An Analysis of the Current Status of Process Control for Color Reproduction in Newspapers

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Keywords

Color reproduction, newspaper printing, process control, SNAP specifications

Abstract

This study on the current status of process control for color reproduction in newsprint is presented in three parts. The first part is a fresh analysis of data gathered from 102 U.S. newspapers that printed a test form to apply for certification of conformance to the SNAP specifications. The data from these pressruns were used by the CGATS committee in calculating color characterization data for newspaper printing. On examination, this data revealed that only 6 of 102 newspapers were in compliance with the SNAP specifications for solid densities and 50% dot gains. It also revealed high levels of variability in the color values of the 928 patches in the ANSI/IT.8.7/3-2005 across the 102 newspapers.

The second part of the study examined the current process control specifications for newspaper printing from the SNAP Committee and the proposed specifications from ISO TC 130/SC/WG 3. The values being specified were contrasted against the production measurement practices of a sample of newspapers from various countries. It was found that none of the papers regularly print the targets that would be required to test conformance with the specifications. The most common process control target used by newspapers in daily production was the three-color gray bar.

The third part of the study addressed the question of whether control of solid densities, dot gains, or three-color gray is an effective way to predict the color appearance of a printing system. It was shown through correlation matrix analysis that there were only weak relationships between the specified process control attributes and the overall color appearance of a printing system.

This study proposed that a practical avenue for color control in newspaper printing is measurement within the pictorial images themselves. The bases for this recommendation were that measurements of solid inks, dot gains, and three-color gray are not sufficiently predictive of color appearance, and, due to the absence of trim space in which to run process control targets, it is impractical for newspapers to make multiple measurements within each ink-key zone, as would be required for compliance with existing specifications.

Background

Newspapers were the last of the publication methods to make the switch from black and white to color reproduction. Newspapers had printed occasional color images for decades, but the 1982 launch of *USA Today* by the Gannett Corporation, who at the time owned 78 daily newspapers in

33 states and Guam, provided the catalyst that precipitated a mass migration to color reproduction by the nation's newspapers. *USA Today* was the first national newspaper, thus it competed against all of the local papers. *USA Today* gained popularity quickly selling 1.3 million copies daily by the end of 1983. The full-color format became popular with advertisers and local papers needed to move to color to compete.

In the early years, *USA Today* went to extreme lengths to assure color quality and consistency among its 24 printing plants. They operated a small proofing press at their Arlington, VA headquarters where they would print the color pictures for the next day's edition along with color bars to control ink density. After the proofs were approved, areas within the images were selected as control targets. The density values of these areas were recorded and a template with the target areas circled was made to overlay the pictures. Press proofs were prepared for each of the printing companies, with the target areas identified and the density values for those target areas displayed. These proofs were sent by overnight delivery to each of the printing plants to use as guides during the production runs. To complete the quality circle, work was done with X-Rite to provide the printing companies with densitometers of the same model that had been tested for inter-instrument agreement. After a couple of years this system was modified to eliminate the need to send overnight packages to each printing plant. However, the color quality reputation of *USA Today* was initially founded on inner-image measurement.

In 1984, the first edition of SNAP (*Specifications for Non-Heat Advertising Printing*) was published by the Non-Heatset Web Unit of the Printing Industries of America. By this time, it had become clear that the newspaper industry needed a set of color reproduction specifications similar to those provided by SWOP (*Specifications for Web-Offset Publications*) for the magazine publishing industry since 1976.

In North America, SNAP, which has evolved into the *Specifications for Newsprint Advertising Production,* has become a widely supported and referenced specification. After the fourth revision of the SNAP specifications in 2005, it became available as an electronic document in pdf format at *www.naa.org* where it is revised periodically based on SNAP Committee recommendations. Today, the SNAP specifications are based on ISO 12647-3:2005, *Graphic technology — Process control for the production of half-tone colour separations, proofs and production prints — Part 3:Coldset offset lithography on newsprint.* This study used the downloaded pdf file of the SNAP specifications as the basis for analysis.

Part 1: New Analysis of Data from the CGATS Newspaper Characterization Study

The data used here were from 102 newspaper pressruns that were submitted for Certification of Compliance with the SNAP specifications from the Newspaper Association of America. These runs targeted the SNAP specifications. The data from these press sheets were used by the Committee for Graphic Arts Technologies Standards (CGATS) as the basis for the ANSI Technical Report, *Graphic technology — Color characterization data for coldset printing on newsprint* (CGATS/SNAP TR 002—2007).

These data were described in CGATS/SNAP TR 002—2007 as follows:

> *These data are based on the measurement of press sheets produced by practical printing, and have been approved by the SNAP Committee as the best current estimate of the characterization of this class of printing. The samples used to create this data set were press sheets, produced by printing organizations seeking SNAP certification, through conformance pressruns conducted by the SNAP committee during the period 2004–2005. A sample from each of 102 press tests that met the SNAP conformance requirements, were accepted for inclusion in the data set. These data were averaged to produce the reference data set.*

The data were from measurements of the 928 color patches of the ANSI/IT.8.7/3-2005 target. There were no physical samples examined in this study; all analysis was made from the 102 data files that were submitted to CGATS. The measurements included CIELAB values and cyan, magenta, yellow and black Status-T absolute density measurements for each of the 928 color patches in the target. A key to the ANSI/IT.8.7/3-2005 target provided the CMYK dot values associated with each of the target patches.

The target values from the SNAP July 2006 Edition—the targets for these pressruns—are summarized in Table 1.

SNAP Aimpoints	Cyan	Magenta	Yellow	Black
Solid Density	0.90 +/- 0.05	0.90 +/- 0.05	0.85 +/- 0.05	1.05 +/- 0.05
25% dot gain	28% +/- 3%	28% +/- 3%	28% +/- 3%	28% +/- 3%
50% dot gain	30% +/- 4%	30% +/- 4%	30% +/- 4%	30% +/- 4%
75% dot gain	20% +/- 3%	20% +/- 3%	20% +/- 3%	20% +/- 3%
	Cyan	Magenta	Yellow	Black Density
Quartertone gray	25%	18%	18%	0.52 +/- 0.05
Midtone gray	40%	30%	30%	0.65 +/- 0.05
		L*	a*	b*
Paper		82.0 +/- 3	0.0 +/- 3	3.0 +/- 2
If SNAP specifications are met, print contrast should be as follows:				
Print contrast	13 +/- 5	12 +/- 5	15 +/- 5	16 +/- 5
Reference values provided by SNAP (not specifications)				
		Blue	Green	Red
Ink trapping (Preucil method)		69	80	50
		Cyan	Magenta	Yellow
Hue Error (including paper)		28	58	10
Grayness		42	34	25

Table 1. Summary of aimpoints from SNAP 2006 Edition.

In addition, the SNAP publication presents colorimetric aim values taken from ISO 12647-3 for the solid ink colors and the two-color overprints. These values are listed in Table 2.

	L*	a*	b*
Cyan	57	-23	-27
Magenta	54	44	-2
Yellow	78	-3	58
Black	36	1	4
Blue	41	7	-22
Green	53	-34	17
Red	52	41	25

Table 2. Colorimetric aimpoints for solid inks and overprints from SNAP 2006 Edition.

The data from the 102 pressruns was combined into an Excel spreadsheet. The key to the dot values for the ANSI/IT.8.7/3-2005 target enabled the identification of certain patches that corresponded with process control targets specified in SNAP. The target does not include patches that would enable complete evaluation of the compliance of participating newspapers with SNAP. For example, calculations of print contrast, 25%, and 75% dot gains could not be made. The sections that follow give the results of the SNAP specifications that *could* be evaluated.

Solid Ink Densities

The analysis with reference to achieving solid ink density goals is summarized in Table 3. The table displays the average densities of the 102 different pressruns, the percentage of samples that were out of specification, and the breakdown of the numbers that were below spec and above spec.

	Cyan	Magenta	Yellow	Black
Target Densities	0.90 +/- 0.05	0.90 +/- 0.05	0.85 +/- 0.05	1.05 +/- 0.05
Average	0.900	0.896	0.823	1.024
Range	0.30	0.32	0.31	0.34
Std. Deviation	0.055	0.056	0.055	0.061
Coef. of Variation	0.061	0.062	0.067	0.059
Out of Spec.	29.4%	31.4%	35.3%	36.3%
Too Low	12	18	30	28
Too High	18	14	6	9

Table 3. Summary of solid density.

Although the average densities from the 102 pressruns were close to the SNAP aimpoints, about one-third of the samples for each color were outside the acceptable density ranges. In fact, only

28 of the 102 participating newspapers were within specification for all four process color densities. The cyan and magenta average densities were very close to the target densities, while the yellow and black average densities were lower than the aimpoints.

In addition, the out-of-specification results for cyan and magenta were reasonably balanced between being too high and too low, but the yellow and black out-of-spec densities were distinctly imbalanced toward being too low (yellow: 30 low, 6 high; and black: 28 low, 9 high). A probable cause for this imbalance was improper allowance for ink dryback. The SNAP specifications refer to dry density values, and they caution that printers need to calibrate the dryback values for their particular ink and paper combinations. SNAP reports that dryback values from 0.02 to 0.05 are common. The results in Table 3 indicate that the dryback values for yellow and black were typically underestimated by about 0.03 density units.

Although dryback can explain the low average densities for yellow and black, it does not explain the large number of samples that fell outside the density specifications. To demonstrate this, the yellow and black densities for each of the 102 samples were corrected by the probable errors in ink dryback. This caused the average densities of the yellow and black inks to match the SNAP targets, but the percentages of samples that were out of spec were only slightly reduced. However, better balance was achieved between the number of samples on the low and high sides.

The unadjusted out-of-spec yellow densities consisted of 30 samples that were low and 6 that were high (representing 35.3% of the 102 newspapers). The adjusted yellow densities had 18 low and 16 high (33.3% of the 102).

Similarly, the unadjusted black densities had 28 samples too low and 9 too high, totaling 36.3%. The adjusted black ink densities yielded 18 too low and 18 too high, or 35.3% of the total.

