgis, 2017). Coca Cola red and Starbucks green are just two of the many brand colours consumers instantly associate with the companies they represent. Janet Odgis, President and Creative Director of Odgis + Co., an award-winning branding firm, states that “given how colo[u]r so radically increases brand identification (which, in turn, can boost sales and engagement), [it is] crucial that colo[u]r remain consistent across all expressions of the brand, whether online or in print” (2017). To maintain this key level of consistency, brands have long turned to Pantone spot colours to reproduce their brand colours in print. However, the testing conducted for the twelve colour samples, as discussed previously, concluded that printing using expanded gamut offers comparable or superior colour accuracy than printing with spot colours does.

Should these results hold true for the majority of Pantone spot colours, brands that currently use spot colours for their identity can switch to an EG process, producing more accurate colours at a reduced cost. As well, smaller companies that may not be able to afford the use of spot colours for branding purposes can be provided with a more accurate solution than the four colour process at a fraction of the price of printing with spot colours. Either way, expanded gamut printing makes maintaining colour accuracy and consistency more affordable than ever before for brand owners, both big and small.

Footer notes

1. The CIEDE2000 equation was used to calculate the Delta E values for this testing.
2. For the purpose of this report, expanded gamut (EG) printing will refer to a seven colour (7/C) process using orange, green, and violet inks in addition to the traditional cyan, magenta, yellow, and black (CMYK) process inks.
3. Pantone recommends replacing colour guides every 12-18 months as age and usage can cause fading and yellowing that affect the colour of swatches (Did you know?, 2018). Although these colour books are due to be replaced according to Pantone's guidelines, they have been stored appropriately in a dark cabinet and been handled with care when used, minimizing the negative aging effects they may have experienced.
4. After verifying the hue angles, the colours were also compared to both the GRACoL 2006 and Epson SureColor P9000 (a proofer with 7/C capabilities) gamuts using CHROMiX ColorThink for reference. However, because spot colours and expanded gamut colours are able to reproduce colours outside the conventional CMYK gamut, this step is not necessary to conduct this testing (which is why it is not listed as a step in the Procedure). If the samples being tested had been printed internally, however, this step of comparing the gamuts in ColorThink would be crucial to ensuring that the device being used for printing would be able to accurately reproduce the colours.
5. For a variety of reasons, including (but not limited to) hue, chromacity, and saturation, the colour purple is often difficult to reproduce accurately on press (Prakhya, 2014). This may be the reason for the higher CIEDE2000 values of Pantone 264 C/XGC.
6. In Photoshop, the twelve colours have different reference values listed in the Formula Guide and Extended Gamut Guide. The twelve spot colour samples were compared to the reference values listed in the Formula Guide and the twelve expanded gamut samples were compared to the reference values

listed in the Extended Gamut Guide. For comparison, the difference in colour between each set of references is listed in the Appendix.

7. M2 measurement mode was used as the lowest common denominator between the two Pantone colour books and Photoshop.
8. As stated previously, the L*a*b* values listed in Photoshop were used as the reference values for the printed samples tested. However, for Pantone 2925 XGC, Pantone 356 XGC, and Pantone 377 XGC, there was a glitch in Photoshop that resulted in it displaying incorrect L*a*b* values for these three colours. For examples, Pantone 2925 XGC, a bluish colour which should have an L*a*b* of 60, -15, -41, was listed in Photoshop as 47, 76, 19, a reddish colour instead. To get around this problem, a .cxt file of the Extended Gamut Guide, which lists the L*a*b* values of all the colours in the colour book, was exported from PANTONE Color Manager and used for those three samples instead. To verify that the L*a*b* values listed in the .cxt file were consistent with those listed in Photoshop, the values of several colours listed accurately in Photoshop were compared to those listed in the .cxt file. This comparison confirmed that the values matched and the .cxt file values could be used for the missing three colours without inconsistency in the Delta E calculations.

