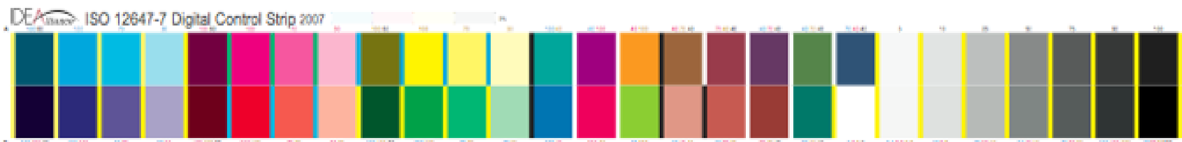
IDEAlliance SWOP Proofing Study 2008

prepared for IDEAlliance by CHROMiX with Maxwell technology



Purpose of Study

While specific tolerances exist for certification of SWOP proofing systems, these only apply to the capabilities of the system as a whole. The tight numeric tolerances required to pass SWOP Proofing System Certification may be unrealistic for those producing proofs daily in a production environment. Just because a proofing system was able to achieve such tight tolerances to obtain certification, doesn't mean it will be able to in practical everyday use. Tolerances will also need to accommodate the variation in measurements. The SWOP Proofing Study was designed to gather real-world data about what is actually happening with regard to meeting proofing specifications. This information is to be used by the SWOP and GRACoL committees to establish tolerances for real-world proofing conditions.

Once the idea of a proofing study was undertaken, it was decided that a study of measurement systems would be a worthwhile and relatively easy component to add to the study. The study developers also added a repeatability component to the study to get real-world data on consistency of instruments. ISO 12647-7 proofing tolerances are approximately twice those of the SWOP and GRACoL certification tolerances due to measurement variation. In system certification, vendor instruments are expected to be calibrated to the reference instrument used by RIT to perform the certifications.

Study Overview

This study is actually two studies in one:

- Phase one: "The Proofing Study" - evaluates proofing systems, tracking the behavior of proofing systems over a two-month period.
- Phase two: "The Measurement Study" - evaluates and compares measurement systems and devices. A repeatability component provides data on the stability of the instruments' measurements over a five-day period.

Procedure

Participants in the Proofing Study signed up by accessing an IDEAlliance website and filling out an online form, providing basic information about proofing procedures and equipment. Each participant was to provide proofing data at least once a week during the length of the study. Participants were required to proof to either the GRACoL 1 2006, SWOP 3 2006, or the SWOP 5 2006 specifications. The proof aims colors are available in CGATS TR003 (SWOP #3), CGATS TR005 (SWOP #5) and CGATS TR006 (GRACoL #1).
<http://www.idealliance.org/swop/resources/studysignup.asp>

Participants downloaded the *IDEAlliance ISO 12647-7 2007 Color Control Strip* from the www.gracol.org website, and included this control strip on their proof prints. Using a pre-release version of the *IDEALink Verify* software, this control strip was measured using (in most cases) an Eye-One Pro spectrophotometer, and the resulting measurement file was uploaded to the study database[1] directly.
<http://www.gracol.org/resources/IDEAlliance_ISO12647-7_2007_Color_Control_Strip.zip>

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1. details about the study database can be found in Appendix A

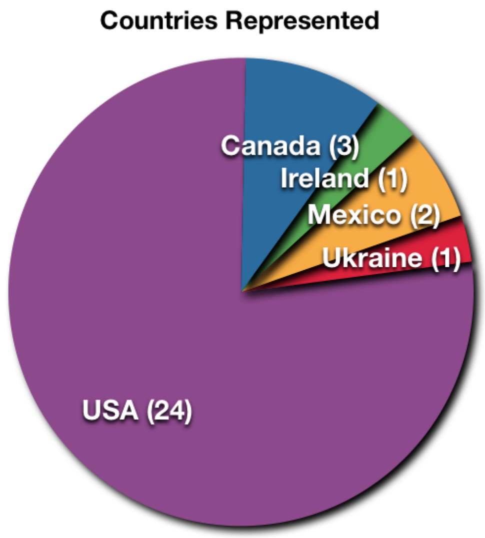
In the case of participants who did not use an Eye-One Pro spectrophotometer, customized targets and reference files were emailed to them for their instrument. The IDEALink Verify software was updated to allow for importing measurement files from these devices, which could then be uploaded into the Study database.

<u>Participants</u>

In June of 2008, an open invitation went out from IDEAlliance to invite those interested in participating in the study. In all:

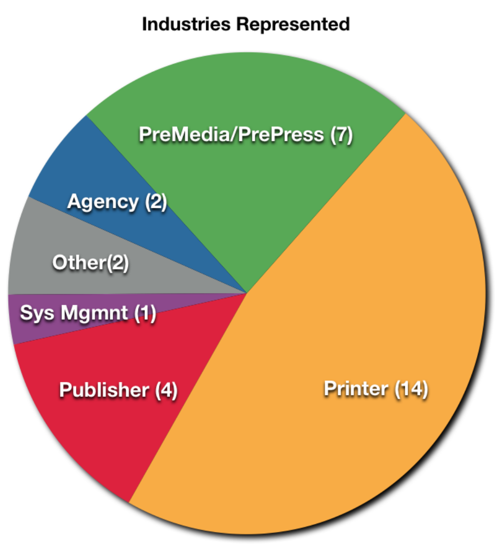
- 67 responded with interest in the study, and
- 31 of those who responded actually participated by submitting sufficient data.
- There were 44 total proofing systems involved in the study.

