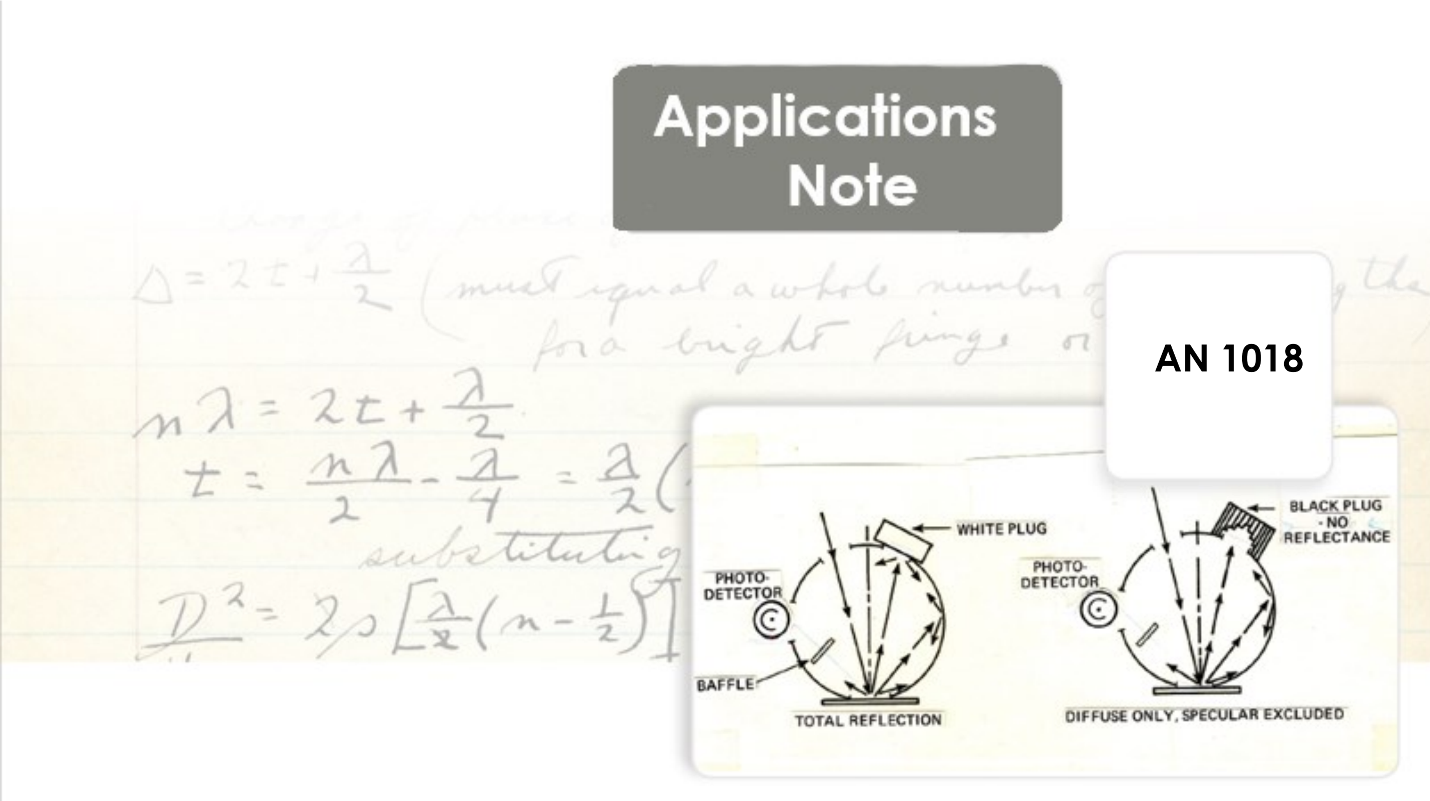
Applications Note

AN 1018




# Using Hitch Standardization to Maximize Inter-instrument Agreement

***One challenge in color measurement is the communication of color between locations or to a customer.***


## Abstract

Hitch standardization is a process by which two or more instruments of similar design can be made to read the same color values on a group of specimens. This process is very useful in expanding the communications of color around the world or between vendor and customer.

This application note considers the technique and mathematical calculations for Hitch Standardization.