The standard deviations for the four process colors were each slightly higher than the 0.05 tolerances that SNAP specifies for solid densities (see Table 1). This is consistent with the numbers of samples that were out of spec for each color. For normal distributions 67% of samples fall within one standard deviation of the mean. This indicates that the SNAP density tolerances are not achievable by the population of newspapers in this study. The goal of many process control strategies is to develop a capability of six-sigma with respect to the tolerances of the manufacturing process. In other words, if the standard deviation of the manufacturing operation is one-third of the tolerance established for the process, then 99.7% of the samples can be within tolerance if the process is aimed properly. However, in order for this population of newspapers to be in compliance with the SNAP density specifications, then the standard deviations between the ink densities of the newspapers for each of the process colors would need to be about 0.017 rather than C:0.055, M:0.056, Y:0.055 and K:0.061. Conversely, if the ink density standard deviations remained the same, then the SNAP tolerances would have to be expanded to +/-0.150 to have 99.7% of the newspapers from this study in density compliance.

It is common for standards bodies to set ink density tolerances at the same level for each of the four process colors. However, since the target densities for the four colors are not the same, the tolerances actually represent different percentages for the four colors. The coefficient of variation provides a normalized index of variation that corrects for these differences, making comparisons more meaningful. Examining the standard deviations in Table 3, it appears that the deviations of cyan, magenta, and yellow were very close and black was somewhat higher. However, the coefficients of variation give a more accurate picture, showing that black had the lowest normalized variability and yellow had the highest.

Only 28 of 102 newspapers were in spec for all four solid ink densities. Clearly, most newspapers found it challenging to achieve the target density values for SNAP.

In addition to the statistics shown in Table 3, skewness and kurtosis of the density samples were examined, and standard errors of these values were calculated. These data indicated it was reasonable to treat this sample as a normal distribution.

Dot Gain

The analysis of the dot gain compliance of the samples with the SNAP specification could only be made for the 50% tone value since the ANSI/IT.8.7/3-2005 target does not contain one-color 25% or 75% patches. The 50% dot gain analysis showed even less compliance with the SNAP specifications than did the solid densities. Only 17 of the 102 participating newspapers were within dot gain specifications for all four process color inks. A summary of the results is shown in Table 4.

	Cyan	Magenta	Yellow	Black
50% dot gain	30% +/- 4%	30% +/- 4%	30% +/- 4%	30% +/- 4%
Average	25.5%	25.7%	25.4%	25.7%
Range	39.4	44.9	35.9	47.6
Std. Deviation	7.10	7.76	7.16	8.38
Coef. of Variation	0.28	0.30	0.28	0.33
Out of Spec.	56.9%	56.9%	58.8%	59.8%
Too Low	50	46	51	46
Too High	8	12	9	15

Table 4. Summary of 50% dot gain.

About 58% of the samples were out of spec for each of the four colors. Unlike the density values, the average dot gains are substantially lower than the aimpoints in the SNAP specifications. The average dot gains are all about 4.5% lower than the SNAP targets. These levels of tone value difference would be clearly noticeable in pictorial images. This is clear evidence that the dot gain aimpoints of SNAP are not representative of this sample of newspapers.

As with the density values, when the dot gain values of the samples were adjusted such that the average of the samples was equal to the targets specified by SNAP, the out-of-specification totals were about the same as in Table 4, although there were more uniform distributions of samples whose values were too high and too low. This indicates that the problem of improper aimpoints does not explain the large number of newspapers that were out of specification for dot gain. This is worrisome since dot gain has been shown to have a more pronounced effect on picture quality than does solid ink density.

Of greater concern are the high standard deviations and large ranges of the dot gain attribute among the 102 samples. The standard deviations can be interpreted to mean that a randomly selected newspaper from the 102 samples would have from 7–9% dot gain discrepancies from the mean dot gain of all the samples. These high discrepancies would result in color pictures that had drastically different color appearances among the papers. Two concerns with this condition are that (1) the newspapers are not able to achieve the SNAP specification for dot gain and (2) the newspapers are not a cohesive population with respect to dot gain.

The SNAP tolerance for dot gain variation is +/-4%, which is slightly more than half of the standard deviations found among newspapers in this sample. This indicates that even if the average dot gains of the samples had hit the SNAP target values, only about 35% of the newspapers would have been within specification for dot gain in any given color. In practical terms, in order to achieve acceptably uniform color appearance across this sample of newspapers, corrective output profile curves would have to be applied at platemaking.

Again, skewness and kurtosis analysis indicated that this sample of dot gain values could be treated as a normal distribution.

The dot gain spread *between* colors is addressed in the SNAP specifications. A maximum dot gain spread of 4% is recommended to maintain color balance within images. Of the 102 newspapers in this data set, only 12 of them met this criterion.

Within a given printing system, there typically is a strong correlation between solid ink density and dot gain. Linear regression analysis was performed on the 102 newspapers in this study to determine if there was a relationship *across* printing systems, but *within* an industry segment. The scatterplots and statistics relating to this analysis are shown in Appendix A. There was no appreciable relationship between density and dot gain for any of the ink colors. We suspect that the dot gain variances among these newspapers were primarily influenced by ink rheology, ink water balance, mechanical transfer characteristics of the press, and other factors.

Ink Trapping

The efficiency with which an ink transfers to a previously printed ink film is measured with ink trapping. The SNAP guidelines do not include ink trapping values in their specifications, but they include them as a cross-check for printers who are adhering to SNAP. The trap values are calculated by the Preucil method. Table 5 contains statistics for the calculated trap values for the 102 newspapers that participated in this study.

	Green	Blue	Red
Target	80.0	69.0	50.0
Mean from 102 newspapers	88.0	70.1	56.1
Standard Deviation	5.4	5.4	7.7
Coef. of Variation	0.061	0.078	0.137
Range	28.9	31.0	46.0

Table 5. Summary of ink trapping values.

The measured trap values are higher than the trap values from SNAP. As with other attributes, there were broad ranges and high standard deviations for the trap values, indicating substantial discrepancy among the printed samples. The overall high values indicate more efficient ink transfer than was anticipated by SNAP.

Paper

The SNAP specifications include CIELAB targets for the printing paper as summarized in Table 1. In addition to the tolerances that "shall" be met, SNAP publishes tighter tolerances that "should" be met. Table 6 shows the numbers of newspapers that exceeded both sets of tolerances, with those outside of the "should" ranges described as "non-ideal." The ANSI/IT.8.7/3-2005 target that was measured for this analysis contained an unprinted patch. Thus, CIELAB measurements of the printing papers were available for analysis; however, there were no data on paper brightness measurements. Interestingly, SNAP did not include tolerances for the brightness attribute. A summary of the color of the papers is shown in Table 6.

	L*	a*	b*
Target	82.0 +/- 3	0.0 +/- 3	3.0 +/- 2
Mean	80.06	-0.01	3.53
Std. Deviation	0.91	0.51	0.76
Maximum	83.2	1.51	5.64
Minimum	77.9	-1.41	1.28
Non-ideal	48	6	23
Out of Spec.	9	0	4

Table 6. CIELAB values of printing papers.

The mean CIELAB values of the newsprint used by the 102 participating newspapers were close to the SNAP aimpoints, except that the mean values were a little less bright and slightly more yellow. In total, there were 13 papers that did not meet the "shall" specifications and an additional 46 that did not meet the "should" specifications. SNAP cautions that adjustments to the SNAP specifications may be necessary if the substrate differs substantially from the aimpoints.

Primary and Secondary Ink Colors

SNAP publishes CIELAB values for the primary and secondary ink colors on newsprint, citing the source for these values as ISO 12647-3. Tolerances are only given for the KCMY inks. Both deviation and variation tolerances are given in terms of ΔEab. In this analysis, only the deviation tolerances are examined since the data from each newspaper is represented by only a single set of measurements and the variation tolerances relate to the variations within a printing system rather than between printing systems. The deviation tolerance for each color is 5ΔE. The CIELAB aimpoints from SNAP are shown in Table 2. The summary statistics for the 102 newspapers from this study with reference to these aimpoints is shown in Table 7.

	Cyn	Mag	Yel	Blk	Blu	Grn	Red
L-targt	57.00	54.00	78.00	36.00	41.00	53.00	52.00
L-mean	56.58	52.71	76.57	36.64	39.75	52.85	50.91
L-std dev	2.08	1.79	1.30	2.43	1.86	2.28	1.67
a-targt	-23.00	44.00	-3.00	1.00	7.00	-34.00	41.00
a-mean	-23.39	44.10	-4.05	1.68	5.99	-34.89	40.73
a-std dev	1.00	2.22	1.14	0.22	2.75	1.64	2.62
b-targt	-27.00	-2.00	58.00	4.00	-22.00	17.00	25.00
b-mean	-26.42	-1.08	54.67	4.26	-22.42	15.69	22.34
b-std dev	1.95	1.42	3.98	0.76	1.52	3.28	2.67
mean DE	2.73	3.13	4.90	2.24	3.53	4.07	4.52
Out of spec	8	13	34	6	-	-	-

Table 7. CIELAB matches of single color and two-color overprints.

The mean CIELAB values of the 102 participating newspapers differ slightly from the target values. The most pronounced difference is in the b-values of the yellow ink. The standard deviation of the ΔE values of the yellow ink is higher than the other three process inks. This is evident from the large number of papers, 34, whose yellow inks were out of tolerance from the SNAP CIELAB targets. The yellow inks showed much higher variability than the other process colors.

The wisdom of setting tolerances for both solid density values and CIELAB coordinates is questionable since it represents a form of “double tolerancing.” This can easily lead to confusion as to which tolerance should take precedence if there is a conflict.

Predictably, the overprint colors showed higher variability with respect to the SNAP CIELAB aimpoints than did the single colors. SNAP does not specify tolerance levels for the CIELAB values of blue, green, and red.

Color Characterization Data

Data from the press tests examined in this study were used by the CGATS committee in defining the color characterization data for newspaper printing. The color characterization data is a standard data set that represents the color gamut for newspaper printing. Vendors who are selling proofing systems, ink optimization software, color management software, and other related products use the characterization data as the target for their processes with respect to the newspaper industry.

