# Quality Analysis of Spot Color Reproduction with an Inkjet Printer

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## Abstract

*Spot color is widely used in commercial, product or packaging printing to obtain a colorful appearance. With the combination of the right software, inks and media, an inkjet printer can be treated as a digital proofer for spot color printing, providing significant time and cost savings compared to conventional procedures for jobs approval. An Epson Stylus Pro 4000 digital printer combined with two commercially available RIPs were tested and compared. ICC profiles were generated for the Epson Stylus Pro 4000 printer, using the actual production printing substrate and manufacturer recommended proofing paper. Color gamuts of different output combinations were compared and the quality of spot color reproduction was evaluated in terms of the ΔE in L*a*b* color space for selected spot colors.*

## Introduction

Recently, the trend in the printing industry includes shorter run lengths and work with fast turnaround times. New developments in digital printing have made it possible to produce small quantities of high-quality color products at affordable prices. With its unique properties, digital printing can be used for proofing, providing significant time and cost savings compared to conventional procedures (preparing cylinders and printing proof samples) for potential product verification [1, 2].

The implementation of digital proofing is highly integrated with color management [3]. The key to achieving the best quality color reproduction is to combine the right equipment, software and media.

The use of raster imaging processor (RIP) has provided better control for accurate digital color reproduction in inkjet printing. The ink can be adjusted and limited in the RIP, achieving the right amount of ink distribution correctly on the media. Because ink is distributed correctly on the media, a larger color gamut can be obtained [4, 5].

Paper is a significant variable in predicting and reproducing color. The interaction between paper and ink, its porosity, roughness, coating structure, together with paper properties such as whiteness, light scattering, and gloss [6, 7] must be considered in the digital proofing process. The gamut of the printer can be significantly affected by the properties of the substrate used for printing [8, 9]. Proofing on the actual production stock more closely predicts print outcome. However, working with different inks and devices, the actual production printing substrate can have a very different color gamut and behave differently in the digital proofing process. Therefore, optimal digital proofing must factor the paper into the color reproduction process [10-12].

The main purposes of this experimental study are to (1) examine the quality of spot color reproduction with an inkjet printer, and (2) establish a digital proofing system for spot color printing. An Epson Stylus Pro 4000 digital printer combined with CGS ORIS RIP and GMG ColorProof RIP were tested and compared. ICC profiles were generated for the Epson Stylus Pro 4000 printer, using the actual production printing substrate and the manufacturer recommended proofing paper. Color gamuts and L*a*b* values of different print combinations were compared.

## Experimental

The objective of this investigation was to establish a digital proofing system for spot color printing. Color management with ICC profiles was used to investigate the reproduction of specific spot colors. The digital printer, an Epson Stylus Pro 4000 combined with commercially available RIPs - GMG ColorProof RIP and CGS ORIS RIP, was tested for different printing substrates.

Seven spot colors were selected for evaluation: Blue-347, Black-392, Red-314 and Red-349, and Yellow-355, Yellow-357, and Yellow-385. Each chart consisted of 66 patches of different gray levels, generating a chart with a variety of shades for the color (as shown in Figure 1). The colors were printed on the substrate by a drum cylinder gravure proofing press. Each specific measured area on the individual chart was measured for $L^*a^*b^*$ values five times to reduce the measuring error and the average value was computed as original data. According to these original data, the spot color test charts in digital form were generated by using Photoshop CS2, so that these charts could be used for actual digital printing reproduction.