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Appendix

Results of Conducted Testing
(see following pages)

Pantone 103 C	L*	a*	b*	Mode ⁷	CIEDE2000
Reference	71	-1	87	N/A	N/A
1	69.22	1.17	86.36	D50/2°/M2/ABS	N/A
2	69.61	1.13	86.43	D50/2°/M2/ABS	N/A
3	69.39	1.21	86.36	D50/2°/M2/ABS	N/A
4	69.41	1.15	86.32	D50/2°/M2/ABS	N/A
5	69.5	1.26	86.77	D50/2°/M2/ABS	N/A
6	69.68	1.09	86.45	D50/2°/M2/ABS	N/A
7	69.75	1.17	86.54	D50/2°/M2/ABS	N/A
8	69.15	1.2	86.05	D50/2°/M2/ABS	N/A
9	69.45	1.26	86.6	D50/2°/M2/ABS	N/A
10	69.5	1.24	86.65	D50/2°/M2/ABS	N/A
Avg.	69.47	1.19	86.45	N/A	1.7

Pantone 103 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	72	-2	76	N/A	N/A
1	73.25	0.18	76.27	D50/2°/M2/ABS	N/A
2	73.33	0.18	76.31	D50/2°/M2/ABS	N/A
3	73.2	0.2	76.13	D50/2°/M2/ABS	N/A
4	72.96	0.18	75.52	D50/2°/M2/ABS	N/A
5	73.01	0.2	76.1	D50/2°/M2/ABS	N/A
6	72.49	-0.07	75.31	D50/2°/M2/ABS	N/A
7	72.69	0.03	75.51	D50/2°/M2/ABS	N/A
8	72.68	0.24	75.92	D50/2°/M2/ABS	N/A
9	72.96	0.22	75.82	D50/2°/M2/ABS	N/A
10	72.53	0.16	75.68	D50/2°/M2/ABS	N/A
Avg.	72.91	0.15	75.86	N/A	1.4

Pantone 150 C	L*	a*	b*	Mode	CIEDE2000
Reference	78	29	58	N/A	N/A
1	80.05	24.07	61.9	D50/2°/M2/ABS	N/A
2	80.41	24.09	61.72	D50/2°/M2/ABS	N/A
3	79.92	23.8	61.4	D50/2°/M2/ABS	N/A
4	80.07	24.23	62.09	D50/2°/M2/ABS	N/A
5	80.44	23.18	60.41	D50/2°/M2/ABS	N/A
6	80.16	23.36	60.79	D50/2°/M2/ABS	N/A
7	80.26	23.44	60.89	D50/2°/M2/ABS	N/A
8	80.4	23.71	61.3	D50/2°/M2/ABS	N/A
9	80.41	23.7	61.3	D50/2°/M2/ABS	N/A
10	80.43	23.88	61.41	D50/2°/M2/ABS	N/A
Avg.	80.26	23.75	61.32	N/A	4.2

Pantone 150 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	81	21	54	N/A	N/A
1	81.37	21.41	51.2	D50/2°/M2/ABS	N/A
2	81.21	21.82	51.33	D50/2°/M2/ABS	N/A
3	81.36	21.28	51.04	D50/2°/M2/ABS	N/A
4	80.98	21.87	51.75	D50/2°/M2/ABS	N/A
5	80.85	21.8	51.95	D50/2°/M2/ABS	N/A
6	80.73	21.9	51.88	D50/2°/M2/ABS	N/A
7	81.31	21.61	51.11	D50/2°/M2/ABS	N/A
8	81.29	21.51	51.27	D50/2°/M2/ABS	N/A
9	81.31	21.72	51.4	D50/2°/M2/ABS	N/A
10	80.95	21.77	51.97	D50/2°/M2/ABS	N/A
Avg.	81.14	21.67	51.49	N/A	1.2

Pantone 187 C	L*	a*	b*	Mode	CIEDE2000
Reference	38	57	29	N/A	N/A
1	33.93	53.68	30.36	D50/2°/M2/ABS	N/A
2	34.42	53.97	30.27	D50/2°/M2/ABS	N/A
3	35.64	54.53	29.46	D50/2°/M2/ABS	N/A
4	34.48	53.75	29.92	D50/2°/M2/ABS	N/A
5	33.49	53.24	30.41	D50/2°/M2/ABS	N/A
6	34.61	53.93	29.92	D50/2°/M2/ABS	N/A
7	34.69	54.25	30.5	D50/2°/M2/ABS	N/A
8	34.02	53.7	30.51	D50/2°/M2/ABS	N/A
9	33.87	53.53	30.31	D50/2°/M2/ABS	N/A
10	35.46	54.36	29.46	D50/2°/M2/ABS	N/A
Avg.	34.46	53.89	30.11	N/A	3.3