The world's true measure of color

HunterLab

## Challenge: To Maximize Interinstrument Agreement

Inter-instrument agreement is actually quite a complex topic and to maximize interinstrument agreement, measurement parameters need to be standardized for all instruments in the set. These six parameters include:

1. Color scale being reported
2. CIE illuminant
3. CIE standard observer
4. Instrument type, geometry, and standardization mode
5. Sample Preparation
6. Method of presenting the sample to the instrument.

When any one or more of these parameters is changed, the resulting color values change. The best inter-instrument agreement in terms of absolute color values will always be found using the same model of instrument from the same manufacturer with all of the six parameters matching at all sites.

Consider a company with a ColorFlex 45/0 at one plant (Facility A) and an Aeros at another plant (Facility B). Each facility is reading powder samples and comparing the color values to an absolute color specification. The table below shows the six parameters for the two plants.

Table 1. Comparison of Instruments at Facility A & B

| No. | Parameter | Facility A | Facility B | Comparison |
|---|---|---|---|---|
| 1 | Color Scale | CIE L*a*b* | CIE L*a*b* | Match |
| 2 | Illuminant | D65 | C | MisMatch |
| 3 | Observer | 10° | 2° | MisMatch |
| 4 | Instrument Configuration | ColorFlex, circumferential 45°/0°, xenon flash lamp, reflectance | Aeros dual beam non-contact, LEDs, reflectance | MisMatch |
| 5 | Sample Preparation | Dry sample for 8 hours and grind to fine powder with no lumps | Dry sample for 8 hours and grind to fine powder with no lumps | Match |
| 6 | Sample Presentation | Scoop into glass sample cup and read once through glass bottom of cup. | Measuring using the 6" rotating pan. | MisMatch |

In comparing the parameters for the two facilities, the following changes will make them correlate as closely as possible.

1. **Color Scale** – The color scales agree in the above table which is a good start.
2. **Illuminant** – Both instruments have the same selection.
3. **Observer** – the same Observer should be used at both plants.
4. **Instrument Configuration** - The models are not the same. Both have different geometries and have different illumination. If the two instruments have already been purchased, we will not be able to completely standardize this parameter. If we were starting from scratch, we would choose one instrument model or the other and purchase the same for both plants.
5. **Sample Preparation** - The same for both plants.
6. **Sample Presentation** - No match. However, Facility A will use sample cup presentation method and Facility B will average the sample using a 6” rotating pan.

Other instrument capabilities, such as varying port sizes, UV filters, and light sources, should be well-defined and as standardized as possible for all the instruments. Similarities between the instruments should be maximized for the best results.

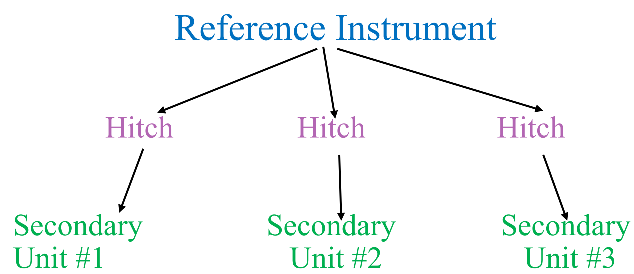
Once these parameters agree as much as possible, the next step is to establish how different the readings are at the two plants. A single standard is sent around as a ‘round robin standard’ and read on both instruments. If the new readings between sites are not acceptable, there are three options for reconciling the problem:

1. **Establish a New Tolerance:** Read a physical product standard on each instrument and establish a new tolerance specification based on <u>differences</u> from that product standard. Instruments of the same geometry should agree on difference values from a physical standard, even if they don’t agree exactly on absolute color values. See Application Note No. 1019 for more information on Tolerancing.
2. **Separate the Color Specification for each instrument.** Establish a separate absolute color specification for each instrument/site by reading acceptable, borderline, and out-of-spec samples of your product (as established visually) on each instrument. See Application Note No. 1019 for more information on Tolerancing.
3. **Hitch Standardization.** This is recommended for absolute value measurement once the six parameters are in agreement as much as possible. Note that hitching is not recommended for instruments with different geometries.

## The Basic Technique of Hitch Standardization

The process of hitch standardization also known as transfer standardization involves assigning one instrument to be the reference, or master, unit and mathematically adjusting the secondary, or slave, unit(s) to read the "same" values. In this way, two or more instruments can be hitched together.