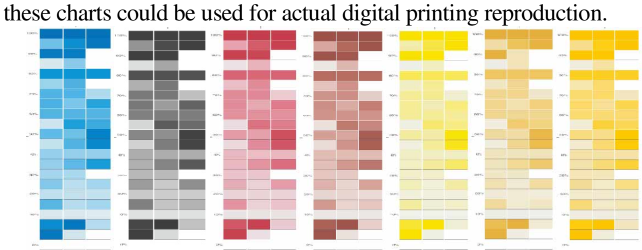


***Figure 1.*** *Spot Color Test Chart*

ICC profiles were generated for the Epson Stylus Pro 4000, using selected printing substrates (the actual production printing substrate and manufacturer recommended proofing paper). The device was profiled as a CMYK device. For the GMG ColorProof RIP and CGS ORIS RIP, the ECI2002V CMYK chart was printed on the tested substrates without any ink limitation, because a specific full gamut color profile was needed to reproduce the desired spot colors. Those printed charts were then measured with a GretagMacbeth SpectroScanT in reflection mode, operated by GretagMacbeth Measure Tool 5.0.4 software. The measurement files were used to generate profiles using GretagMacbeth ProfileMaker Pro 5.0.4. ICC profiles were loaded into the RIPs' spot color functions. Seven spot color test charts were then printed via the RIPs on the tested substrates and the L*a*b* values for each color patch of the chart were measured using the GretagMacbeth SpectroScanT.

The quality of spot color reproduction was evaluated in terms of the ΔE in L*a*b* color space. The Epson 4000 printer with GMG ColorProof RIP was employed to print spot color chart on different printing substrates and the color gamuts of the output combination were compared using ColorThink 3.0 Pro software.

## Results and Discussion

In this study, Epson Stylus Pro 4000 printer was profiled using CGS ORIS RIP and GMG Color Proof RIP on the actual production printing substrate and the manufacturer recommended proofing paper. Selected spot color test charts were then printed via CGS ORIS RIP and GMG ColorProof RIP. The color gamuts of four output combinations were tested and compared. The quality of spot color reproduction was evaluated in terms of the color difference (ΔE).

## Gamut Comparison

Figure 2 illustrates color gamut comparison for GMG RIP and ORIS RIP on the actual production printing substrate (with L*a*b* values of original data for reference). GMG Color Proof RIP demonstrated larger gamut of Epson Stylus Pro 4000 Printer on the actual gravure printing substrate, especially in yellow, red, and magenta area. The gamut volume for GMG Color Proof RIP and CGS ORIS RIP are 227,700 and 193,900, respectively. It is important to note that some shadow tints in spot color test charts are out of color gamut of printers.

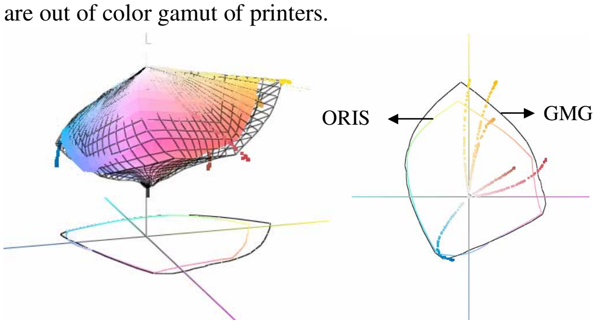


***Figure 2.*** *Epson 4000 gamut comparison on the actual production printing substrate: GMG (wireframe) vs. ORIS (true color).*

**Figure 3** depicts color gamut comparison for GMG RIP and ORIS RIP on the manufacturer recommended proofing paper. The color gamut of GMG Color Proof RIP is similar to that of CGS ORIS RIP, with exception of yellow and blue area. The gamut volumes are 630,500 for GMG Color Proof RIP and 630,800 for CGS ORIS RIP. Obviously, the color gamut of manufacturer recommended proofing paper is larger than that of actual production printing substrate in terms of gamut volume.