Pantone 187 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	37	60	23	N/A	N/A
1	37.58	59.8	25.47	D50/2°/M2/ABS	N/A
2	38.25	60.33	25.79	D50/2°/M2/ABS	N/A
3	37.26	59.93	26.43	D50/2°/M2/ABS	N/A
4	37.65	59.85	25.73	D50/2°/M2/ABS	N/A
5	38.26	60.46	25.54	D50/2°/M2/ABS	N/A
6	38.06	60.25	26.39	D50/2°/M2/ABS	N/A
7	38.25	60.26	25.63	D50/2°/M2/ABS	N/A
8	38.03	60.14	25.72	D50/2°/M2/ABS	N/A
9	37.62	59.78	25.55	D50/2°/M2/ABS	N/A
10	37.75	59.95	25.41	D50/2°/M2/ABS	N/A
Avg.	37.87	60.08	25.77	N/A	1.6

Pantone 227 C	L*	a*	b*	Mode	CIEDE2000
Reference	36	68	-4	N/A	N/A
1	37.53	68.18	0.85	D50/2°/M2/ABS	N/A
2	37.58	68.7	0.51	D50/2°/M2/ABS	N/A
3	38.15	68.17	-0.39	D50/2°/M2/ABS	N/A
4	37.25	68.27	0.96	D50/2°/M2/ABS	N/A
5	38.31	68.65	-0.49	D50/2°/M2/ABS	N/A
6	37.42	68.32	1.42	D50/2°/M2/ABS	N/A
7	37.27	67.97	0.96	D50/2°/M2/ABS	N/A
8	37.9	68.1	-0.16	D50/2°/M2/ABS	N/A
9	37.69	68.59	0.71	D50/2°/M2/ABS	N/A
10	37.67	68.35	0.3	D50/2°/M2/ABS	N/A
Avg.	37.68	68.33	0.47	N/A	2.4

Pantone 227 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	38	63	-4	N/A	N/A
1	38.36	63.16	-2.2	D50/2°/M2/ABS	N/A
2	38.14	62.79	-2.26	D50/2°/M2/ABS	N/A
3	38.39	63.03	-2.31	D50/2°/M2/ABS	N/A
4	38.42	63.09	-2.19	D50/2°/M2/ABS	N/A
5	37.99	62.61	-2.21	D50/2°/M2/ABS	N/A
6	37.9	62.5	-2.51	D50/2°/M2/ABS	N/A
7	38.76	63.1	-2.43	D50/2°/M2/ABS	N/A
8	38.29	63.17	-2.17	D50/2°/M2/ABS	N/A
9	38.23	63	-2.16	D50/2°/M2/ABS	N/A
10	38.68	63.15	-2.41	D50/2°/M2/ABS	N/A
Avg.	38.32	62.96	-2.29	N/A	0.8

Pantone 251 C	L*	a*	b*	Mode	CIEDE2000
Reference	73	33	-22	N/A	N/A
1	73.32	38.78	-19.75	D50/2°/M2/ABS	N/A
2	72.9	39.04	-19.61	D50/2°/M2/ABS	N/A
3	72.77	38.83	-19.79	D50/2°/M2/ABS	N/A
4	74.4	36.07	-18.96	D50/2°/M2/ABS	N/A
5	72.96	38.83	-19.69	D50/2°/M2/ABS	N/A
6	72.75	38.99	-19.59	D50/2°/M2/ABS	N/A
7	72.92	38.87	-19.78	D50/2°/M2/ABS	N/A
8	72.42	38.62	-19.67	D50/2°/M2/ABS	N/A
9	74.01	36.93	-18.97	D50/2°/M2/ABS	N/A
10	73.08	38.46	-19.67	D50/2°/M2/ABS	N/A
Avg.	73.15	38.34	-19.55	N/A	2.9