Hitching a secondary unit to a reference instrument requires that a specimen be read on both units and the values compared and adjusted accordingly. This specimen, known as the hitch standard, is first read on the reference instrument and its values recorded as spectral data or colorimetric (tristrimulus) data. The hitch standard is then physically moved to the secondary instrument where it is reread and the values from the reference unit are input into the secondary instrument's processor.




Here's a simple example: Reference instrument was used to read a standard. It was then hitched to another instrument and the standard was read again. The values read on the reference instrument are shown in Table 1 and the results as expected indicate that the readings after hitch standardization are closer to the reference instrument readings than before hitch standardization.

In general, hitch standardization is useful for localized areas of color space, i.e. 5 units or less. Due to the visual non-uniformity of the color scales, it is recommended that each distinct color be assigned a separate hitch standard. This will improve the reproducibility of the measurements between the reference and secondary units.

Table 2. Before & After Hitch

| **Instrument** | **L*** | **a*** | **b*** |
|---|---|---|---|
| Reference Instrument | 51 | 51 | 51 |
| Secondary Before Hitch Standardization | 50 | 50 | 50 |
| Secondary After Hitch Standardization | 51 | 51 | 51 |

In comparing the parameters for the two facilities, the following changes will make them correlate as closely as possible.

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5. **Sample Preparation** - The same for both plants.
6. **Sample Presentation** - No match. However, Facility A will use sample cup presentation method and Facility B will average the sample using a 6" rotating pan.

## The Calculations

Through firmware or software, the secondary unit is "biased" to the reference unit using either an additive or a ratio calculation, as shown below.

***BIAS (Additive) Calculation:***

Hitched Sample Value = Unhitched Sample Value + Hitch Bias
Hitch Bias = Assigned Standard Value – Measured Standard Value.

***RATIO (Scalar) Calculation:***

Hitched Sample Value = Unhitched Sample Value * Hitch Ratio
Hitch Ratio = Assigned Standard Value/ Measured Standard Value

For the Reference example cited above, the following BIAS calculations apply:

L*: 51 = 50 + Hitch Bias; Hitch Bias = 1.0
a*: 51 = 50 + Hitch Bias; Hitch Bias = 1.0
b*: 51 = 50 + Hitch Bias; Hitch Bias = 1.0

For measurements made using RATIO calculations:

L*: 51 = 50 * Hitch Ratio; Hitch Ratio = 51.00/50.00 = 1.02
a*: 51 = 50 * Hitch Ratio; Hitch Ratio = 51.00/50.00 = 1.02
b*: 51 = 50 * Hitch Ratio; Hitch Ratio = 51.00/50.00 = 1.02

***Note: the bias type of hitch is preferable for dark colors and when the samples to be measured are very close in color to the hitch standard. Ratio hitches tend to be more robust.***

## Choosing the Best instrumentation

The best hitch results are obtained when the instrument set contains units of similar geometry. This means that hitched instruments should all have either diffuse or directional geometry and that these differing geometries are not combined in a hitch.

When using a combination of colorimeters and spectrophotometers (sometimes referred to as spectrocolorimeters) in the hitch network, it is recommended that a spectrophotometer (such as a ColorFlex EZ, Aeros, Agera, or UltraScan), rather than a colorimeter, serve as the reference unit.

This makes the most of the spectrophotometer's ability to measure across the entire visual spectrum and takes advantage of the tightness in readings that can be achieved within a population of spectrophotometers. In the case where all spectrophotometers or all colorimeters are being used for the hitch, the reference unit can be selected at random. It is recommended that the reference unit be placed in a central laboratory where performance can be monitored on a regular basis.

Some spectrocolorimeters have the additional ability to perform a hitch based on each point of spectral data, which means you can then view the hitched data under any color scale, and observer. Tristimulus hitches limit your data viewing capabilities to the illuminant and observer conditions under which the hitch was created. For specific instrument operation instructions, refer to your instrument user's manual.

## Selecting a Hitch Standard

There are many cases where multiple copies of the hitch standard are unavailable or the stability of the specimen is in question. For these cases, a material of the same color with the following characteristics would be ideal:

- Readily-available quantity
- Uniform surface
- Stable over time
- Non-metameric to the sample
- Non-photochromic
- Non-thermochromic.