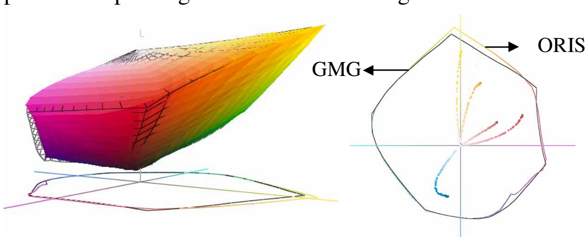


***Figure 3.*** *Epson 4000 gamut comparison on the manufacturer recommended proofing paper: GMG (wireframe) vs. ORIS (true color).*

## ΔE comparison of original and printed $L^*a^*b^*$ values for Spot Color Test Charts

The ΔE values calculated for original and actual printed $L^*a^*b^*$ values for each spot color are shown in **Table 1**. The first ΔE value indicates the average ΔE value for each spot color chart. The second ΔE value is the minimum ΔE value, while the third value shows the maximum ΔE value among 66 patches for each spot color. For actual production printing substrate, both commercially available RIPs provide good color reproduction for the selected spot colors except for the Yellow-385 spot color (the average ΔE values of selected spot colors are all lower than 3 with exception of Yellow-385 color). For manufacturer recommended proofing paper, the GMG ColorProof RIP offers better color reproduction for the selected spot colors, while the CGS ORIS RIP tends to have larger ΔE values (the average ΔE values are over 3).

**Table 1. Summary of ΔE comparison for different print combinations**

| | ΔE on actual production printing substrate | | ΔE on manufacturer recommended proofing paper | |
|---|---|---|---|---|
| Spot colors | GMG RIP | ORIS RIP | GMG RIP | ORIS RIP |
| Blue-347 | 1.4, 0.1, 8.3 | 2.4, 0.1, 9.9 | 0.6, 0.1, 2.0 | 3.1, 1.6, 5.6 |
| Black-392 | 1.5, 0.2, 6.9 | 2.6, 0.2, 10.6 | 0.6, 0.2, 1.7 | 3.3, 1.7, 5.3 |
| Red-314 | 1.5, 0.3, 7.8 | 2.3, 0.0, 9.9 | 0.9, 0.1, 2.9 | 4.2, 3.3, 5.6 |
| Red-349 | 1.1, 0.1, 4.9 | 1.4, 0.2, 4.8 | 1.0, 0.1, 5.6 | 3.9, 2.5, 5.5 |
| Yellow-355 | 1.4, 0.1, 5.3 | 1.1, 0.2, 2.7 | 1.6, 0.6, 2.5 | 5.5, 4.6, 6.9 |
| Yellow-357 | 1.1, 0.1, 2.2 | 1.0, 0.2, 2.1 | 0.9, 0.1, 1.4 | 5.4, 4.4, 7.8 |
| Yellow-385 | 4.5, 0.2, 16.4 | 4.1, 0.0, 12.4 | 3.4, 0.4, 6.4 | 6.1, 4.8, 9.0 |

**Figures 4** to **Figures 10** present ΔE comparisons of original and printed $L^*a^*b^*$ values for selected spot color charts. The dashed-line represents the reference of 4 ΔE, where 2-5 ΔE stands for minute color differences in high-quality imaging systems. For the Blue-347 spot color test chart, the ΔE values of the actual production printing substrate with GMG RIP (black thick-line) and ORIS RIP (black thin-line) are lower than 4 except for the shadow area. The manufacturer recommended proofing paper with the GMG RIP combination (gray thick-line) has good reproduction capabilities in selected spot colors in terms of lower ΔE values. Conversely, the manufacturer recommended proofing paper with the ORIS RIP combination (gray thin-line) yields higher ΔE values compared to other print combinations.