Pantone 251 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	72	20	-12	N/A	N/A
1	72.52	19.47	-12.44	D50/2°/M2/ABS	N/A
2	72.46	20.03	-12.69	D50/2°/M2/ABS	N/A
3	72.66	19.93	-12.8	D50/2°/M2/ABS	N/A
4	72.17	19.93	-13	D50/2°/M2/ABS	N/A
5	73.03	19.16	-12.63	D50/2°/M2/ABS	N/A
6	72.3	19.93	-13.13	D50/2°/M2/ABS	N/A
7	71.96	19.98	-12.92	D50/2°/M2/ABS	N/A
8	72.9	19.58	-12.68	D50/2°/M2/ABS	N/A
9	72.28	19.6	-12.62	D50/2°/M2/ABS	N/A
10	72.59	19.39	-12.81	D50/2°/M2/ABS	N/A
Avg.	72.49	19.70	-12.77	N/A	0.7

Pantone 264 C	L*	a*	b*	Mode	CIEDE2000
Reference	75	15	-25	N/A	N/A
1	72.55	24.72	-23.47	D50/2°/M2/ABS	N/A
2	72.63	25.1	-23.32	D50/2°/M2/ABS	N/A
3	72.8	24.9	-23.61	D50/2°/M2/ABS	N/A
4	73.42	24.38	-23.22	D50/2°/M2/ABS	N/A
5	73.17	24.75	-23.4	D50/2°/M2/ABS	N/A
6	72.91	24.63	-23.2	D50/2°/M2/ABS	N/A
7	72.6	25.23	-23.71	D50/2°/M2/ABS	N/A
8	72.85	25.14	-23.68	D50/2°/M2/ABS	N/A
9	73.21	24.6	-23.23	D50/2°/M2/ABS	N/A
10	72.67	24.68	-23.01	D50/2°/M2/ABS	N/A
Avg.	72.88	24.81	-23.39	N/A	6.9

Pantone 264 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	74	1	-17	N/A	N/A
1	71.73	13.74	-20.72	D50/2°/M2/ABS	N/A
2	71.87	13.79	-20.83	D50/2°/M2/ABS	N/A
3	71.28	13.89	-20.86	D50/2°/M2/ABS	N/A
4	71.08	13.85	-20.75	D50/2°/M2/ABS	N/A
5	72.06	13.71	-20.59	D50/2°/M2/ABS	N/A
6	71.5	13.69	-20.69	D50/2°/M2/ABS	N/A
7	71.61	13.69	-20.7	D50/2°/M2/ABS	N/A
8	71.27	13.84	-20.77	D50/2°/M2/ABS	N/A
9	71.32	13.66	-20.51	D50/2°/M2/ABS	N/A
10	71.56	13.59	-20.57	D50/2°/M2/ABS	N/A
Avg.	71.53	13.75	-20.70	N/A	3.0

Pantone 2925 C	L*	a*	b*	Mode	CIEDE2000
Reference	58	-18	-46	N/A	N/A
1	59.42	-23.5	-42.7	D50/2°/M2/ABS	N/A
2	60.18	-23.47	-42.61	D50/2°/M2/ABS	N/A
3	59.56	-23.49	-42.7	D50/2°/M2/ABS	N/A
4	59.87	-23.56	-42.72	D50/2°/M2/ABS	N/A
5	59.61	-23.54	-42.88	D50/2°/M2/ABS	N/A
6	59.66	-23.5	-42.7	D50/2°/M2/ABS	N/A
7	59.71	-23.67	-43.06	D50/2°/M2/ABS	N/A
8	59.53	-23.59	-42.79	D50/2°/M2/ABS	N/A
9	59.29	-23.55	-42.61	D50/2°/M2/ABS	N/A
10	59.2	-23.57	-42.85	D50/2°/M2/ABS	N/A
Avg.	59.60	-23.54	-42.76	N/A	3.3