Although there are times when the IT8 committee members perform some data smoothing and consider other data sources in establishing the standard characterization data, in this case it was decided to simply average the data, as explained in the following passage:

> *Characterization data may be prepared in a variety of ways. Limited, controlled printing tests which are carefully adjusted to exactly match the specification aims are one approach. Here the resultant small sample of data is often mathematically adjusted and smoothed to allow it to "fit" the predefined process control aims. A second approach, and the one chosen by SNAP, is to collect and average a large body of test data from printing tests which have all met the aims within specified tolerances. The averaging of a large volume of data inherently provides the smoothing desired in a characterization data set. While this approach may not achieve data that exactly matches all of the predefined aims, it does provide a more realistic picture of the real printing that is being done to these aims. Both approaches have their advantages. The most important issue is a clear understanding and definition of the source and provenance of the data. That is the purpose of this Technical Report.*

The mean CIELAB values from the 102 newspapers examined here formed the basis for the characterization data. It is a matter of concern that the newspapers in this study represented such a disparate population. Even though the pressruns were all aimed at the SNAP targets, about one-third of the group was out of tolerance for solid densities, and more than half of the newspapers were not acceptable with respect to midtone dot gain.

To examine the variability of this sample with respect to color, ΔEab and ΔE2000 values were calculated for each of the 928 patches in the ANSI/IT.8.7/3-2005 target between the mean CIELAB values of the group and each of the participating newspapers. Summary statistics of the average color differences for the 928 patches are shown in Table 8.

	Mean ΔEab	Mean ΔE2000
Mean	3.68	2.71
Std. Deviation	1.30	1.07
Range	6.38	4.99
Minimum	1.56	1.14
Maximum	7.94	6.13

Table 8. Summary of color difference measurements.

The data in Table 8 summarizes more than 180,000 calculations. Two color difference calculations were made for 928 patches from the ANSI/IT.8.7/3-2005 target and 102 participating newspapers. Table 8 is based on the mean color differences for each newspaper across all 928 target patches. Summary statistics for each of the newspapers are shown in Appendix B.

Table 8 shows that the average of the mean color differences for all the newspapers was 3.68 with a standard deviation of 1.30. The mean color differences of the newspapers were found to be normally distributed, indicating that a newspaper that was two standard deviations above the mean would have an average deviation of more than 7ΔEab. This would result in distinctly different color appearance from the mean of the group.

Conclusion of Part 1

Although it was not possible from the data available to make a complete evaluation of the adherence of the 102 contributing newspapers to the SNAP specifications, it is clear from the print attributes and color differences that could be calculated that a substantial majority of the newspapers were out of compliance with the SNAP specifications. In fact, only 6 of 102 newspapers were in compliance with both the solid ink density and 50% dot gain specifications. This is disconcerting because the newspapers who participated in this study were targeting the SNAP specifications with sufficient process control targets and instrumentation to achieve that aim. They were not in the midst of a production pressrun, and they did not have to run their presses at production speeds.

The results reviewed here call into question whether newspapers could meet SNAP specifications in their daily production environments. They also beg the question of whether these test results were a good basis for the establishment of color characterization data.

Part 2: Process Control Targets in Daily Use by Newspapers

The second part of this study examined the process control targets used by newspapers in daily production. Several newspapers are known for consistent high-quality color graphics. However, it is unclear whether these newspapers are able to adhere to the SNAP or ISO specifications in their daily environment, or whether they follow internal process control procedures. Also, some are clearly dependent on a high degree of skill and judgment on the part of their employees.

The SNAP and ISO specifications call for measurement of solid ink densities and dot gain values for each process color. Additionally, they specify gray balance aimpoints. Typically, newspaper presses have eight ink key zones across each page. These ink key zones can have significantly different density levels than their neighboring zones and therefore must be measured separately. It is critically important to measure the ink keys that control the area of a page where a color picture is printed.

To control the solid ink densities and dot gains in the critical areas, a full-width color bar would need to be printed across the page. To control three-color gray, a gray bar would also have to extend across the entire page. Since newspapers have no trim space in which to place these targets, these process control devices would be visible in the finished paper. This is typically unacceptable from an aesthetic point of view, and, therefore, compromises must be made and/or more surreptitious targets must be used.

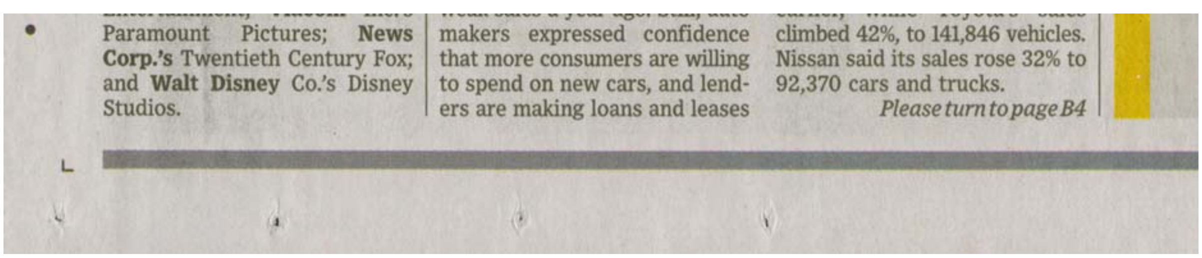
The authors gathered evidence of the process control targets imaged in newspapers in several countries. A total of 161 newspapers from twelve countries (but principally India, the United States, and England) were included. Table 9 shows the process control targets that are used in daily production by these newspapers.

None	Gray Bar	Solids	Tints	Solids/Tints
57	67	42	1	9

Table 9. Process control target in daily newspaper production.

Table 9 shows that the most popular process control device among newspapers is the three-color gray bar, although there are nearly as many newspapers that do not image any process control devices in their papers at all. The total of the columns in Table 9 is greater than 161 because some papers have both gray bars and solid patches and thus are counted in two columns.

The most common scenario for the three-color gray bar is to calibrate the density values on the bar with occasional press tests, then to run to those density values in daily production. Some of the newspapers that have reputations for high-quality color use this method. Typically, the gray bar is imaged across the entire press form so that the balance between ink key zones can be assessed. The gray bar has the advantage that it is not too obvious and does not distract the readers of the paper. It is also visually sensitive, showing clear shifts in hue if the cyan, magenta, and yellow inks across the page drift out of balance. Figure 1 shows a three-color gray bar printed in a daily newspaper.



Paramount Pictures; **News Corp.'s** Twentieth Century Fox; and **Walt Disney** Co.'s Disney Studios.

makers expressed confidence that more consumers are willing to spend on new cars, and lend-ers are making loans and leases

climbed 42%, to 141,846 vehicles. Nissan said its sales rose 32% to 92,370 cars and trucks.

Please turn to page B4

Figure 1. Three-color gray bar.

Many newspapers print the three-color gray bars on a restricted number of pages (sometimes one page only). Other papers print the bar on each page that contains a color image. The three-color gray bar has the advantage that it prints across the entire page, covering all ink key zones.

When color solids and tints are used for daily process control, the most common scenario is that they are imaged only in one place on the page (thus, one ink key zone). It is common for this to be at the edge of a page where few color photographs are printed, as shown in Figure 2.

Figure 2. Solid and tints printed for process control.

As with the gray bars, the solids and tints are often printed on a limited number of pages. Some newspapers combine the use of three-color gray bars with solids and tints, as shown in Figure 3.

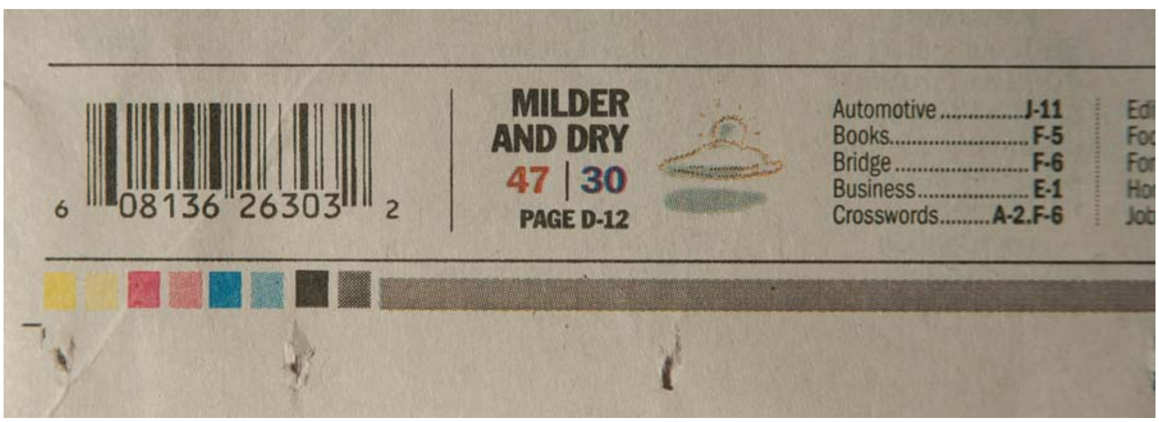


Figure 3. Solids and tints printed for process control.

Some of the newspapers that do not image any targets for process control measurements utilize features of their newspapers—like mastheads—as targets that can be measured to set solid ink densities.

Conclusion of Part 2

In conclusion to part 2 of this study, it is apparent from this sample that very few, if any, newspapers are printing process control targets on a daily basis that would enable them to measure their print attributes against the SNAP specifications or those contained in ISO 12647-3.

Part 3: Correlation of Print Attributes with Color Reproduction

So, are the print attributes specified by SNAP and ISO good targets for color reproduction? Parts 1 and 2 led to the implication that the usefulness of ISO 12647-3 might be increased adding two options to the current standard color bar compliance that it currently features: compliance with a gray bar, and compliance within the work.

Can the Use of a Gray Bar Be Justified?

The fact that standard color bars are not widely accepted for newspapers is partial justification for other options. After all, the standard is not useful if it does not get used. However, any alternative should ideally provide for similar control as the existing requirement. Do measurements from a gray bar allow one to demonstrate sufficient compliance to color reproduction?

The success of Dow Jones in implementing gray bar control (Cousineau, 2010) and the success of System Brunner gray balance control are two instances that suggest that gray bars might be useful as color monitoring devices. The SNAP data set described earlier provides data that enables direct comparison of the effectiveness of a gray bar versus a standard color bar for monitoring color reproduction.