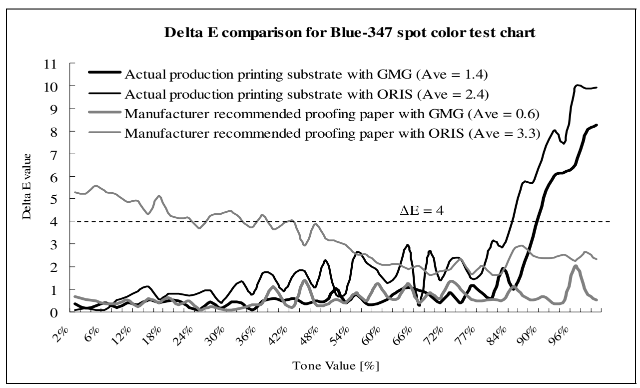


***Figure 4.*** *ΔE comparison of original and printed L*a*b* values for Blue-347 color.*

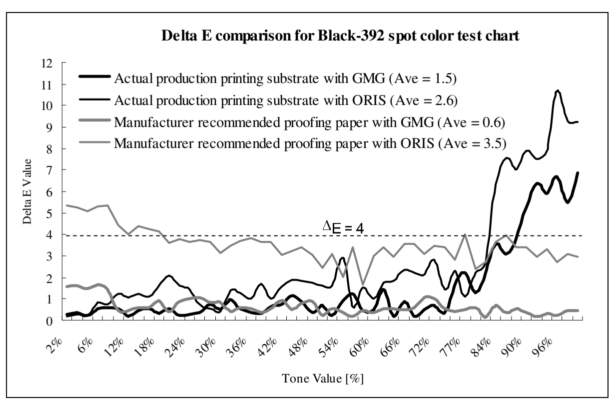


***Figure 5.*** *ΔE comparison of original and printed L*a*b* values for Black-392 color.*

As shown in **Figures 5** to **7**, printing via either GMG RIP or ORIS RIP, the actual production printing substrate tends to have larger ΔE values for black and red spot color in shadow areas. The manufacturer recommended proofing paper with the GMG RIP combination (gray thick-line) has better reproduction capability in the black and red spot colors in terms of lower ΔE values. The manufacturer recommended proofing paper with ORIS RIP combination (gray thin-line) has higher ΔE values with the range of 3.3-5.6. For Yellow-355 and Yellow-357 charts, as shown in **Figure 8** and **Figure 9**, the ΔE values of the manufacturer recommended proofing paper with the ORIS RIP combination (gray thin-line) are significantly larger than those of others.The Yellow-385 spot color chart, compared to other spot color charts, has relatively high ΔE values.

