



Color iQC and Color iMatch Color Calculations Guide

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Attributes for Standard/Multi-Trial View Display

Color iControl has a wide variety of possible attributes available for display for either the standard or any trial data loaded into a job. Following is a complete list, with brief definitions, of each of those attributes. This list is comprehensive and includes attributes for both Standard and Trial display; however, not all of these attributes will be applicable to the standard (delta values, for example).

General Attributes

Date/Time	Displays the day and time that the measurement was taken.
Comment	This option allows you to display any comments entered into the Comment field in the measurement's Name tab of its Properties... dialog box
Oper ID	This attribute displays the operator ID for the measurement, ie, the person who took the reading.
Group/Sequence	This attribute will only be available if you have purchased the SLI-Taper/W32 option with your Color iControl system. It identifies each sample's place in a set(s) of tapered samples. If more than one group was tapered with a data set, then the groups will be identified as well as the sequence.
Group_1, Group_2, Group_3	These attributes allow you to display any User Groups that the sample has been included within. See User Groups for more information.
Visual Comment	The comment entered for the e-Submit visual comment field.
ILL-Observer	The name for the current primary illuminant / observer combination used for the colorimetric calculations.
Meas Conditions	Displays spectrophotometer settings used for this measurement
Length	This attribute displays the length of the fabric in whatever units have been selected by the user. You can set the program to prompt for a length value whenever you do an instrument read in the Options tab of the Settings dialog box.

Pass Fail Decisions

Pass/Fail/Margin	This item displays a pass, fail, or marginal indicator for samples measured against the standard. It must be selected in order for the pass/fail/marginal icons (green ball, stop sign, yellow question mark, respectively) to be displayed in the Standard/Multi-Trial view. Color iControl - Color iQC / Color iMatch Color Difference/How To <input type="checkbox"/>135
Roll-Roll DEcmc	This item displays the DE _{cmc} from roll to roll when the SLI-Taper software is used to sequence a set of measurements depicting rolls

	of fabric.
Ext DE*	DE* value using the extended (alternate) spectral data. Typically used to display the DE* comparison of the transmittance spectral data between a standard and a sample in an extended R/T measurement type.
Summary Count, Summary DE, Summary Cluster	Values that are calculated and displayed by the statistics summary view. Count is the number of samples, DE is the average DE_{cmc} or DE* for the selected samples, and Cluster is the average DE_{cmc} for the samples compared to the average (rather than the standard).

Opacity Indices

Opacity_CR	<p>This value is the opacity using the contrast ratio method. To use this value, the calibration mode of the spectro must include extended measurements for over light and over dark. Samples must then be measured using both a light backing and a dark backing. See Extended Measurements in Setting Up the Measurement Process and Additional Elements of the Measure Dialog for more information. See also Calibration Mode Properties Dialog in Select Mode.</p> $\text{Opacity} = 100.0 * (\text{Dark}Y_{C2} / \text{Light}Y_{C2})$
Tappi_Opacity	<p>This index is a measure of opacity (sometimes called hiding power or contrast ratio). It is the ratio of Y tristimulus for the sample measured over a black substrate divided by the Y tristimulus for the sample measured over a white substrate, expressed as a percentage. This calculation is based on the 1931 standard observer (2 degree) and Illuminant A.</p>
DIN Transparency D53-147	<p>Displays transparency of a semi-transparent material using DIN D53-147 equation.</p>

Transmittances Indices

Haze	<p>Calculation requiring extended measurements TRA/TRA. Correlated Haze requires measurement of transmission using a white then a black trap. See Extended Measurements in Setting Up the Measurement Process and Additional Elements of the Measure Dialog for more information. See also Calibration Mode Properties Dialog in Select Mode. Color iControl - Color iQC / Color iMatch Color Difference/How To □ 133</p>
APHA	<p>This attribute is defined by the American Public Health Association for determining color (clarity) of water.</p>
OJ_Index	<p>This index was developed by the U.S. Department of Agriculture for use with the GretagMacbeth Color-Eye 2020+ or GretagMacbeth Color-Eye 3000 spectrophotometers equipped with an orange juice test tube holder accessory.</p>

Gloss Indices

SRR Gloss	ASTM method E429 Specular Reflectance Ratio gloss calculation for sphere spectrophotometers using Specular included versus Specular excluded measurements. SRR Gloss requires Extended Measurements.
Gloss 60*	This attribute displays a correlated 60 degree gloss method using SCI/SCE measurement and an equation that correlates the differences to measurements taken on a true 60 degree gloss meter. Gloss 60* requires Extended Measurements. See Extended Measurements in Setting Up the Measurement Process and Additional Elements of the Measure Dialog for more information. See also Calibration Mode Properties Dialog in Select Mode.