The following findings are from the initial sign-up survey and therefore reflect answers from the full number of initial respondents.



Those who participated included companies from all over the US, Mexico, and Canada with a few from the Ukraine and Ireland.

Participant Industry Sector Breakdown:

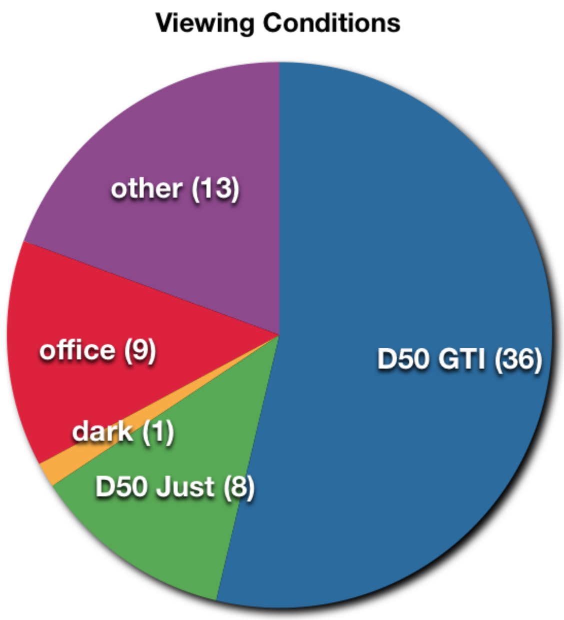


Almost half of the participants were printers, with the rest being pre-media, agencies, publishers, or other businesses.

Instruments

Most of the participants used an i1 Pro to make their measurements. Others used the iSis spectrophotometer and the X-rite DTP-70 spectrophotometer. Some of these devices made use of UV filtering in their measurements and some did not.

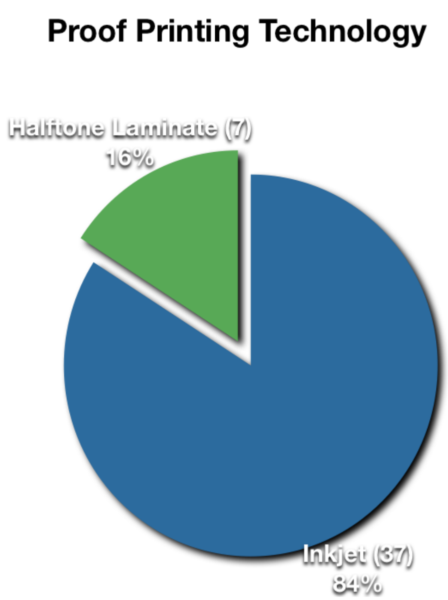
Viewing Conditions

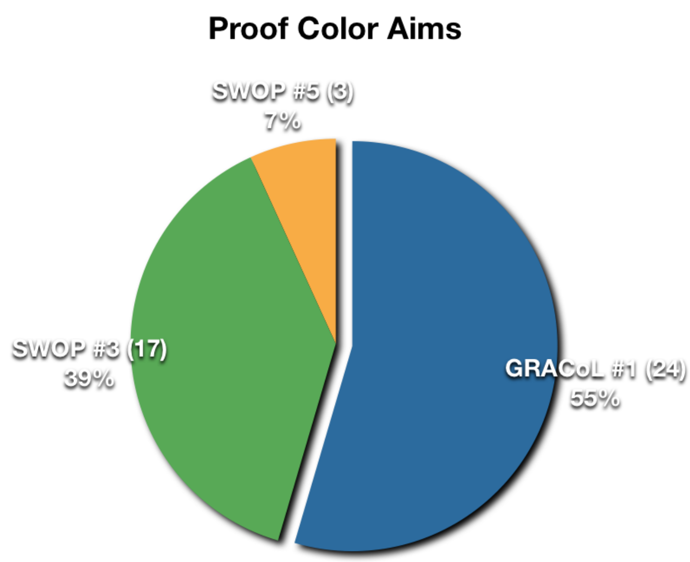


Those who filled out the online questionnaire were asked about their proof viewing conditions. Over half said they used a GTI viewing booth with D50 lighting. The rest were divided between "other", regular office lighting, D50 Just Normlicht viewing booth, and "dark".

Proofing Systems

By far, the largest number of proofing systems used were inkjet-based, with the rest being halftone laminate. As the purpose of the study was not to be a "vendor shoot-out" no further distinction about proofing systems was attempted. Over half of the participants were proofing to the GRACoL1 reference, with SWOP3 taking second place, followed by SWOP5.