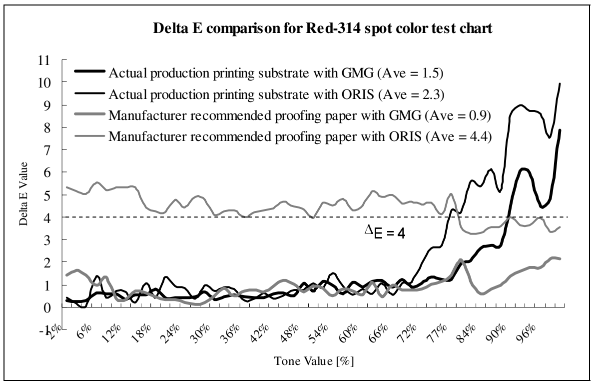


***Figure 6.*** *ΔE comparison of original and printed L*a*b* values for Red-314 color.*

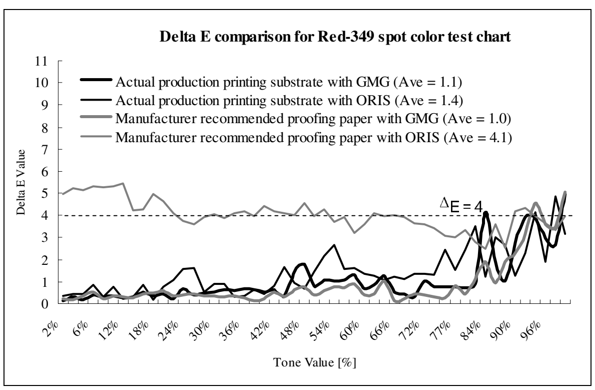


***Figure 7.*** *ΔE comparison of original and printed L*a*b* values for Red-349 color.*

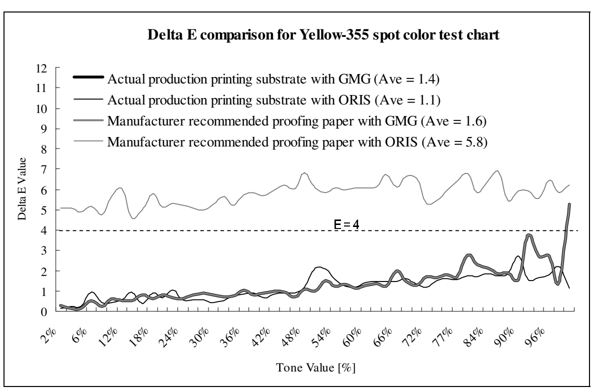


***Figure 8.*** *ΔE comparison of original and printed L*a*b* values for Yellow-355 color.*

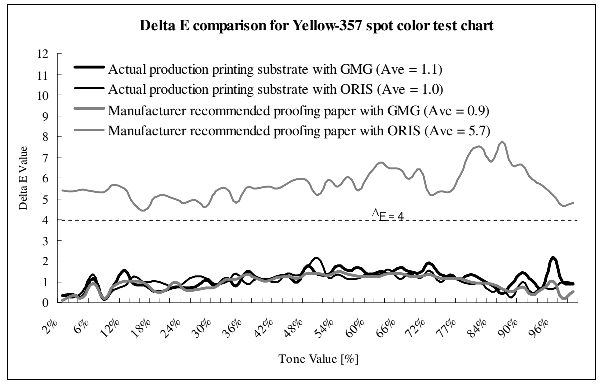


***Figure 9.*** *ΔE comparison of original and printed L*a*b* values for Yellow-357 color.*

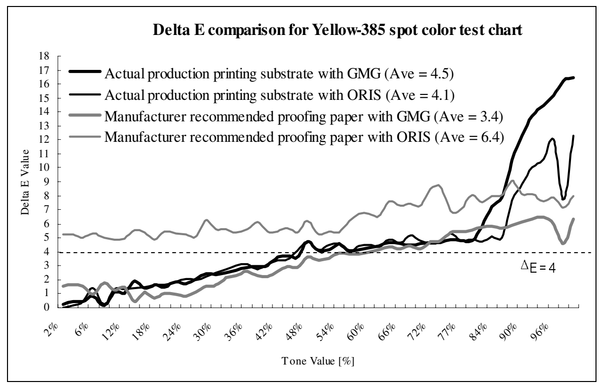


***Figure 10****. ΔE comparison of original and printed L*a*b* values for Yellow-385 color.*

As shown in **Figures 4** to **Figures 10**, the ΔE values increase significantly in highly saturated areas for some selected spot colors. **Table 2** presents ΔL* and $\Delta E_{ab}$* comparison for different print combinations in shadow areas (80%-100% tints). The Lightness/darkness differences (ΔL*) were calculated for each color in the test chart and each printing device. The chroma difference ($\Delta E_{ab}$*) calculation helps to establish how close each device is able to create the desired color hue. In this study, for Blue-347 and Black-392 spot colors, ΔL* contributes more to ΔE than $\Delta E_{ab}$*. For Red and Yellow spot colors, $\Delta E_{ab}$* contributes more to ΔE* than ΔL*.

## Conclusions

For color gamut comparison, either printing via GMG ColorProof RIP or CGS ORIS RIP, the color gamut of manufacturer recommended proofing paper is significantly larger than that of the actual production printing substrate. The actual production printing substrate printing via the GMG RIP results in better spot color reproductions for Blue-347, Black-392, Red-314, and Red-349 spot colors, whereas CGS ORIS RIP has better spot color reproduction in Yellow spot colors. For manufacturer recommended proofing paper, GMG ColorProof RIP provides better color reproduction for all selected spot colors except for Yellow-385 spot color. Conversely, CGS ORIS RIP has larger ΔE values for all selected spot colors due to poor paper white simulation.