A good example of a commonly-used and stable hitch standard is a ceramic tile. This type of standard can easily be sent to the various locations of the secondary instruments after being read on the reference unit.

## Preparation of a Secondary Hitch Standard

In the case where the color of the hitch standard will change over time, care must be taken to ensure optimum shipping conditions and quick use of the hitch standard. Once the hitch standard is read on the secondary instrument to establish the initial hitch, a secondary standard should be chosen for use in routine product evaluation. This secondary standard should be a more stable material that can be used to re-establish the hitch as needed.

The secondary hitch standard procedure is used, for example, in the determination of United States Department of Agriculture (USDA) grade color for tomato products. The instrument network is composed of directional colorimeters that are hitched together to the reference instrument at USDA via an actual tomato paste sample. This "soft" standard is prepared and read on each secondary instrument, and the assigned values from the reference unit are entered into each unit. Since the standard is biodegradable, its shelf-life in an open container is relatively short. Therefore, the next step is to read a red ceramic tile, the "tomato tile," relative to this hitch.

When the tomato tile is read on each secondary instrument with the soft standard hitch in place, the values obtained become the "new assigned" values from the reference instrument. The secondary instrument can then be rehitched using the tomato tile in the future rather than the soft standard. The tomato tile becomes the secondary hitch standard. It is checked periodically against a new soft standard.

## Instrument Performance and Hitch Standardization

Each instrument should be standardized prior to working with a hitch standard to ensure robustness of the data. .Periodic restandardization should be done per the individual instrument recommendations. Each hitch standard or product standard should be reread and compared to itself as a sample on a routine basis to ensure confidence in the hitch calculations.

In addition, a checking program should be implemented for evaluating the performance of the hitch standardization on each secondary unit for each color relative to the reference instrument. A set of stable specimens that could be read on each instrument and compared would serve as a check on the program. Changes in the hardware on any reference or secondary unit will affect the assignment of hitch factors. It is recommended that routine diagnostics be performed on each unit in the network to ensure proper maintenance. Refer to specific diagnostic routines described in your User's Manual. Maintenance of the instruments (i.e., replacement of the lamp or preventative maintenance work by a service technician), followed by rereading of the instrument standards and the hitch standards are recommended on a scheduled basis.

## Summary of Hitch Standardization Procedure

1. Check the 6 method parameters and get them to match.
2. Choose the reference instrument and the specimens to be used as hitch standards. Each color should have its own hitch standard for best results. Each secondary unit should have its own set of hitch standards.
3. Label each standard for easy identification.
4. Standardize the reference unit using its calibrated instrument tiles. Read each hitch standard on the reference unit and record the data. If tristimulus data is being obtained, record the standard observer and illuminant. Note that use of a colorimeter as a reference or secondary unit will require the use of Illuminant C and the 2° standard observer. If spectral data is being used, write down or print the 10 nm data for the entire measurement range of the instrument.
5. Forward the hitch standards and the recorded hitch data to each secondary unit location.
6. Read the instructions for hitch standardization in the User's Manual for the secondary instrument. Set up this instrument to read the same color scale, illuminant, standard observer, etc. as the hitch data from the reference instrument. Standardize the secondary instrument using its own calibrated tiles.
7. Following the specific instrument procedures, read the hitch standard on the secondary unit. When prompted, input the values from the reference unit. The computer or processor will then determine the hitch offset, and the instrument is ready for sample analysis.
8. If you plan to use a secondary hitch standard, read the secondary standard as a sample. Record the values read for this standard with the hitch implemented. These values will now serve as the assigned values from the reference instrument. The instrument can now be rehitched using this secondary standard.
9. Implement a check program to evaluate the hitch for each secondary unit relative to the reference instrument

## References

ASTM E1455, "Standard Practice for Obtaining Colorimetric Data from a Visual Display Unit Using Tristimulus Colorimeters."

Berns, Roy S., *Billmeyer and Saltzman's Principles of Color Technology*, New York: John Wiley & Sons, 2000.

## About HunterLab

HunterLab is the technology leader in color measurement solutions, providing instruments, software, knowledge and service to a wide variety of industries.
With over 5 decades of experience in more than 65 countries, HunterLab applies our leading edge technology to your products helping you measure and communicate color simply and effectively.

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