Correlation of Variations Between Patches

The premise of this analysis is that a certain color patch is useful as a control element to the extent that changes in that patch can predict changes in the rest of the CMYK values. An ideal set of color patches would be able to stand proxy for the entire CMYK color space.

The SNAP data set that was discussed in the first part of this paper provides an excellent opportunity to put various sets of control patches to the test. The data is ideal in that it is not part of a well-organized test carried out on a single press; rather, it includes all the normal sorts of variation that occur in the real world. This sort of data isneeded when designing a color bar that works best in a production environment.

For example, looking across the 102 press sheets from different printers, there is variation in the color of the solid magenta patches. Some sheets will be lower or higher than average; and some will have a slightly different hue to their magenta ink. One would expect that the same printer who printed the solid magenta patch high will also print the 90% magenta patch high. There should be a correlation between the deviations in color measurements between the solid and the 90.

Figure 4 shows the color deviations for the M100 patches (in blue) and those of the M90 patches (in red). Along the horizontal axis, the data is sequenced as L* deviation for the first press sheet, a* variation for the first press sheet, b* variation for the first press sheet, L* variation for the second press sheet, and so on. In this way, there are 306 values along the horizontal axis. The vertical axis represents the variations in L*, a*, or b*, as compared against the average of all press sheets for that patch. The blue graph represents the color variations for the M100 patch, and the red represents the color variations for the M90 patch.

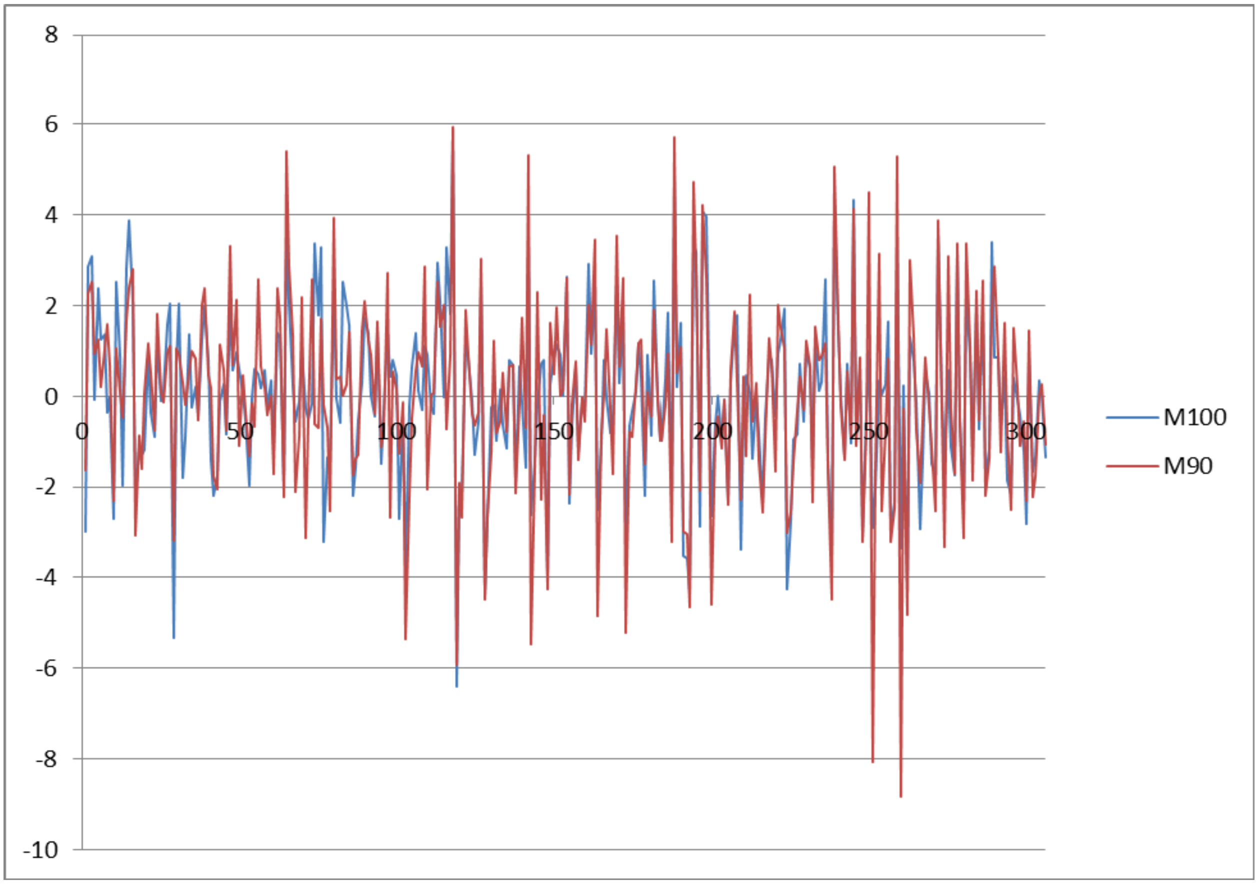


Figure 4. L*a*b* color deviations for M100 and M90 patches of all 102 press sheets in the SNAP data set.

From Figure 4 it is a bit difficult to see how well the two correlate. A more visually revealing way to graph the data is to use a scatter plot with the deviations for the M100 patch on one axis and the deviations in the M90 patch along the other. This graph is shown in Figure 5.

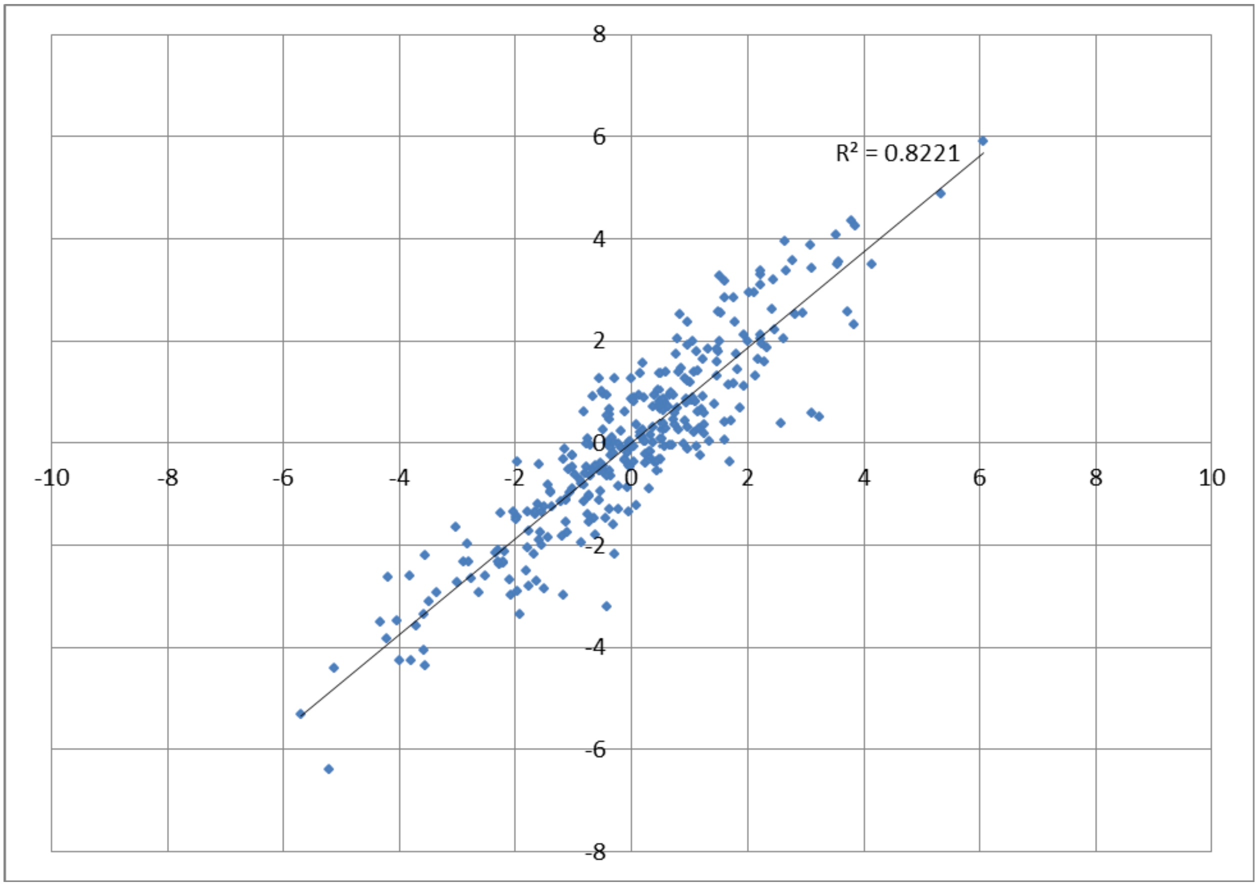


Figure 5. Scatter plot of each press sheet's color deviations for the M100 patch on one axis vs. the deviations in the M90 patch along the other.

There is a clear correlation, with a coefficient of .9067. The square of the coefficient, or r^2 value, is 0.8221. That means that 82% of the variation in one data set is correlated to the variation in the other. The remaining 18% might be caused by variation in paper among the printers, or perhaps by different dot gains among the printers. Note that the solid patches are presumably not affected by dot gain, whereas the M90 patches are slightly affected by dot gain.

This correlation demonstrates that under real-world conditions, measurements of an M100 patch can be used to reliably predict the measurements of an M90 patch. In other words, an M100 can serve as a proxy for the M90. That in itself is not a remarkable result. The important point is that this correlation provides a way to assess which patches a given patch may serve proxy for. By combining results from all patches in a proposed color bar, we can determine how well a proposed color bar can serve proxy for the rest of the colors.

Case 1, The Solids

In the beginning, we monitored the density of the four solids. The reasoning behind this was simple. All we really were able to control was the amount of ink put on the page, so why measure anything else?