Sorting Codes

Sort Codes (DL*C*H*, DL*a*b*, DLab)	This attribute displays the 555 Sort Codes for the selected samples compared to the standard. You may select Sort Codes for DL*C*H*, DL*a*b*, or DLab. Also available in Strength Adjusted form for the DL*C*H* and DL*a*b* sort codes..
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Density Indices

% Density_1, _2, _3	% strength calculation between a standard and a sample using the density values for each.
Density_1,2,_ 3	- Provides density calculation using the selected Density equation (as specified in the general settings tab). Density values are given for 3 "filters" (cyan, magenta, yellow) based on weighting s provided for that method in the Density.table. Users can add to this table to create custom density functions. 136 <input type="checkbox"/> Color Difference/How To Color iControl - Color iQC / Color iMatch

Yellowness Index

Yellowness is defined as “the attribute by which an object color is judged to depart from a preferred white towards yellow’.

The Yellowness Index is a number calculated from spectral data that describes the change in color of a test sample from clear or white toward yellow. This test is most commonly used to evaluate color changes in a material caused by real or simulated outdoor exposure.

Yellowness Indices are limited to specimens having dominant wavelength in the range 570 to 580 nm. For Samples, which do not fulfill this criteria the results have no value.

Typically the Yellowness index is measured for a reference, which represents the ideal white. Samples (or changes) are compared to the reference and differences are calculated. Positive values will indicate, that then sample will be more yellow. Negative will indicate that the sample is more blue.

ASTM D 1925 Yellowness Index for Plastics

ASTM D1925 has been specifically developed for the definition of the Yellowness of homogeneous, non-fluorescent, almost neutral-transparent, white-scattering or opaque plastics as they will be reviewed under daylight condition. It can be other materials as well, as long as they fit into this description.

The calculation for ASTM D1925 is:	$YI = \left[\frac{100 \times (1.28X - 1.06Z)}{Y} \right]$
X, Y and Z are the tri-stimulus values for the calculated for illuminant C	

ASTM E 313 Yellowness index

ASTM E313 has successfully been used for a variety of white or near white materials. This includes coatings, Plastics, Textiles.

The calculation for ASTM E313 is:	$YI = 100 \times \left[1 - \frac{0.847Z}{Y} \right]$
X, Y and Z are the tri-stimulus values for the calculated for illuminant C	

Whiteness Indices

Certain industries, such as paint, textiles and paper manufacturing, evaluate their materials and products based on standards of whiteness. Typically, this whiteness index is a preference rating for how white a material should appear, be it photographic and printing paper or plastics. Thus Whiteness Index is a measure which correlates the visual ratings of whiteness for certain white and near-white surfaces.

According to ASTM (American Society for Testing and Materials) as “the attribute, by which an object color is judged to approach some preferred white” . There is a number of different indices available. No matter which index you choose you have to verify how this relates to your visual observation. If you communicate any whiteness data with some partners in your supply chain, you will always have to clearly identify which index you selected.

ASTM E313 Whiteness

The calculation for ASTM E313 is

$$WI = 3.388 \cdot Z - 3 \cdot Y$$

- Y and Z are the tri-stimulus values for the sample

CIE Whiteness

The CIE Whiteness index is quite wide spread in the industry. It will strictly be used for D65 for 2 or 10 deg observer

The calculation for CIE Whiteness is:

$$W_{CIE} = Y + 800 \cdot (x_0 - x) + 1700 \cdot (y_0 - y)$$

- Y is the tri-stimulus value for the sample
- x and y the color coordinates for the sample as this calculated using the illuminant/observer condition
- x_0 and y_0 are the color coordinates of the achromatic point

Interpretation of data

- Values bigger than 100 indicate a bluish white
- Values smaller than 100 indicate a yellowish white

Berger (59) Whiteness

This formula was developed by A. Berger (formerly employee of Bayer AG, Germany and was presented in 1959.