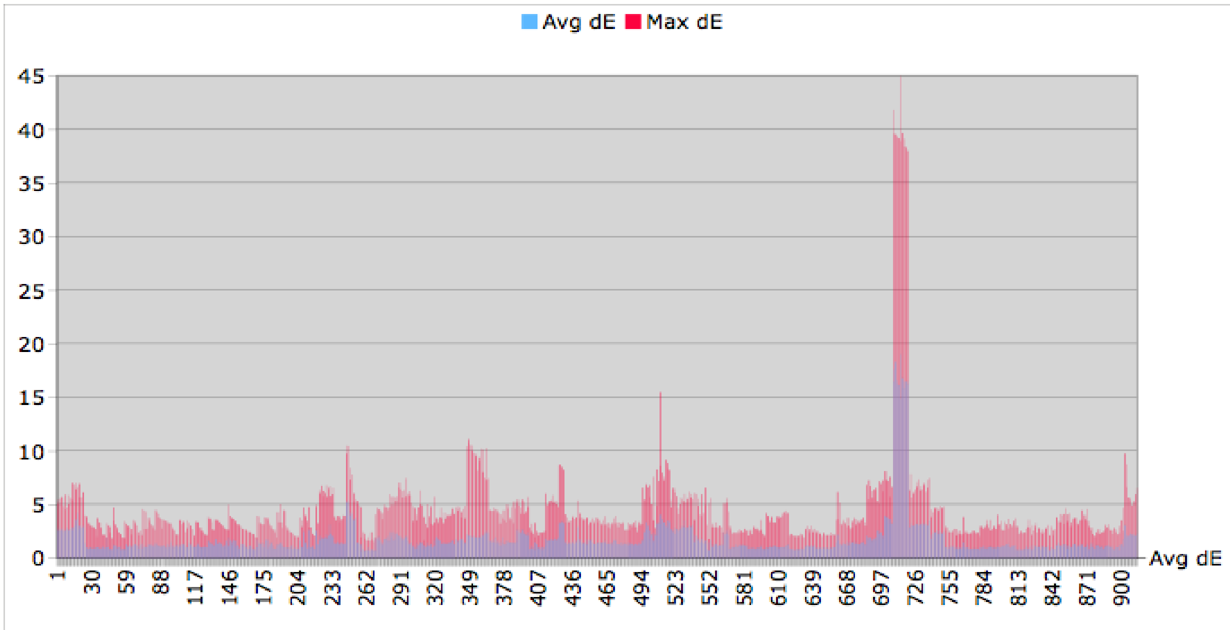
RESULTS

Overall Measurement Results - Single Proofs

In all, there were a total of 913 separate proof measurements uploaded into the study database.

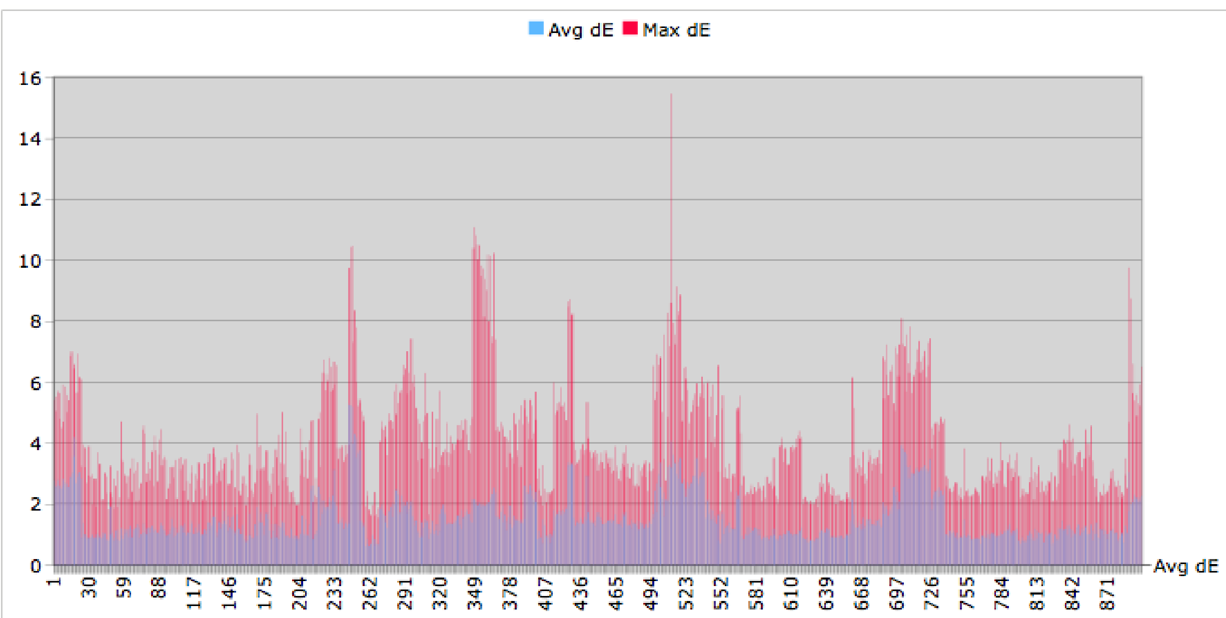
Among these: (All data reported are in delta E 1976.)