Among the seven selected spot colors, Yellow-385 is the hardest one to reproduce, due to some spot colors in the test charts that are out of color gamut of the test printer. Blue-347 and Black-

392 spot colors have higher $\Delta L^*$ values, which contribute more to $\Delta E$ than $\Delta E_{ab}^*$. As for Red and Yellow spot colors, the chroma difference ($\Delta E_{ab}^*$) is higher than $\Delta L^*$, contributing more to $\Delta E$.

Overall, either the selected substrates printing via GMG ColorProof RIP or CGS ORIS RIP result in better spot color reproduction in highlight and mid-tone areas. However, they have poor color reproduction in highly saturated colors. It also found that the actual production printing substrate cannot accept such large amounts of ink in solid areas for blue and black color and causes ink smearing. Effort must be taken to improve the color reproduction of shadow areas. Users can proof spot colors on the manufacturer recommended proofing paper printing via GMG ColorProof RIP if good color-matching is considered crucial. The color match is better with ColorProof RIP than with Photoshop with printer drivers [13].

**Table 2. $\Delta L^*$ and $\Delta E_{ab}^*$ comparison for different print combinations in shadow areas (80%-100%)**

| Spot colors / Tint [%] | | Actual production printing substrate | | | | Manufacturer recommended proofing paper | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | GMG RIP | | ORIS RIP | | GMG RIP | | ORIS RIP | |
| | | $\Delta L^*$ | $\Delta E_{ab}^*$ | $\Delta L^*$ | $\Delta E_{ab}^*$ | $\Delta L^*$ | $\Delta E_{ab}^*$ | $\Delta L^*$ | $\Delta E_{ab}^*$ |
| Blue-347 | 80 | 0.1 | 0.6 | 0.7 | 3.1 | 0.5 | 0.2 | 1.0 | 1.3 |
| | 84 | 1.0 | 0.3 | 2.6 | 3.3 | 0.7 | 0.9 | 1.9 | 1.9 |
| | 88 | 3.2 | 0.9 | 4.6 | 3.4 | 0.4 | 0.3 | 2.1 | 1.2 |
| | 92 | 5.5 | 2.5 | 7.8 | 2.8 | 0.2 | 0.3 | 2.2 | 1.1 |
| | 96 | 5.9 | 2.7 | 8.4 | 2.3 | 1.3 | 1.6 | 1.9 | 1.3 |
| | 100 | 7.8 | 2.8 | 9.0 | 4.1 | 0.3 | 0.4 | 1.9 | 1.4 |
| Black-392 | 80 | 1.1 | 0.7 | 2.2 | 0.5 | 0.3 | 0.5 | 1.6 | 1.8 |