Whiteness values calculated after the formula of Berger was very popular during the sixties until beginning of the eighties mainly in the paper and also in Textile areas

Berger Whiteness is defined for illuminant C and the 2° Observer. However it is used for other illuminant observer condition as well.

The calculation for Berger Whiteness is:	$WI_{Berger(59)} = 0.333Y + 125 \frac{Z}{Z_0} - 125 \frac{X}{X_0}$
<ul style="list-style-type: none">• X,Y and Z is the tri-stimulus value for the sample• X_0 and Z_0 are the tri-stimulus values of the illuminant Observer	

Interpretation:

☐ Values bigger than 33.33 indicate a bluish white

☐ Values smaller than 33.33 indicate a yellowish white

Stensby Whiteness

This formula was developed by Mr. P. Stensby (formerly employee of J.R. Geigy AG in US.) It was presented in 1968.

Whiteness values calculated after the formula of Stensby found its use in the detergent area, especially in the USA. Today it is rarely seen.

The calculation for Stensby Whiteness is:	$WI_{Stensby} = L - 3b + 3a$
<ul style="list-style-type: none">• L, a and b are Hunter Color Coordinates	

Interpretation:

☐ Values bigger than 100 indicate a bluish white

☐ Values smaller than 100 indicate a yellowish white

Taube Whiteness

This Formula was developed by Mr. Taube (formerly an employee of BASF AG, Germany). It was presented in 1960 and has found it's application mainly in the plastic sector.

The calculation for Taube Whiteness is:	$WI_{Taube} = 400 \frac{Z}{Z_0} - 3Y$
<ul style="list-style-type: none">• X,Y and Z is the Tri-stimulus value for the sample• Z_0 is the Tri-stimulus value of the illuminant observer	

Interpretation:

- ☐ Values bigger than 100 indicate a bluish white
- ☐ Values smaller than 100 indicate a yellowish white

Hunter (60) Whiteness-Index

This Formula was developed by Mr. Hunter. It was presented in 1960.

The calculation for Hunter Whiteness is:	$WI_{Hunter} = L - 3b$
<ul style="list-style-type: none">• L, a and b are Hunter Color Coordinates	

Interpretation:

- ☐ Values bigger than 100 indicate a bluish white
- ☐ Values smaller than 100 indicate a yellowish white

Ganz and Griesser Whiteness

Dr. E. Ganz (formerly employee of Ciba AG, Switzerland) and Mr.R. Griesser (formerly employee of J.R.Geigy) developed the Ganz Griesser Whiteness Method. It is the first formula which referred to a neutral white and in order to take the difference to the preferred whites it used a second dimension the tint or shade deviation.

The calculation for Ganz Whiteness is:	$W_{Ganz} = Y + P \cdot x + Q \cdot y + C$
The calculation for Ganz Griesser Tint is	$T_{Ganz-Griesser} = m \cdot x + n \cdot y + k$
<ul style="list-style-type: none">• Where nominal coefficients are given for $D_{65/10}$ as• $P = -1868.322$• $Q = -3695.690$• $C = 1809.441$• $m = -1001.223$• $n = 748.366$• $k = 68.261$	

Interpretation

- Tint >0 = white has a greenish shade
- Tint <0 = white has a reddish shade
- Whiteness differences of less than 5 Ganz units appear to be undistinguishable to the human eye
- Tint differences of less than 05 Ganz-Griesser units appear to be undistinguishable to the human eye

Strength calculations

Color strength is defined as a pigments or dyes ability to change the color of a otherwise color less material. Strength indices are used to compare Standard and Sample and define the ratio of the sample strength in relation to the standard. Strength indices allow you to define how strong or weak a sample is in comparison to the reference standard. Different lots of the same colorant material are prepared in the same way and the difference between the two samples is measured. A strength correction based on spectral data will adjust the spectral data of the sample to those of the standard. The corrected data afterwards will be used for color comparisons. With this method color comparison can done on the bases of equivalent color strength.