Table 1	Average dE	Maximum dE
Lowest	0.64	1.55
Highest	19.03	44.96
Average	1.76	4.52



Fourteen proofs measured 35-45 dE away from their reference (as stated by the participant). All of these high-error proofs were found to belong to 2 proofing systems that were relatively stable and consistent, and yet a long way from any of the three IDEAlliance color aims. With this in mind we decided to exclude these two proofing systems and their fourteen proofs from the remainder of the study calculations. When they are removed from the population, the remaining population of proofs have a more predicable distribution.

Below is a graph showing the average and maximum delta-E results of the remaining 899 proofs:



Thus, when we remove from the study the outlying samples (most likely to be mistakes), we get the following results:

Table 2	Average dE	Maximum dE
Lowest	0.64	1.55
Highest	5.27	15.46
Average	1.53	3.97

Overall Measurement Results - Proofing Systems

The 913 proof measurements we received were from 44 separate proofing systems. For those participants that submitted samples relative to different color aims (multiple proofing systems), we did not distinguish between single systems producing proofs to different aims and multiple, separate systems producing proofs. There is also a wide range in the number of proofs submitted for each system. In fact the number of proofs per system ranged between 1 and 198. The average was 20.8.

If we group the measurements according to proofing systems, and remove the two problem systems discussed above, we get the following results:

Table 3	Average dE (std dev)	Maximum dE (std dev)
Lowest	0.74 (0.00)	1.89 (0.00)
Highest	4.35 (0.78)	9.45 (2.69)
Average	1.80 (0.22)	4.64 (0.63)

Proofing System Types

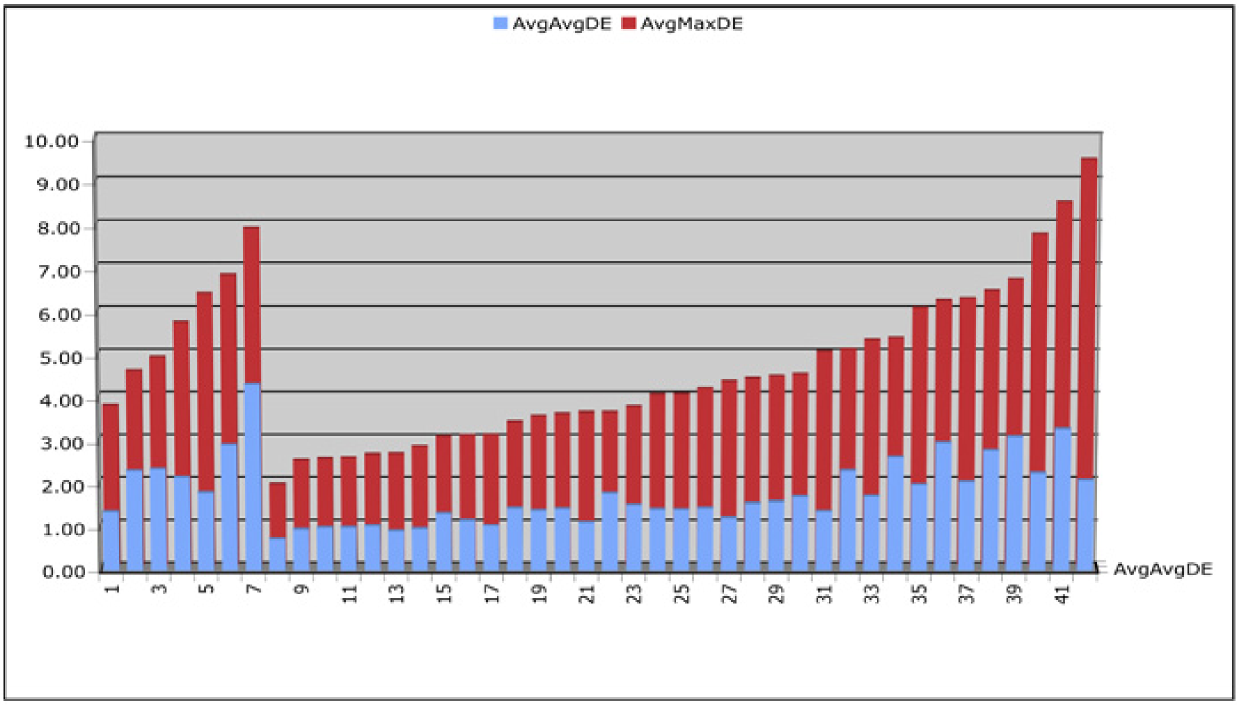
The type of proofing systems were broken down into two sets. Those created on an inkjet system and those created on a halftone laminate system. The results are as follows:

Table 4	Average dE (std dev)	Maximum dE (std dev)
InkJet	1.67 (0.20)	4.43 (0.60)
Halftone Laminate	2.49 (0.31)	5.69 (0.75)
Overall Average	1.80 (0.22)	4.64 (0.63)

Clearly, inkjet proofs have exceeded halftone laminate proofs in terms of absolute color accuracy. They also appear to have lower variation from proof to proof, which may surprise some readers.