Pantone 2925 XGC	L*	a*	b*	Mode	CIEDE2000
Reference ^s	60	-15	-41	N/A	N/A
1	59.94	16.45	-41.42	D50/2°/M2/ABS	N/A
2	59.93	16.43	-41.25	D50/2°/M2/ABS	N/A
3	59.98	16.43	-41.31	D50/2°/M2/ABS	N/A
4	59.7	16.45	-41.32	D50/2°/M2/ABS	N/A
5	59.72	16.41	-41.15	D50/2°/M2/ABS	N/A
6	59.59	16.49	-41.12	D50/2°/M2/ABS	N/A
7	59.77	16.44	-40.96	D50/2°/M2/ABS	N/A
8	59.47	16.31	-41.33	D50/2°/M2/ABS	N/A
9	59.64	16.35	-41.24	D50/2°/M2/ABS	N/A
10	60.03	16.47	-41.1	D50/2°/M2/ABS	N/A
Avg.	59.78	16.42	-41.22	N/A	0.8

Pantone 306 C	L*	a*	b*	Mode	CIEDE2000
Reference	67	-36	-36	N/A	N/A
1	65.39	-36.65	-36.79	D50/2°/M2/ABS	N/A
2	65.8	-36.89	-37.09	D50/2°/M2/ABS	N/A
3	65.93	-36.55	-36.83	D50/2°/M2/ABS	N/A
4	65.42	-36.73	-36.71	D50/2°/M2/ABS	N/A
5	65.39	-36.62	-36.87	D50/2°/M2/ABS	N/A
6	66.06	-36.2	-36.47	D50/2°/M2/ABS	N/A
7	66.49	-36.26	-36.45	D50/2°/M2/ABS	N/A
8	65.74	-36.9	-37.19	D50/2°/M2/ABS	N/A
9	65.23	-36.64	-37.04	D50/2°/M2/ABS	N/A
10	65.48	-36.69	-36.8	D50/2°/M2/ABS	N/A
Avg.	65.69	-36.61	-36.82	N/A	1.1

Pantone 306 C	L*	a*	b*	Mode	CIEDE2000
Reference	67	-36	-36	N/A	N/A
1	65.39	-36.65	-36.79	D50/2°/M2/ABS	N/A
2	65.8	-36.89	-37.09	D50/2°/M2/ABS	N/A
3	65.93	-36.55	-36.83	D50/2°/M2/ABS	N/A
4	65.42	-36.73	-36.71	D50/2°/M2/ABS	N/A
5	65.39	-36.62	-36.87	D50/2°/M2/ABS	N/A
6	66.06	-36.2	-36.47	D50/2°/M2/ABS	N/A
7	66.49	-36.26	-36.45	D50/2°/M2/ABS	N/A
8	65.74	-36.9	-37.19	D50/2°/M2/ABS	N/A
9	65.23	-36.64	-37.04	D50/2°/M2/ABS	N/A
10	65.48	-36.69	-36.8	D50/2°/M2/ABS	N/A
Avg.	65.69	-36.61	-36.82	N/A	1.1

Pantone 306 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	65	-31	-35	N/A	N/A
1	64.71	32.25	-34.26	D50/2°/M2/ABS	N/A
2	65.03	-32.5	-34.43	D50/2°/M2/ABS	N/A
3	65.16	32.37	-34.34	D50/2°/M2/ABS	N/A
4	64.78	-32.3	-34.43	D50/2°/M2/ABS	N/A
5	64.83	32.23	-34.22	D50/2°/M2/ABS	N/A
6	64.83	32.17	-34.32	D50/2°/M2/ABS	N/A
7	65.05	32.44	-34.42	D50/2°/M2/ABS	N/A
8	65.09	32.34	-34.38	D50/2°/M2/ABS	N/A
9	65.02	32.32	-34.24	D50/2°/M2/ABS	N/A
10	64.82	32.26	-34.26	D50/2°/M2/ABS	N/A
Avg.	64.93	32.32	-34.33	N/A	0.7

Pantone 322 C	L*	a*	b*	Mode	CIEDE2000
Reference	41	-44	-18	N/A	N/A
1	38.28	-43.06	-18.39	D50/2°/M2/ABS	N/A
2	38.67	-43.27	-18.55	D50/2°/M2/ABS	N/A
3	39.14	-43.22	-18.67	D50/2°/M2/ABS	N/A
4	38.04	-42.83	-18.32	D50/2°/M2/ABS	N/A
5	39.52	-43.72	-18.69	D50/2°/M2/ABS	N/A
6	38.06	-43.21	-18.31	D50/2°/M2/ABS	N/A
7	38.03	-43.09	-18.37	D50/2°/M2/ABS	N/A
8	38.68	-43.16	-18.53	D50/2°/M2/ABS	N/A
9	38.98	-43.61	-18.59	D50/2°/M2/ABS	N/A
10	38.36	-43.06	-18.36	D50/2°/M2/ABS	N/A
Avg.	38.58	-43.22	-18.48	N/A	2.2