Strength calculations will be done on the base of a color value. This is a numerical value related to the amount of light-absorbing material (colorant) contained in a sample. The calculation is done based on spectral data by one of three acceptable methods (SWL, SUM, WSUM). The results of the different methods may not agree with any other method. The choice of method usually depends on the nature of sample and the need to obtain a color value.

Color Value SWL

The Color Value SWL is calculated as the sum of K/S values for the sample read across the spectrum for reflectance measurements and from the sum of absorbance's for the sample read across the spectrum for transmittance measurements.

There are several ways to define the color strength indices.

% (Color) Strength SWL

This strength is also known as the chromatic color strength. It describes the ratio based on the (K/S-value) of the Sample in relation to the (K/S-value) of the Standard at a single wavelength and will be expressed in percent. This calculation typically is meaningful, if it will be made at the wavelength of maximum absorption (lowest reflectance). In daily application often it will be made at other wavelength, but results have to be evaluated very carefully. If standard and sample have different wavelengths of maximum of absorption this method will not deliver correct results.

The calculation for SWL color strength based on Reflectance is	$Strength\% = 100 \times \frac{(K/S)_{trial}}{(K/S)_{std}} \quad \text{using} \quad (K/S) = \frac{(1-R)^2}{2R}$
<ul style="list-style-type: none">R is the reflectance at the wavelength of maximum absorption in a decimal way (20%R = 0.20R)	

The calculation for SWL color strength based on Transmission is	$R = \log_{10}(1/T)$
<ul style="list-style-type: none">T is the Transmission in a decimal way (20%T = 0.20T)	

Interpretation

- Percent color strength >100 = sample is more strong in color than the standard
- Percent color strength <100 = sample is weaker in color than the standard
- Percent color strength =100 = sample and standard have the same color strength

% (Color) Strength SUM (DIN55986)

This strength method is sometimes listed as apparent strength

The % strength SUM represents the ratio of (K/S) data between sample and standard at all visual wavelength (400-700nm) and will be expressed in % . The selection of different illuminant observer condition has no influence on the result.

The calculation for SUM strength based on reflectance is	$Strength\% = 100 \times \frac{\sum_{400}^{700} (K/S)_{trial}}{\sum_{400}^{700} (K/S)_{std}}$ <p style="text-align: right;">using $(K/S) = \frac{(1-R)^2}{2R}$</p>
<ul style="list-style-type: none"> • R is the reflectance at the wavelength of maximum absorption in a decimal way (20%R = 0.20R) 	

The calculation for SUM strength based on Transmission is	$R = \log_{10}(1/T)$
<ul style="list-style-type: none"> • T is the Transmission in a decimal way (20%T = 0.20T) 	

Interpretation

- Percent color strength >100 = sample is more strong in color than the standard
- Percent color strength <100 = sample is weaker in color than the standard
- Percent color strength =100 = sample and standard have the same color strength

% (color) Strength WSUM

This strength method is sometimes listed as integrated strength. The strength WSUM represents the ration of sums of (K/S) data multiplied by the sum of weighted observer/illumination at all wavelengths for the sample in relation to the standard. It will be expressed in percent. The result is illuminant/observer depending. F.e. If a red color is evaluated for strength difference this method will show for D65 illumination a smaller color strength difference than for illuminant A.

The calculation for WSUM color strength based on reflectance is	$Strength\% = 100 \times \frac{\sum_{400}^{700} (K/S)(f_x + f_y + f_z)_{trial}}{\sum_{400}^{700} (K/S)(f_x + f_y + f_z)_{std}}$ using $(K/S) = \frac{(1-R)^2}{2R}$
<ul style="list-style-type: none"> R is the reflectance at the wavelength of maximum absorption in a decimal way (20%R = 0.20R) 	

The calculation for WSUM strength based on Transmission is	$R = \log_{10}(1/T)$
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Interpretation

- Percent color strength >100 = sample is more strong in color than the standard
- Percent color strength <100 = sample is weaker in color than the standard
- Percent color strength =100 = sample and standard have the same color strength

Color Value

The Color value as used in calculating colorant strength, is a single numerical value related to the amount of light-absorbing material (colorant) contained in the sample and is usually based on spectral data. Color value may be calculated by any of the three acceptable methods (SWL, SUM, WSUM). The color value which results from the one method might not agree with any other method. The choice is usually dependent on the nature of the sample and the need to obtain a color value.