Some halftone laminate proofing systems do not attempt to match solid ink colors as precisely as inkjets which may account for some of the differences between the system types. We did not attempt to break down inaccuracies into different patch sets.

<u>Overall Proofing Systems (by Type, avgMaxDE)</u>



The first seven items in this graph are halftone laminate proofing systems, the remaining are inkjet.

<u>Other Findings:</u>

No differences with proofing aim
We were not able to find a correlation between the color aim of the proofing system and the ability of the system to accurately hit the aim. This is not a surprising result as there shouldn't be any significant reason why a proofing system would be able to hit one aim and not another - save one: gamut. If a color aim's gamut was outside the gamut of the proofing system then it would show up as an accuracy difference depending on color aim. Apparently gamut was not an issue with the participant's proofing systems.

Instrument calibration question
The question on the initial sign-up sheet regarding instrument calibration was worded as follows: "How often do you calibrate your measurement device?" Most participants seemed to misunderstand the intended purpose of the question due to its ambiguous nature. A more appropriate wording may have been "How often do you have your instrument re-certified by its manufacturer?". Our favorite response was "What kind of question is this?" Due to the confusion this question was disregarded.

Study Limitations

This study proved to be a useful and informative exercise and we feel it contributes significant information regarding the behavior of real-world proofing systems and their operators. A non-exhaustive list of study limitations and possible sources of error is worthy of consideration however:

- instrumentation - UV filtering and paper brighteners
- instrumentation - inter-technology differences
- instrumentation - repeatability
- instrumentation - certification and maintenance
- measurement - proper and consistent measurement backing
- sample set - patch limitations of ISO 12647-7 proofing target
- study duration
- number of participants
- number of samples received
- paper-white simulation
- effective instrument re-calibration question

The Measurement Study was constructed to address a number of the above sources of error.

Measurement Study

Color instruments are often considered the "shop reference" due to the fact that they cost a considerable sum and they offer their measurements with such precision. It's easy to forget that precision doesn't necessarily mean accuracy and that the instrument in your hand may vary from day to day or even give outright incorrect values. When attempting to match a common color standard it's important to use an instrument you can trust. Your measurements may be checked by a customer or supplier using a different instrument, possibly based on different technology.

In this study we were looking for answers to three overall questions:

- How much do instruments disagree?
- How much do they vary over time?
- How much difference does UV filtration make?

The Measurement Study consisted of three separate exercises for participants to complete:

First, an ISO 12647-7 proofing target from a recent G7 press run was pre-measured using several instruments and then couriered to the participant. The participant was required to measure the target once a day for a minimum of 5 days and upload the measurements into the system. Once the 5 measurements were complete, the participant was to return the target to the study producer. Upon receipt of the returned target they were remeasured with the same pre-posted instruments to check for any drift due to some event in transportation or use.

Second, participants were required to print a proof from their system, measure it, and submit it along with the pre-measured target supplied. This provided additional sampling for each instrument so we had another color set (inks, paper, screening, etc) to use for comparison.

Third, participants were requested to answer a short questionnaire pertaining to paper-white simulation on their proofing system, the "Rev" of their instrument and confirmation of their instrument's UV filtration.

Participants: 43 measurement kits were sent out, 23 were returned.

<u>Instrument Variation</u>
Inter-Instrument Model/Tech Agreement



Color instruments of different makes and models may use different technology to attempt to achieve the same goal. A short review of some instrument differences follows:

Light Source - The light source within each instrument which illuminate the print sample differs depending on instrument design, cost, and sometimes the generation / version of the instrument itself. The primary contribution of light source differences to measurement differences is the amount of UV light in the illuminant and how much UV brighteners are in the measured medium. This particular difference is independent of UV-filtering as discussed below, instead referring to the differing amounts of UV radiation that each particular illuminant technology contains.

UV component / filtering - Modern measuring systems can now include or exclude a UV component of their illuminant by either adding to the illuminant explicitly using additional LED lamps or filtering the illuminant to remove a significant portion of its UV component. In light of these two methods we have adopted the notation of UVi or UVx for UV-included measurements or UV-excluded measurements respectively. For UVi measurements the illuminant is either left unfiltered for light sources that naturally contain a significant UV component or an additional UV-producing lamp is activated to expand the spectral output of the instrument. For UVx measurements the illuminant is filtered or the UV-producing lamp is extinguished.

Light gathering - A spectrophotometer gathers light reflected back from a sample by different means. For the purposes of this study, normal Graphic Arts instrumentation is expected to utilize the standard 0/45 or 45/0 measurement geometry. Other differences which may exist between instruments include the light splitting mechanism and the light gathering sensors.

Calibration - The method and frequency of instrument calibration can have an effect on results. Many proof verification systems require calibration of the instrument before each proof measurement, some require recalibration after a certain amount of time has elapsed. For this study, the Verify software required recalibration prior to each proof measurement.

Measurement Backing - The material behind a measured sample can have a great effect on the resulting measurements. Self-contained instruments such as the DTP-70 and iSis supply their own backing. The DTP-70 allows switching between black and white backing while the iSis only supplies a white backing. The Eye-One Pro can be used with a white backing board or without. In the past "self-backing" - multiple sheets of the same paper - was recommended. Self-backing has been found to be unreliable so white backing is now recommended for most measurements unless a particular standard calls for black blacking to accommodate printing on the backside of the sheet. For this study the supplied print samples were affixed to 100# card stock to ensure a consistent backing for all participants.