| | 84 | 2.8 | 2.2 | 6.2 | 1.3 | 0.4 | 0.6 | 2.1 | 3.0 |
| | 88 | 2.4 | 3.0 | 6.9 | 1.4 | 0.5 | 0.3 | 1.7 | 2.9 |
| | 92 | 5.3 | 3.5 | 7.3 | 1.8 | 0.0 | 0.2 | 1.2 | 2.7 |
| | 96 | 5.8 | 3.4 | 10.6 | 1.2 | 0.0 | 0.2 | 1.4 | 2.3 |
| | 100 | 5.7 | 3.8 | 9.1 | 1.4 | 0.4 | 0.2 | 1.2 | 2.7 |
| Red-314 | 80 | 1.4 | 1.2 | 0.4 | 4.2 | 0.5 | 2.0 | 1.8 | 3.1 |
| | 84 | 0.9 | 2.5 | 0.2 | 5.3 | 0.3 | 0.5 | 1.8 | 2.8 |
| | 88 | 0.7 | 2.7 | 0.3 | 5.2 | 0.5 | 0.9 | 2.2 | 2.9 |
| | 92 | 0.6 | 6.0 | 0.3 | 9.0 | 0.1 | 1.6 | 2.0 | 3.0 |
| | 96 | 0.4 | 4.5 | 1.0 | 8.5 | 0.2 | 1.8 | 2.3 | 3.2 |
| | 100 | 2.0 | 7.6 | 0.5 | 9.9 | 0.1 | 2.2 | 1.7 | 3.1 |
| Red-349 | 80 | 0.3 | 0.7 | 1.3 | 2.0 | 0.1 | 0.4 | 1.6 | 2.9 |
| | 84 | 2.1 | 3.6 | 0.9 | 0.8 | 1.2 | 1.5 | 1.0 | 2.3 |
| | 88 | 0.1 | 1.0 | 0.8 | 2.5 | 1.3 | 1.4 | 1.0 | 2.3 |
| | 92 | 3.3 | 2.1 | 2.2 | 0.7 | 2.4 | 2.1 | 1.3 | 4.1 |
| | 96 | 1.8 | 2.3 | 1.5 | 1.2 | 3.1 | 1.9 | 1.1 | 3.5 |
| | 100 | 4.2 | 2.6 | 2.0 | 2.5 | 4.1 | 3.0 | 1.0 | 3.8 |
| Yellow-355 | 80 | 1.0 | 2.4 | 1.7 | 0.5 | 1.0 | 2.4 | 3.0 | 6.1 |
| | 84 | 1.7 | 1.2 | 1.2 | 1.5 | 1.7 | 1.2 | 3.1 | 5.6 |
| | 88 | 1.3 | 1.4 | 1.3 | 1.3 | 1.3 | 1.4 | 2.8 | 4.7 |
| | 92 | 0.1 | 3.8 | 0.6 | 1.4 | 0.1 | 3.8 | 2.8 | 5.2 |
| | 96 | 1.2 | 2.5 | 1.2 | 1.3 | 1.2 | 2.5 | 3.0 | 5.7 |
| | 100 | 0.6 | 5.2 | 0.9 | 0.7 | 0.6 | 5.2 | 2.7 | 5.6 |
| Yellow-357 | 80 | 0.4 | 1.3 | 0.6 | 0.6 | 0.5 | 0.8 | 2.2 | 7.0 |
| | 84 | 0.1 | 0.8 | 0.2 | 0.5 | 0.1 | 0.9 | 1.7 | 6.6 |
| | 88 | 0.1 | 0.9 | 0.1 | 0.2 | 0.4 | 0.2 | 1.7 | 6.4 |
| | 92 | 0.4 | 1.0 | 0.3 | 0.3 | 0.1 | 0.4 | 2.1 | 5.6 |
| | 96 | 0.5 | 2.1 | 0.3 | 0.6 | 0.2 | 1.0 | 2.2 | 4.7 |
| | 100 | 0.2 | 0.8 | 0.4 | 0.8 | 0.2 | 0.4 | 2.5 | 4.0 |
| Yellow-385 | 80 | 4.1 | 2.4 | 3.6 | 3.3 | 4.4 | 3.4 | 4.5 | 6.6 |
| | 84 | 3.2 | 6.5 | 3.7 | 3.5 | 5.0 | 3.0 | 5.0 | 6.2 |
| | 88 | 2.0 | 10.3 | 2.5 | 7.2 | 5.2 | 2.8 | 5.1 | 7.5 |
| | 92 | 1.7 | 13.6 | 3.0 | 9.6 | 5.8 | 2.6 | 5.4 | 6.1 |
| | 96 | 0.8 | 15.1 | 2.5 | 11.7 | 5.5 | 2.4 | 5.0 | 6.1 |
| | 100 | 1.0 | 16.3 | 3.0 | 12.0 | 5.7 | 2.7 | 5.3 | 6.0 |

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