The table below shows a count of how many patches from the IT8 set that are well proxied by each of the solid ink patches (KCMT). A ”good proxy” was defined as those patches where the correlation is at least 0.7, meaning that they share at least 50% of the variations. ”Fair proxy” is defined as those patches where the correlation is between 0.5 and 0.7, meaning that the patches share at least 25% of the variation but less than 50%.

Solid	Good proxy	Fair proxy
Cyan	6	26
Magenta	10	61
Yellow	9	35
Black	3	9
C+M+Y+K	28	131

Table 10. Number of patches from the 928 patches of the IT8 target that are proxied by KCMY solids.

The results are disappointing and perhaps surprising. Of the 928 patches on the IT/8 target, a solid cyan patch has a good correlation with only 6 patches. One of those 6 is itself. Another of the patches is a second solid cyan patch that is included in the target. The final row shows the combined results of all four solid patches. The numbers 28 and 131 represent the count of all patches that can be proxied by at least one of the four patches. Considering all four, only 14% of the IT8 target (or 159 out of 928 patches) can be proxied even at the fair level by any of the solid ink patches.

The conclusion is that the variation in ink film thickness is not the only variable, and, possibly,it is not even the most important variable.

Case 2, Solids Plus Midtones

ISO 12647-3 requires that solids agree with CIELAB values, but also requires that tone value increase be within a certain range. So, what if we add four midtone patches to the mix. The IT8 target does not include 50% patches, so the four 40% single ink patches and the four 60% single ink patches were examined.

The table below includes the results for the four solids for comparison. A column has been added for the number of patches in the set, and the percentages of the IT8 set that is proxied are indicated.

Patch set	No. of patches	Good proxy	Fair proxy
Solids	4	28 (3%)	131 (14%)
Solids + 40%	8	186 (20%)	587 (63%)
Solids + 60%	8	178 (19%)	601 (65%)

Table 11 Number of patches proxied by solids plus tints.

The results are significantly better when either set of midtone patches are added in. This says that under normal conditions, tone value increase has a larger effect on the overall color than does ink film thickness.

Still, even with eight patches, there is a good proxy for only one patch out of five.

Case 3, A Single CMY Gray Patch

The IT8 target includes a number of patches that are reasonable approximations to three-color gray. Five of them have been included in Table 12.

Patch set	No. of patches	Good proxy	Fair proxy
Solids	4	28 (3%)	131 (14%)
Solids + 40%	8	186 (20%)	587 (63%)
Solids + 60%	8	178 (19%)	601 (65%)
(40, 27, 27)	1	100 (11%)	399 (43%)
(40, 40, 40)	1	159 (17%)	503 (54%)
(40, 40, 40)	1	147 (16%)	509 (55%)
(60, 45, 45)	1	65 (7%)	396 (43%)
(70, 70, 70)	1	59 (6%)	367 (40%)

Table 12. Number of patches proxied by solids, tints, and gray patches

Of those three-color "gray" patches in the IT8 set, the (40, 40, 40) patch provides the best coverage. This patch by itself can stand good proxy for 16% to 17% of the IT8 set. While this is slightly less than the number proxied by the eight "Solids + 60%" patches, the (40, 40, 40) patch is a single patch.

Many newspaper printers use a midtone gray patch along with the CMY gray patch. The table below looks at this pair of patches as compared against various other previous combinations.

Patch set	No. of patches	Good proxy	Fair proxy
Solids	4	28 (3%)	131 (14%)
Solids + 40%	8	186 (20%)	587 (63%)
CMY40	1	159 (17%)	503 (54%)
CMY40 + K40	2	257 (28%)	576 (62%)

Table 13. Number of patches proxied by solids or gray plus a single black tint patch.

The pair of patches (a CMY gray patch and a midtone black patch) is able to stand good proxy for 28% of the IT8 set, as compared with 20% for the set of patches that are required by ISO 12647-3:2005.

Put another way, if the purpose of a set of control patches is to stand in for the rest of the possible colors, then the set of eight patches required by ISO 12647-3:2005 is inferior to the set of two gray patches that is currently favored by newspaper printers.

What Are Reasonable Tolerances?

As with the tolerances for the L*a*b* values of the solids that are in the existing ISO 12647-3, there would need to be tolerances for these two gray patches. What tolerances make sense?

There are several ways one might approach this question. The easiest is to use the existing tolerances for the solid patches, which are either 4 ΔE or 5 ΔE, depending on ink and whether the tolerance is for the OK sheet or for the rest of the pressrun. Perhaps these should be decreased just a bit on the theory that lighter colors generally have less variation. Or perhaps one might go the other way. A midtone has the additional variability of TVI, and an overprint has the additional variability of overprint trap, so perhaps the tolerances should be somewhat larger.

It was decided to take 4 ΔE value as a reasonable first approximation to what the tolerance should be.

Another way to determine a tolerance is to use the data from the 102 printers to establish what printers are capable of when they are putting forth good effort to make a test target. Figure 6 shows a histogram of the ΔE values between the mean L*a*b* values for the CMY 40 patch and the individual printers.

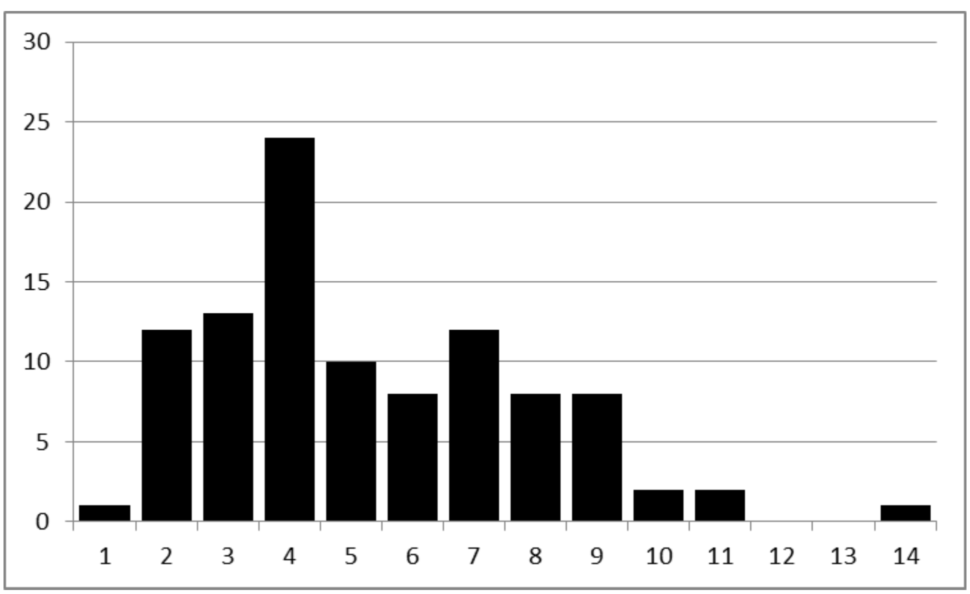


Figure 6. Histogram of ΔE between mean CMY 40 patch and individual printers.

Deciding on a tolerance is essentially asking which printers should be excluded. The printer that was at 14 ΔE can safely be excluded as an outlier. One could argue that the additional four printers above 10 ΔE could also be excluded. Thus, in order to include 97 of the 102 printers, we would need to set the tolerance at 10 ΔE. This is clearly out of line with the reasonable approximation that we started with.

Setting the tolerance to 4 ΔE would have the effect of eliminating exactly half of the printers in this study. Notwithstanding the results of the first part of this paper, this seems a bit draconian.

Another way to look at this is to consider that 67 of the 102 printers managed to pass the 5 ΔE criterion (in 12647-3) for cyan, magenta, yellow, and black. To create an alternate tolerance that is equally restrictive, then the bar might be set so that roughly the same number of printers would be able to pass this test. If the tolerance for CMY40 were set to 6 ΔE, then 69 of the printers would meet the goal for each of the three inks.

Yet another way to set a tolerance is to convert the TVI tolerance into a ΔE value. Thirty-two patches were selected from the IT8 target. All of the patches were within ±28% of the C50 M42 Y42 patch. Linear regression was performed on the L*, a*, and b* values as a function of dot area. Regression results were very good: all three r^2 values were above 0.97. All coefficients were very significant, statistically. In this area of CMY space, the relationship to L*a*b* is fairly linear and well behaved.

The following matrix formula described the approximation

$$\begin{bmatrix} L* \\ a* \\ b* \end{bmatrix} = \begin{bmatrix} 51.92 \\ -0.48 \\ 1.04 \end{bmatrix} + \begin{bmatrix} 0.152 & 0.204 & 0.029 \\ -0.308 & 0.407 & -0.068 \\ -0.235 & -0.119 & 0.321 \end{bmatrix} \begin{bmatrix} \Delta C \\ \Delta M \\ \Delta Y \end{bmatrix}$$

where ΔC, ΔM, and ΔY are the differences in dot area from the gray patch.

The tolerance for TVI from 12647-3:2005 is ±5%. This matrix equation allows us to estimate the effect of a ±5% change in tone value for any of the three inks. The largest changes in ΔE occurs when all three inks are at either +5% or -5%, and they are not all positive or negative. These all correspond to a color error of about 4.0 ΔE.

As an aside, if the TVI of all three inks change in the same direction (that is, they are all equal to +5% change) then the color change is only 1.9 ΔE. This agrees with the observation that the eye is most sensitive to tone value changes when at least one of the inks is moving in a different direction than the others.

Thus, the ±5% tolerance in TVI for the 50% patches corresponds to a 4 ΔE color change for a gray 50. Based on this analysis, a 4 ΔE tolerance on the gray patch would be recommended.

This same analysis was made for other gray patches. Since there are not established TVI tolerances for all the rest of the tone values, Table 14 provides a conversion between TVI and

ΔE. For the 10% gray patch, for example, each step change in tone value can cause as much as 1.782 ΔE change in color.

C	M	Y	ΔE per %TV
10	8	8	1.78
20	16	16	1.52
30	24	24	1.07
40	33	33	1.07
50	42	42	0.81
60	53	53	0.78
70	64	64	0.72
80	76	76	0.45
90	88	88	0.45

Table 14. Conversion between TVI tolerance and ΔE for various CMY gray values.