Inter-Instrument Agreement (same model)

Differences between instruments of the same model may exist due to manufacturing variation, changes in design and manufacturing or simply due to aging and wear. The same instrument in different uses can also produce different readings. The Eye-One Pro when hand held may produce different results than the same Eye-One when inserted into the iO automating table, for instance.

Repeatability

A single instrument will naturally vary from measurement to measurement. Temperature changes, dust and debris, calibration frequency, sample backing and operator technique can all affect measurement consistency.

Measurement Study Findings

Inter-Instrument Agreement

Measurements from each sample instrument were compared to an instrument of similar technology - the "tech reference" - as well as an additional instrument of different make and model - the "bench reference". The bench reference in this case was a recently re-certified SpectroLino / Spectroscan. Comparisons and calculations below refer to either the tech reference (a "Rev B" Eye-One or DTP-70, depending on the sample instrument model) or the bench reference.

Average of all instruments vs References

Table 5	Average of all instruments vs **Tech** Reference		Average of all instruments vs **Bench** reference	
	Average dE	Maximum dE	Average dE	Maximum dE
Lowest	0.39	1.21	0.62	1.20
Highest	2.58	5.57	1.97	5.08
Average	**1.32**	**3.33**	**1.20**	**3.05**

Average of Eye-One instruments vs References

Table 6	Average of Eye-One instruments vs **Tech** Reference		Average of Eye-One instruments vs **Bench** reference	
	Average dE	Maximum dE	Average dE	Maximum dE
Lowest	0.52	1.21	0.62	1.20
Highest	2.58	5.57	1.97	5.08
Average	**1.40**	**3.37**	**1.21**	**2.91**

Average of DTP-70 instruments vs References

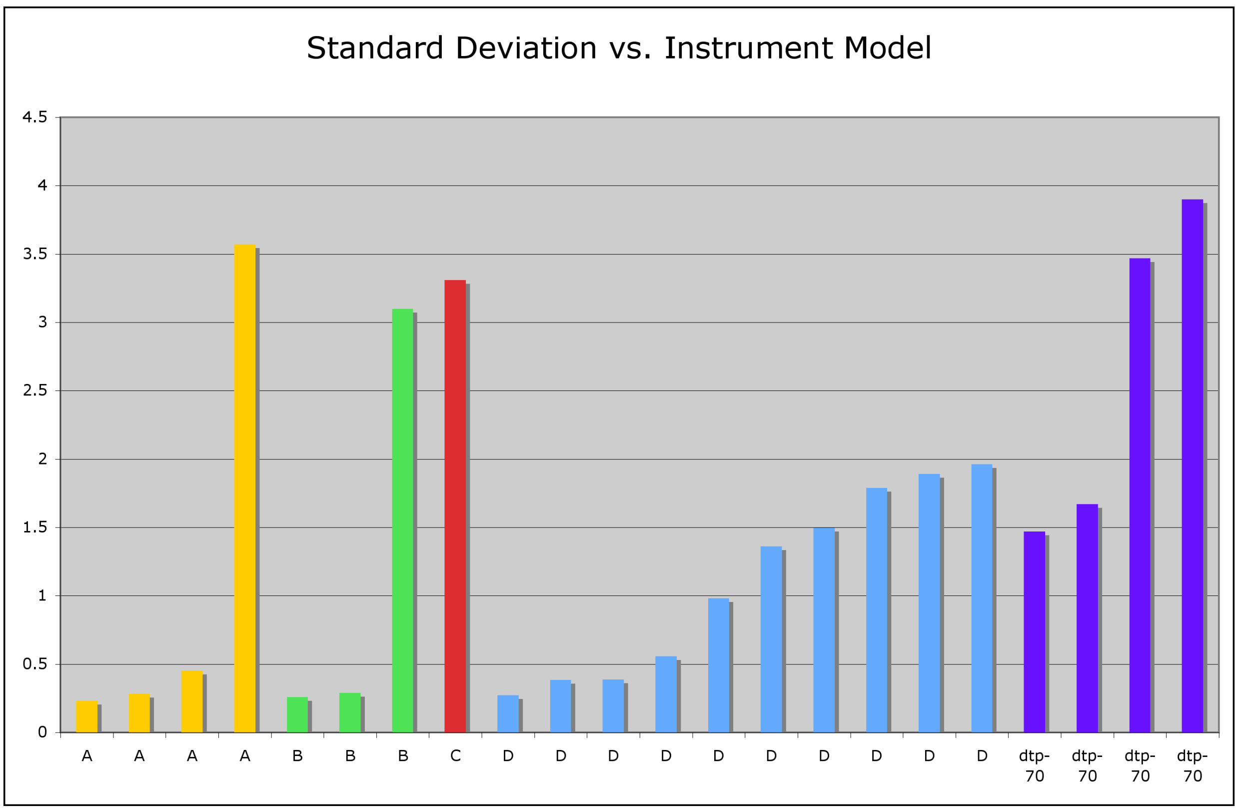
Table 7	Average of DTP-70 instruments vs **Tech** Reference		Average of DTP-70 instruments vs **Bench** reference	
	Average dE	Maximum dE	Average dE	Maximum dE
Lowest	0.39	2.91	0.70	3.57
Highest	1.49	3.45	1.54	3.99
Average	**0.91**	**3.17**	**1.15**	**3.76**