Pantone 322 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	40	-47	-17	N/A	N/A
1	43.03	47.04	-15.41	D50/2°/M2/ABS	N/A
2	42.49	46.63	-15.51	D50/2°/M2/ABS	N/A
3	42.47	-46.4	-15.63	D50/2°/M2/ABS	N/A
4	42.32	46.84	-15.32	D50/2°/M2/ABS	N/A
5	42.46	46.64	-15.16	D50/2°/M2/ABS	N/A
6	42.63	46.79	-15.2	D50/2°/M2/ABS	N/A
7	42.62	46.48	-15.47	D50/2°/M2/ABS	N/A
8	42.19	-46.6	-15.53	D50/2°/M2/ABS	N/A
9	42.45	-46.6	-15.54	D50/2°/M2/ABS	N/A
10	42.59	46.72	-15.35	D50/2°/M2/ABS	N/A
Avg.	42.53	46.67	-15.41	N/A	2.4

Pantone 335 C	L*	a*	b*	Mode	CIEDE2000
Reference	45	-51	1	N/A	N/A
1	41.22	-49.54	1.17	D50/2°/M2/ABS	N/A
2	41.82	-49.55	1.09	D50/2°/M2/ABS	N/A
3	41.57	-49.73	1.12	D50/2°/M2/ABS	N/A
4	40.62	-48.65	1.05	D50/2°/M2/ABS	N/A
5	42.32	-49.23	0.91	D50/2°/M2/ABS	N/A
6	41.29	-49.57	1.25	D50/2°/M2/ABS	N/A
7	42.4	-49.62	1.13	D50/2°/M2/ABS	N/A
8	41.45	-49.24	1.22	D50/2°/M2/ABS	N/A
9	41.33	-49.02	1.11	D50/2°/M2/ABS	N/A
10	41.53	-49.55	1.15	D50/2°/M2/ABS	N/A
Avg.	41.56	-49.37	1.12	N/A	3.2

Pantone 335 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	44	-54	1	N/A	N/A
1	44.53	52.28	2.9	D50/2°/M2/ABS	N/A
2	44.56	-52.6	2.97	D50/2°/M2/ABS	N/A
3	44.74	52.53	2.87	D50/2°/M2/ABS	N/A
4	44.86	52.63	2.95	D50/2°/M2/ABS	N/A
5	44.64	52.47	2.89	D50/2°/M2/ABS	N/A
6	44.93	-52.8	2.95	D50/2°/M2/ABS	N/A
7	44.21	52.08	2.88	D50/2°/M2/ABS	N/A
8	44.67	52.47	2.94	D50/2°/M2/ABS	N/A
9	44.61	52.53	2.91	D50/2°/M2/ABS	N/A
10	44.26	51.92	2.86	D50/2°/M2/ABS	N/A
Avg.	44.60	52.43	2.91	N/A	1.3

Pantone 356 C	L*	a*	b*	Mode	CIEDE2000
Reference	43	-50	26	N/A	N/A
1	42.41	-48.89	27.44	D50/2°/M2/ABS	N/A
2	42.68	-48.71	27.26	D50/2°/M2/ABS	N/A
3	42.98	-48.64	27.2	D50/2°/M2/ABS	N/A
4	43.39	-48.89	27.38	D50/2°/M2/ABS	N/A
5	42.26	-49.00	27.45	D50/2°/M2/ABS	N/A
6	42.52	-48.99	27.4	D50/2°/M2/ABS	N/A
7	42.52	-48.58	27.21	D50/2°/M2/ABS	N/A
8	41.91	-49.13	27.65	D50/2°/M2/ABS	N/A
9	42.86	-48.81	27.31	D50/2°/M2/ABS	N/A
10	42.15	-49.12	27.59	D50/2°/M2/ABS	N/A
Avg.	42.57	-48.88	27.39	N/A	0.9