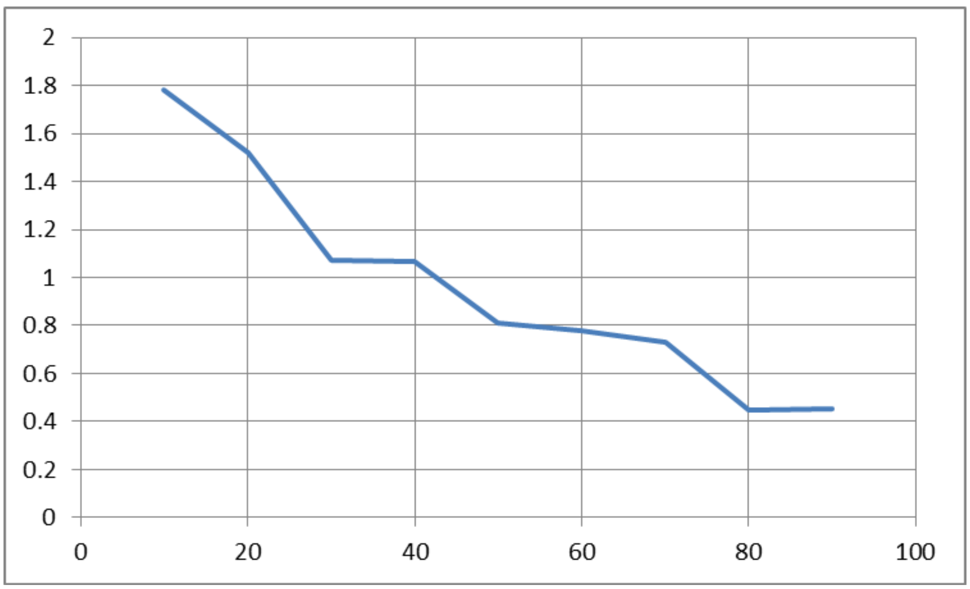


Figure 7. Conversion from TVI tolerance to ΔE for various CMY gray patches.

To summarize, the simple analysis suggests that a tolerance of 4 ΔE is reasonable. If tolerance is set so as to allow about two-thirds of the 102 printers to pass, then 6 ΔE is the appropriate tolerance. Finally, direct conversion from TVI change to ΔE suggests that 4 ΔE is appropriate.

Can Measurements of the Work Be Justified?

The key reason to make measurements of control patches is to provide assurance that the color of the work is correct. The results of the previous section show that the standard color bar requirement in 12647-3:2005 (eight patches, with a solid of each color and midtone of each color) does a good job of proxying only 20% of CMYK space, and does a fair job of proxying only 63% of CMYK space.

If the ultimate goal is to assure that the printed work looks good, then it might be useful to turn the question around. Is it justifiable to use the standard color bar as a proxy for the work? Can the existing standard be justified if technology has gone beyond color bar measurement?

That said, measurements from standard patches do provide useful process control parameters. These are useful as a general check on the health of the process and may help diagnose issues. How do we derive similar measures for measurements from the images themselves?

One simple approach is to look at statistics like "mean ΔE" and "90th percentile ΔE", but interpretation of this is confounded by the fact that the images being printed change from day to day, and therefore so would the CMYK values. The development of the usual control parameters will be an area of development in the future.

What Are Reasonable Tolerances?

There is not much in the current standards to suggest how one might set a tolerance for measurements in the work, so again the data from the 102 printers was examined. As before, it was assumed that roughly two-thirds of the printers have printed acceptably well.

ISO 12647-3:2005 draws a distinction between the tolerable deviations for an OK print ("color OK sheet"), and the tolerable variability over the pressrun. For the OK print, it is necessary that all the tolerances be met for all the control patches. This is quite reasonable if there are 8 control patches on the OK print.

This requirement becomes unreasonable when one considers a job with a full color bar extending the full width of the web. Now, instead of a single sheet meeting eight tolerances, that single sheet must meet perhaps 1,000 tolerances. With normal process variation, this is impossible.

When color is measured within the work, the number of measurements for a single print OK is several orders of magnitude larger than for a full color bar extending across the web. With this many measurements, statistical tolerances (such as 68% of the measurements must be within a given tolerance) seem to make the most sense.

With these observations in mind, the 68th percentile ΔE was computed for each of the 102 printers. This is shown in the figure below.

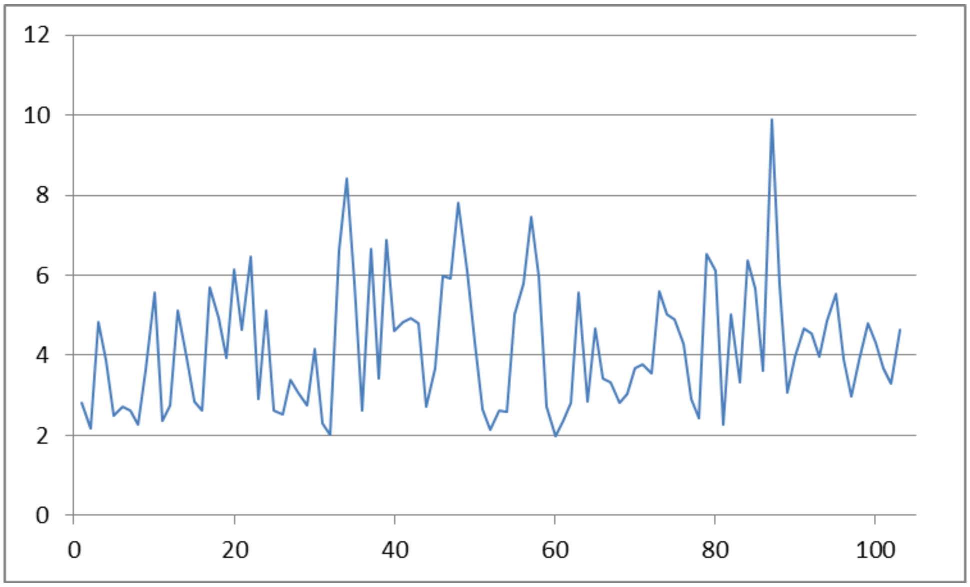


Figure 8. The 68th percentile ΔE was computed for each of the 102 printers.

The 68th percentile for these numbers is 4.87 ΔE. In other words, 68% of the printers are able to hold 68% of their patches to within a tolerance of about 5 ΔE. This would be a reasonable starting point for establishing tolerances for measurement within the work.

Conclusions

In this paper the authors have shown that the SNAP specifications were not adequately met by the 102 newspapers that were submitted to CGATS as the basis for establishing color reference data for this industry segment. The basis for this analysis was the data set compiled by the SNAP committee of density and CIELAB measurements of 928 color patches from the ANSI/IT.8.7/3-2005 target that was printed to demonstrate conformance to the SNAP specifications to obtain certification from SNAP.This paper then found that newspapers are not printing control targets in their daily production that would enable them to confirm adherence to process specifications being proposed by ISO TC 130/SC/WG 3. The basis for this analysis was 161 newspapers sampled from several countries. Nearly one-half of the papers printed no control bars and the most commonly used control target was a 3-color gray bar across the page.

This study also examined the effectiveness of various control patches for predicting the color appearance of all colors. It was found that the combination of a gray patch with a black solid tint was able to serve as an adequate proxy of 28% of the colors from the 928 patches on the IT.8 target. This was better performance than the solids and tints recommended by the ISO, but still deemed to be inadequate for comprehensive color control.

Finally, it was suggested that making color measurements within the color pictures themselves, which today is an available option, might provide a more reliable means of controlling the reproduction of color. The tolerances for inner-image measurements should be approached differently from the tolerances for selected proxy patches because there are orders of magnitude more measurements taken inside images. A starting point for inner-image measurement tolerance was suggested based on the data set examined for this study.

References

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ISO TC 130/SC N, ISO/WD 12647-3, *Graphic technology — Process control for the production of half-tone colour separations, proofs and production prints — Part 3:Coldset offset lithography on newsprint*, 2010.

SNAP, *Specifications for Newsprint Advertising Production,* July 2006 edition.

Cousineau, Paul L. and Kuklen, Tuba, *Use of Ink Modeling and Volumetric Equations for Closed Loop Control of Optical Density in Coldset Newspaper Applications*, TAGA Proceedings, 2010, Pittsburgh, PA, pp. 1—26.

Nurmi, Olli, *Colour quality control in Karkimedia newspapers,* 29th IARIGAI Conference