Repeatability

Standard Deviation by i1 Revision (A, B, C, D)

The X-Rite Eye-One Pro instrument has a long history in color measurement and probably the widest use of any color measurement instrument available. Through its history it has undergone several design (and presumably manufacturing) revisions. GretagMacbeth and X-Rite have marked these revisions on the serial number plate of each Eye-One. The major published revisions to this instrument are "Rev A", "Rev B", and "Rev D". "Rev C" is an OEM version only produced for an OEM relationship and was never released for general use. Indeed, they are rare, but we did have one included in the study.

As these revisions alter the instrument somewhat we decided it would be worthwhile to study each revision's behavior and determine if a correlation between accuracy and variation could be found.



In terms of variation it appears that the older Rev A and Rev B units can perform quite acceptably except in specific cases. One "Rev A", one "Rev B" and the "Rev C" instruments were found to produce widely varying results while the others performed admirably. It seems that older instruments are acceptable for this purpose ***if*** a variation test is performed to rule out problem units ***and*** providing they are returned to the manufacturer periodically for re-certification (as all instruments should be). Two of the automated DTP-70 instruments appear to suffer from excess variation as well which is surprising considering the operator plays a much smaller role in taking measurements.

In Summary:

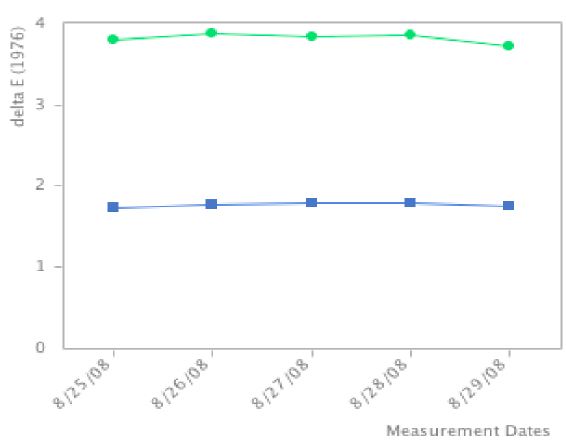
Table 8	Average Standard Deviation
All Instruments	1.50
Eye-Ones	1.25
DTP-70s	2.63

Statistical Carpet - StdDev 0.23 vs 3.47

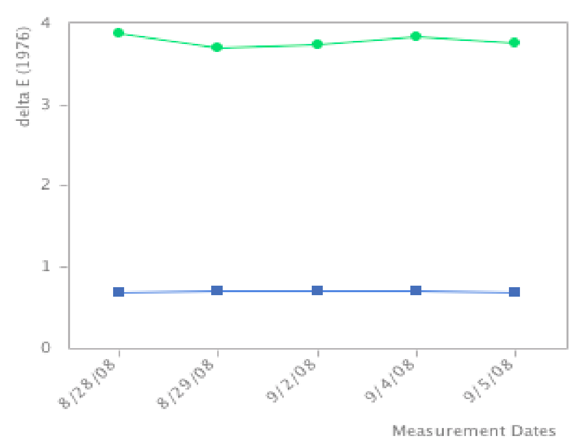
This finding is not exclusive to the measurement study nor is it unusual in these types of measurements but we felt it worth mentioning nonetheless. Standard deviation is a measure of how widely distributed the measurements are from the average. Standard deviation calculations were used in this study to identify measurement systems which deviated significantly over the study period.

The point worth mentioning is that while average dE and maximum dE calculations are popular metrics for describing color accuracy, they do not capture this measurement variation in any way. The following two graphs depict the behavior of two of the study's instruments. While the maximum dE are virtually identical and the average dE are also similar, the standard deviation is not. The instrument on the left, though it had a fairly high average dE of approx 1.66, had a low standard deviation of 0.23. The instrument on the right, however, shows a low average dE but actually has a high standard deviation of 3.47. The instrument (and user) taking the measurements in the right graph had a high degree of variation, to the point of being much higher than the avgDE values and perhaps high enough to warrant review of the instrument and the measurement technique / environment.

Therefore, standard deviation values should always be taken into consideration when deriving dE statistics from pools of measurement data like this - in order to avoid sweeping important data "under the rug."