Pantone 356 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	45	-51	28	N/A	N/A
1	46.1	-	28.62	D50/2°/M2/ABS	N/A
2	46.27	-	28.6	D50/2°/M2/ABS	N/A
3	46.00	-	28.73	D50/2°/M2/ABS	N/A
4	46.10	-	28.92	D50/2°/M2/ABS	N/A
5	46.00	-	29.01	D50/2°/M2/ABS	N/A
6	45.59	-	28.32	D50/2°/M2/ABS	N/A
7	45.41	-	28.5	D50/2°/M2/ABS	N/A
8	45.39	-	28.74	D50/2°/M2/ABS	N/A
9	45.57	-	28.35	D50/2°/M2/ABS	N/A
10	45.62	-	28.84	D50/2°/M2/ABS	N/A
Avg.	45.81	-	28.66	N/A	0.9

Pantone 377 C	L*	a*	b*	Mode	CIEDE2000
Reference	57	-26	59	N/A	N/A
1	56.88	-24.09	59.71	D50/2°/M2/ABS	N/A
2	56.98	-24.28	60.29	D50/2°/M2/ABS	N/A
3	57.11	-24.24	60.14	D50/2°/M2/ABS	N/A
4	56.96	-23.98	59.97	D50/2°/M2/ABS	N/A
5	57.28	-24.22	60.43	D50/2°/M2/ABS	N/A
6	57.06	-24.26	60.1	D50/2°/M2/ABS	N/A
7	57.45	-24.51	60.87	D50/2°/M2/ABS	N/A
8	57.43	-24.28	60.02	D50/2°/M2/ABS	N/A
9	57.25	-24.21	60.35	D50/2°/M2/ABS	N/A
10	57.29	-24.26	60.57	D50/2°/M2/ABS	N/A
Avg.	57.17	-24.23	60.25	N/A	1.1

Pantone 377 XGC	L*	a*	b*	Mode	CIEDE2000
Reference	63	-25	60	N/A	N/A
1	62.74	23.27	60.7	D50/2°/M2/ABS	N/A
2	62.14	23.12	60.69	D50/2°/M2/ABS	N/A
3	62.07	23.11	60.19	D50/2°/M2/ABS	N/A
4	62.06	22.98	60.24	D50/2°/M2/ABS	N/A
5	62.22	23.22	60.34	D50/2°/M2/ABS	N/A
6	61.55	23.37	59.66	D50/2°/M2/ABS	N/A
7	61.34	23.26	59.14	D50/2°/M2/ABS	N/A
8	61.97	23.09	60.18	D50/2°/M2/ABS	N/A
9	61.94	23.18	59.62	D50/2°/M2/ABS	N/A
10	61.93	23.15	60.16	D50/2°/M2/ABS	N/A
Avg.	62.00	23.18	60.09	N/A	1.3

Reference Values	L*	a*	b*	CIEDE2000
Pantone 103 C	71	-1	87	
Pantone 103 XGC	72	-2	76	2.6
Pantone 150 C	78	29	58	
Pantone 150 XGC	81	21	54	4.6
Pantone 187 C	38	57	29	
Pantone 187 XGC	37	60	23	3.7
Pantone 227 C	36	68	-4	
Pantone 227 XGC	38	63	-4	2.1
Pantone 251 C	73	33	-22	
Pantone 251 XGC	72	20	-12	6.9
Pantone 264 C	75	15	-25	
Pantone 264 XGC	74	1	-17	10.1
Pantone 2925 C	58	-18	-46	
Pantone 2925 XGC	60	-15	-41	2.8
Pantone 306 C	67	-36	-36	
Pantone 306 XGC	65	-31	-35	2.5
Pantone 322 C	41	-44	-18	
Pantone 322 XGC	40	-47	-17	1.6
Pantone 335 C	45	-51	1	
Pantone 335 XGC	44	-54	1	1.3
Pantone 356 C	43	-50	26	
Pantone 356 XGC	45	-51	28	2.0
Pantone 377 C	57	-26	59	
Pantone 377 XGC	63	-25	60	5.3