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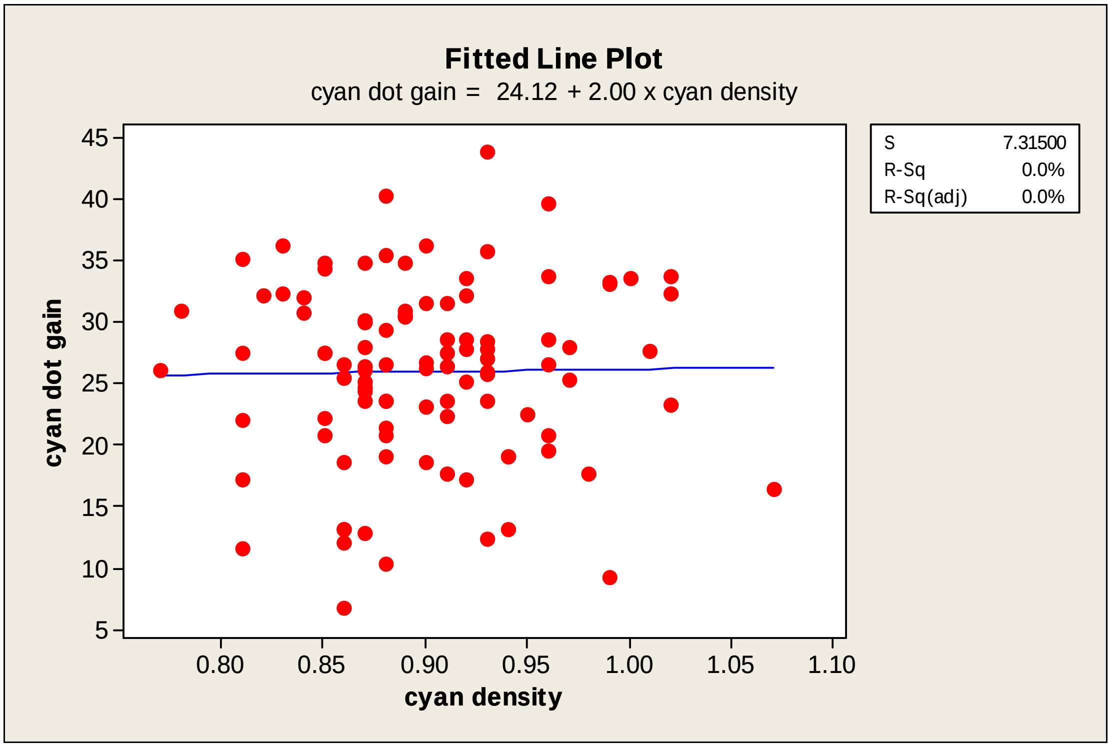
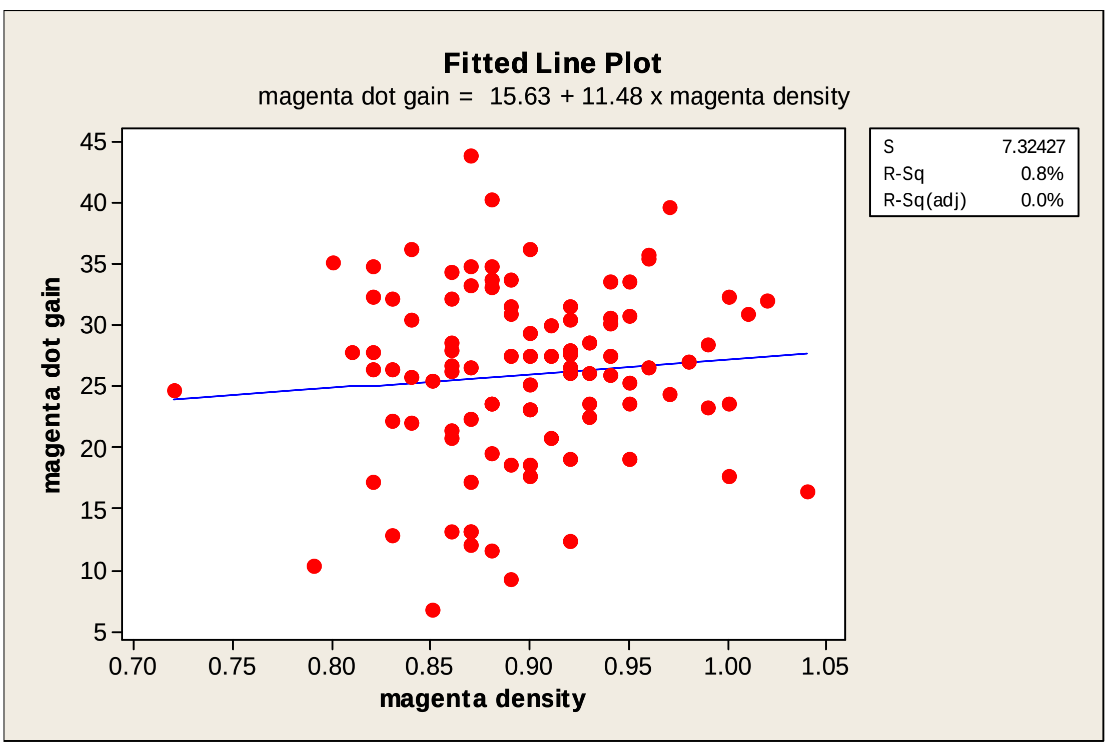
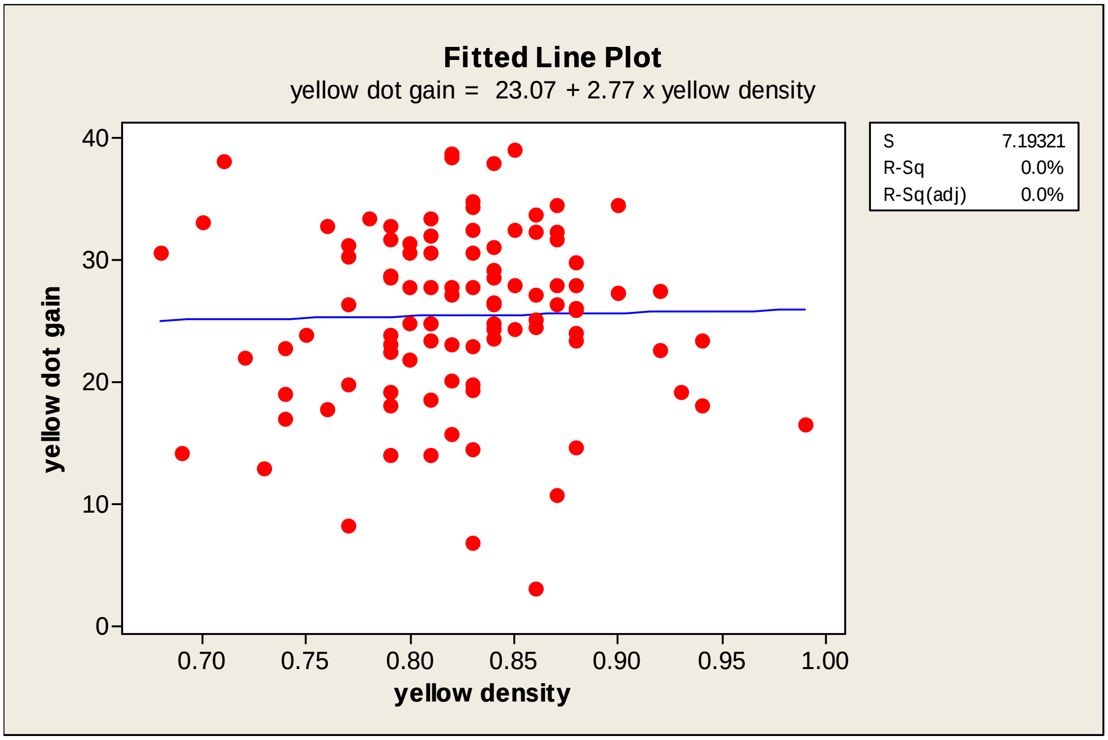
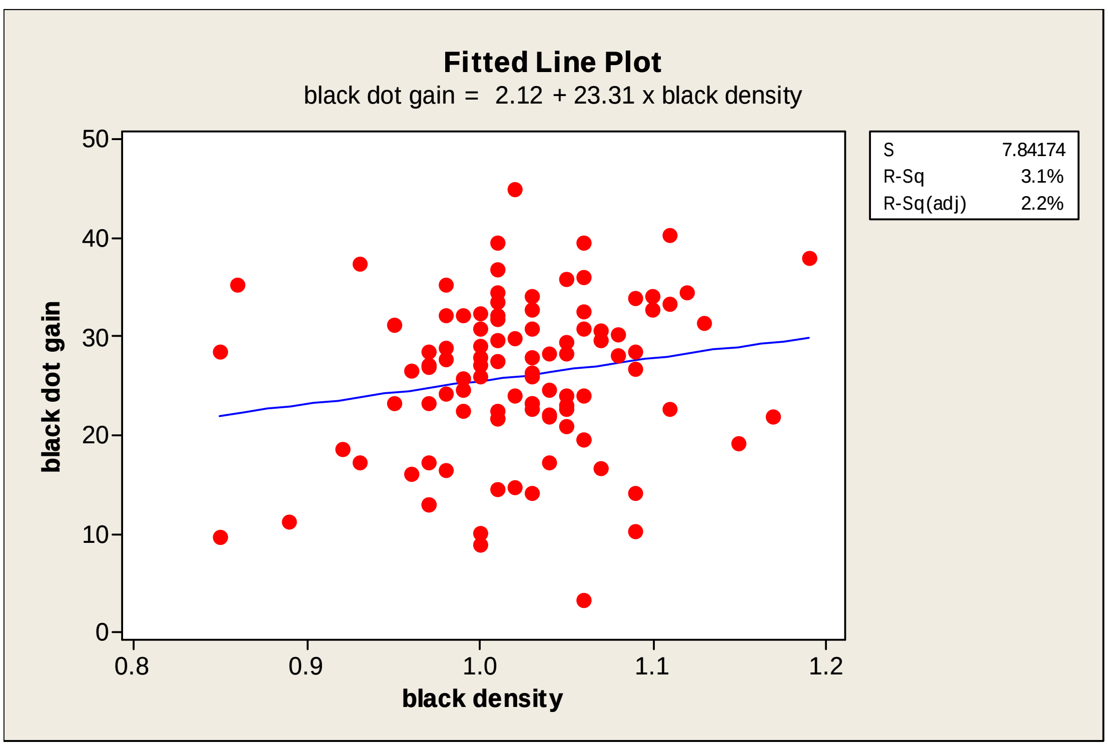
Appendices

Appendix A: Dot Gain vs. Density for Newspapers






Fitted Line Plot
yellow dot gain = 23.07 + 2.77 x yellow density
S 7.19321
R-Sq 0.0%
R-Sq(adj) 0.0%
yellow dot gain
yellow density
0
10
20
30
40
0.70
0.75
0.80
0.85
0.90
0.95
1.00


Fitted Line Plot
black dot gain = 2.12 + 23.31 x black density
S 7.84174
R-Sq 3.1%
R-Sq(adj) 2.2%
black dot gain
black density
0
10
20
30
40
50
0.8
0.9
1.0
1.1
1.2