Instrument with Standard Deviation of 0.23



Instrument with Standard Deviation of 3.47

UV Filtration

As discussed above, UV in the instrument's illuminant can excite fluorescence in the paper and colorants, producing measurement differences. Color references such as those produced by IDEAlliance for GRACoL and SWOP are measured without a UV filter (UVi). Proofs are often measured with a filtered instrument (UVx). Indeed, 50% of the Eye-Ones in this study are UV-filtered devices. Two of the four DTP-70s were also configured to measure with UV filtration. (we did not specify which setting should be selected for DTP-70 users)

Average of all instruments UVi vs UVx

Table 9	Average of all instruments vs **Tech** Reference		Average of all instruments vs **Bench** reference	
	Average dE	Maximum dE	Average dE	Maximum dE
UVi	0.94	2.33	0.90	1.52
UVx	1.79	4.42	2.36	3.82
Difference	**0.79**	**2.09**	**0.62**	**1.46**

In summary the average dE varied by 0.62 to 0.79 and the maximum dE varied by 1.46 to 2.09

If the UVi vs UVx instrument mix in the industry reflects the 50/50 split in this study, allowances will have to be made for measurement variations when different instruments measure the same proof.

It is important to note that this variation depends significantly on the amount of optical brighteners in the measured paper. Theoretically paper with no optical brighteners will exhibit no measurement differences due to UV filtration. The paper used in this study was a fairly typical coated press paper with a moderate amount of optical brightening.

Other Findings

ISO 12647-7 Target Issues

We found that an unusually high number of measurement errors occurred in the second row of the 12647-7 proofing target, resulting in rescanning of the row. Upon closer inspection of the target and experimenting with a black felt pen, we found that altering the target slightly reduced the scanning errors significantly. The paper-white and "3.1 2.2 2.2" and "10 7 7" patches on the bottom right side of the target have yellow gaps between them to aid the i1 in finding transitions between patches. Unfortunately the yellow gaps don't seem to offer enough contrast on some printers. Turning them black with a felt pen solves the problem instantly. The good folks who care for the 12647-7 proofing target have been informed of the problem and are making changes.

In Summary

As proofing systems become more stable and reliable their *measured* accuracy and repeatability continue to improve. It is only natural to start studying the measurements themselves. As evidenced by the results of the Measurement Study portion of this report, the variation introduced by the measurement process and technologies now rivals the variation of the proofing systems themselves. If we are not careful, we will find ourselves chasing the wrong problems when trying to calibrate, maintain and compare proofing systems and their proofs.

We hope the information gathered in these studies will aid industry groups and individuals alike in understanding the behavior and interactions of their equipment. We are grateful for the patient participation of those who chose to contribute to this study and welcome your feedback so we can improve the process. We plan to conduct similar studies in the future.

Thanks for reading,

Steve Upton, Pat Herold - CHROMiX

Appendix: A - Study System and Calculation Methods

Proof Study

- Proof measurements were taken with the participant's measurement device.
  - In the case of Eye-One users, the IDEALink Verify software was used to drive the instrument directly.
  - For iSis and DTP-70 instruments, participants used either ProfileMaker MeasureTool or ColorPort software to drive the instrument, save the measurements in a CGATS-format text file and then import into the IDEALink Verify software.
- At the participant's discretion, proof measurements were uploaded into the CHROMiX Maxwell color management system referencing a particular device "Track" which was pre-configured for their individual proofing system with the appropriate color reference aim (GRACoL #1, SWOP #3, SWOP #5).
- Maxwell calculated dE76 difference values between each target patch and the reference patch. These dE values were summarized into overall average and maximum values.
- Maxwell calculated average, maximum and standard deviation values for each proofing system's track.
- Measurements were exported from Maxwell into spreadsheets and further summarized and graphed for reporting. Graphs generated by Maxwell were also included in this report.

Measurement Study

- Measurements were taken of a single printed proofing target once per day over a 5 day period.
- Targets had been measured prior to shipping to participant and measured again upon return to test for drift.
- At the participant's discretion, proof measurements were uploaded into the CHROMiX Maxwell color management system referencing a particular device "Track" which was pre-configured for their instrument.
- Maxwell calculated dE76 difference values between each target patch and the reference patch. These dE values were summarized into overall average and maximum values.
- Maxwell also calculated standard deviation values for *each patch* across the multiple targets. In this manner we were able to calculate the variation of the instrument as well as glean more information regarding which patches exhibit the most variation. This could be used for better target design and other possibilities in the future.
- Measurements were exported from Maxwell into spreadsheets and further summarized and graphed for reporting.

For more information regarding Maxwell, please go to www.mxwell.com or www.chromix.com/maxwell

Appendix: Raw Study Results

Raw study calculations and summaries will be supplied to the IDEAlliance Print Properties Group. These will include:

Study Participants list

- Identifying information such as contact name, company name, email address, mailing address will be removed and replaced by an identifying code number.
- This list contains such information as: viewing conditions, industry sector, number of proofing systems submitted, measurement study participation.

Proofing Systems list

- Proofing systems will be correlated to Study Participants using the participant's unique code number.
- Identifying information such as system manufacturer will be removed and replaced by an identifying code number.
- This list contains such information as: proofing technology, number of proofs submitted, instrument technology, color aim (characterization data set), average across all proofs for average DE, maximum dE per-proof values as well as standard deviation for each.

Proof Summary list

- Each submitted proof will be correlated to Proof Systems using the system's unique code number.
- This list contains such information as: date of submission, avg dE for all patches, max dE of all patches.