Appendix B: Color Difference Statistics for Newspapers

	ΔEab					ΔE2000				
ID	Mean	Med	SD	Min	Max	Mean	Med	SD	Min	Max
1	2.77	2.85	1.12	0.15	7.09	2.43	2.50	1.04	0.14	5.88
2	2.09	1.92	1.03	0.26	11.91	1.55	1.43	0.96	0.09	14.66
3	4.42	4.51	1.70	0.52	10.06	3.37	3.23	1.71	0.17	9.52
4	3.66	3.56	1.39	0.31	8.30	3.03	3.01	1.20	0.19	7.74
5	2.45	2.23	1.26	0.14	7.26	1.85	1.70	1.05	0.13	8.62
6	2.02	1.91	0.90	0.28	6.08	1.51	1.42	0.70	0.17	4.76
7	2.24	2.08	1.06	0.12	6.10	1.52	1.40	0.85	0.03	5.33
8	2.05	1.92	1.06	0.19	5.98	1.41	1.26	0.79	0.10	4.57
9	1.84	1.79	0.78	0.13	5.82	1.25	1.17	0.62	0.09	4.47
10	3.44	3.45	1.40	0.28	7.92	2.38	2.23	1.24	0.09	5.87
11	5.00	4.75	2.10	0.52	12.56	2.68	2.48	1.29	0.35	7.49
12	2.19	2.05	1.06	0.27	6.76	1.47	1.37	0.83	0.04	4.80
13	2.13	1.99	1.12	0.16	6.83	1.38	1.22	0.82	0.08	6.53
14	4.71	4.40	2.16	0.33	12.97	3.42	3.16	1.88	0.22	14.07
15	3.46	3.23	1.62	0.27	10.30	2.29	2.18	1.12	0.09	8.83
16	2.89	2.88	0.95	0.25	6.68	2.43	2.41	0.95	0.18	7.24
17	2.69	2.64	1.01	0.16	6.08	2.13	2.09	0.84	0.17	5.10
18	4.52	4.65	1.49	0.23	9.36	3.47	3.60	1.38	0.21	7.05
19	4.53	4.53	1.91	0.44	11.12	3.22	3.07	1.62	0.20	8.11
20	3.61	3.49	2.05	0.24	14.40	2.91	2.62	1.90	0.13	11.14
21	5.61	5.59	2.14	0.56	13.20	4.60	4.48	1.86	0.20	9.30
22	4.43	4.51	1.61	0.68	11.85	3.94	4.11	1.56	0.25	11.73
23	6.16	6.11	1.96	0.29	13.06	5.08	5.07	1.68	0.32	9.42
24	2.47	2.18	1.32	0.23	8.04	1.61	1.48	0.88	0.08	5.66
25	4.12	3.74	2.25	0.17	11.64	2.73	2.57	1.55	0.07	8.90
26	2.50	2.22	1.43	0.13	8.88	1.70	1.59	0.86	0.08	4.97
27	2.53	2.20	1.37	0.31	7.40	1.63	1.44	0.94	0.05	4.70
28	3.77	3.55	1.55	0.27	10.16	2.86	2.72	1.16	0.25	6.22
29	2.42	2.30	1.09	0.18	7.49	1.58	1.49	0.81	0.06	4.82
30	2.04	1.93	0.99	0.16	5.75	1.61	1.46	0.99	0.08	5.79
31	1.56	1.49	0.78	0.12	6.57	1.14	1.05	0.66	0.04	6.37
32	5.53	5.39	2.38	0.84	13.84	3.57	3.56	1.80	0.37	7.67
33	6.95	6.93	3.49	0.45	16.63	5.27	4.82	3.05	0.30	12.82
34	5.58	5.61	1.65	1.19	10.52	5.10	5.21	1.50	0.99	8.62
35	2.34	2.26	1.08	0.19	7.55	1.57	1.46	0.96	0.10	8.43
36	3.36	3.18	1.42	0.10	9.62	2.73	2.58	1.49	0.12	12.63
37	5.53	5.23	2.03	0.40	13.26	4.35	4.34	1.69	0.49	9.97
38	3.24	2.92	1.48	0.24	9.02	2.40	2.22	1.14	0.24	5.84
39	5.36	5.49	2.05	0.45	11.03	4.12	4.15	1.98	0.15	8.21

40	3.92	3.67	2.00	0.48	9.56	2.58	2.14	1.60	0.27	8.80
41	4.44	4.08	2.34	0.45	12.45	3.54	3.08	2.28	0.15	14.76
42	4.16	3.90	2.03	0.16	11.63	2.70	2.54	1.35	0.16	9.32
43	4.38	3.92	2.27	0.61	14.11	2.71	2.24	1.99	0.29	17.23
44	2.50	2.20	1.36	0.27	9.30	1.85	1.67	1.04	0.07	6.29
45	3.59	3.39	1.53	0.43	9.88	2.86	2.67	1.31	0.25	7.25
46	4.62	4.24	2.42	0.27	13.82	2.96	2.69	1.75	0.13	8.14
47	4.70	4.43	2.35	0.43	12.50	3.19	3.04	1.76	0.08	10.53
48	6.21	6.13	2.50	0.19	14.31	5.02	4.97	2.27	0.14	11.06
49	4.92	4.95	1.90	0.36	12.35	3.49	3.30	1.71	0.23	8.86
50	3.96	3.67	2.08	0.47	18.92	2.86	2.75	1.38	0.24	12.40
51	1.89	1.85	0.83	0.05	5.05	1.49	1.40	0.75	0.05	5.01
52	1.56	1.51	0.61	0.12	3.99	1.14	1.08	0.60	0.07	3.92
53	2.42	2.22	1.26	0.16	6.56	1.63	1.42	0.99	0.09	5.66
54	2.64	2.22	1.67	0.19	11.66	2.00	1.68	1.36	0.10	7.80
55	4.16	3.89	1.87	0.06	13.64	2.92	2.81	1.25	0.04	6.95
56	4.67	4.35	2.44	0.53	13.60	3.17	2.89	1.78	0.06	10.25
57	5.98	6.04	2.26	0.43	13.34	3.85	3.50	2.09	0.14	9.62
58	4.59	4.55	2.00	0.30	11.17	3.67	3.57	1.77	0.24	8.09
59	2.34	2.03	1.29	0.18	8.72	1.58	1.50	0.77	0.12	5.31
60	2.00	1.82	0.97	0.15	6.36	1.47	1.36	0.80	0.11	4.38
61	2.24	2.16	0.94	0.18	6.42	1.71	1.67	0.81	0.08	5.53
62	4.52	4.65	1.49	0.23	9.36	3.47	3.60	1.38	0.21	7.05
63	2.38	2.28	1.05	0.25	6.92	1.77	1.61	0.94	0.10	4.73
64	2.62	2.43	1.25	0.18	7.99	1.89	1.77	0.99	0.17	6.22
65	2.34	2.03	1.29	0.18	8.72	1.58	1.50	0.77	0.12	5.31
66	4.16	3.94	2.16	0.27	11.28	3.36	3.34	1.90	0.19	10.16
67	3.01	2.77	1.80	0.17	9.94	2.34	2.07	1.58	0.06	10.49
68	3.02	2.41	2.01	0.19	11.10	1.98	1.54	1.47	0.13	9.46
69	2.31	2.17	1.18	0.12	6.88	1.53	1.36	0.87	0.11	5.66
70	2.38	2.28	1.05	0.25	6.92	1.77	1.61	0.94	0.10	4.73
71	3.55	3.49	1.52	0.23	8.95	2.67	2.60	1.38	0.14	7.31
72	3.53	3.34	1.42	0.62	10.40	2.60	2.41	1.31	0.16	8.04
73	3.43	3.34	1.66	0.11	9.01	2.47	2.27	1.38	0.08	6.47
74	4.77	4.36	2.41	0.34	13.00	3.28	2.99	1.76	0.08	10.46
75	4.09	3.82	1.90	0.19	12.91	2.65	2.51	1.27	0.20	6.82
76	4.69	4.59	1.81	1.00	11.97	3.87	3.78	1.58	0.46	9.32
77	3.62	3.43	1.83	0.18	9.59	2.59	2.16	1.63	0.14	8.09
78	2.27	2.10	1.14	0.18	6.11	1.64	1.44	1.00	0.07	6.66
79	2.21	1.97	1.08	0.24	7.57	1.66	1.48	0.95	0.09	6.14
80	5.20	5.06	1.93	0.20	11.68	3.93	3.76	1.95	0.16	8.68
81	5.97	5.74	2.03	0.61	14.64	4.92	4.96	1.84	0.50	12.36
82	2.38	2.32	0.81	0.36	4.97	1.88	1.81	0.82	0.18	4.52

83	4.37	4.15	2.06	0.41	17.29	3.05	2.94	1.73	0.13	13.09
84	2.65	2.55	0.96	0.23	6.12	2.05	2.02	0.80	0.15	5.12
85	5.37	5.34	1.56	1.15	11.96	3.98	4.05	1.54	0.67	7.58
86	4.41	4.40	1.80	0.33	9.64	3.34	3.09	1.71	0.17	7.44
87	3.31	2.67	2.15	0.14	12.59	2.30	1.81	1.73	0.05	11.65
88	7.94	7.97	3.54	0.22	20.08	6.13	5.99	3.00	0.19	13.40
89	5.09	4.97	2.44	0.46	14.64	4.34	4.31	2.23	0.28	11.76
90	3.14	2.71	1.82	0.29	11.43	2.03	1.94	1.06	0.09	7.84
91	3.21	2.87	1.91	0.11	10.22	2.02	1.78	1.21	0.09	7.33
92	4.22	3.95	2.11	0.34	13.27	3.02	2.81	1.64	0.18	7.89
93	4.32	4.07	2.12	0.43	12.21	3.25	3.12	1.62	0.30	10.60
94	3.61	3.41	1.46	0.13	11.01	2.64	2.47	1.21	0.10	8.05
95	4.70	4.70	1.54	0.80	11.76	4.06	3.90	1.42	0.26	9.48
96	5.19	5.13	1.78	0.48	10.69	4.38	4.45	1.69	0.30	10.28
97	3.61	3.29	1.89	0.42	13.79	2.53	2.23	1.63	0.29	11.81
98	2.95	2.68	1.34	0.21	9.27	1.97	1.88	0.89	0.14	6.72
99	3.23	2.99	1.61	0.25	9.63	1.80	1.67	0.96	0.05	5.90
100	4.69	4.54	1.61	0.72	11.38	3.97	3.84	1.41	0.49	8.23
101	4.10	3.58	2.03	0.32	12.91	2.72	2.48	1.45	0.15	11.57
102	3.15	3.04	1.36	0.08	8.17	1.99	1.94	0.97	0.04	6.39