The color value is normally calculated based on the spectral data.

Reflectance Methods

The calculation of color value of a sample is based on the reflectance values of the sample and uses the K/S calculation either at one (SWL) or multiple wavelength (SUM, WSUM)	$\frac{K}{S} = \frac{(1.0 - \beta)^2}{2.0\beta}$
<ul style="list-style-type: none"> • β = percentage reflectance at each wavelength 	

Color Value SWL

The calculation of the Color Value SWL is calculated as the K/S values for the sample at **one** wavelength (typically at the wavelength of maximum absorption) for reflectance measurements.

$$CV_{swl} = \left(\frac{K}{S} \right)_{\lambda}$$

Color Value SUM

The calculation of the Color Value SUM is calculated as the sum of K/S values for the sample read across the spectrum for reflectance measurements

$$CV_{sum} = \sum_{\lambda} \left(\frac{K}{S} \right)_{\lambda} d\lambda$$

- λ = wavelength within across the spectrum

Color Value WSUM

The calculation of the Color Value WSUM is calculated as the sum of K/S values weighted by illuminant and observer for the sample read across the spectrum for reflectance measurements.

$$CV_{wsun} = \sum_{\lambda} \left(\frac{K}{S} \right)_{\lambda} \cdot E_{\lambda} \cdot S_{\lambda} d\lambda$$

- λ = wavelength within across the spectrum / E = Energy distribution of the selected illuminant / S = Observer function

Transmission Method

The calculation of color value of a sample is based on the transmission values of the sample and uses the absorbance calculation either at one (SWL) or multiple wavelength (SUM, WSUM)

$$A_{\lambda} = \log_{10} \left(\frac{1.0}{T_{\lambda}} \right)$$

T8= internal Transmittance - normally measured with a spectrophotometer (100 % T = 1.0)

Color Value SWL

The calculation of the Color Value SWL is calculated as the absorbance value for the sample at **one** wavelength (typically at the wavelength of maximum absorption = minimum transmittance)

$$CV_{swl} = (A_{\lambda})_{\lambda}$$

Relative Strength

The relative strength between a standard and a sample can be calculated from the color values. It will be expressed as a % of the sample in relation to 100% of the standards

The relative strength is

$$\%strength = \left(\frac{ColorValue_{specimen}}{ColorValue_{standard}} \right) \cdot 100.0$$

Strength Adjusted

This attribute appears before many of the colorimetric terms previously listed and allows you to display those terms in their strength adjusted form. That is, Color iControl corrects the sample(s) so that its strength is equal to the standard. Then color difference data is calculated again. Strength adjusted data is helpful in determining whether or not correcting only for strength differences will result in a hue shift. Terms that are available in Strength Adjusted form are so indicated.

X, _Y, _Z - Ratio

% Strength calculation between a standard and a sample using the X,Y,or Z values of each. Normally used in Paints evaluation and in conjunction with Saunderson Corrections.

% Strength (current method)

Used to display the %strength value by whatever calculation method is currently selected in the general settings tab as the current %strength method.

DIN 53235 Tint % Strength

A percent strength value is calculated for a sample relative to a standard for different apparent strength levels and used by colorant manufacturers to help determine and adjust for strength differences.

DIN 53235 Tint B Value

The actual Tint B value for the measurement and used in the DIN Strength method for calculating the %strength of a standard/sample pair.

<http://www.beuth.de/langanzeige/DIN-53235-1/de/80457684.html>

<http://www.beuth.de/langanzeige/DIN-53235-2/de/80457913.html>

TAPPI-Indices

You will be able to receive each of the following Standards directly at the TAPPI (Technical Association of Pulp and Paper Industries) in the US :

Phone (USA): +1-800-332-8686

address: TAPPI, Technology Park/Atlanta, PO Box 105113, Atlanta, GA 30348-5113

<http://www.tappi.org/>

T 452 TAPPI Brightness for Pulp Paper and Paperboard (1977)

This will be used in the paper industry to evaluate the quality of non-processed pulp, paper and board.

This TAPPI T 452 (1977) is not recommended to be used to evaluate the appearance of white. Especially if fluorescent material is used you better should use a whiteness index.

Further information at:

<http://www.tappi.org/Downloads/unsorted/UNTITLED---0104T452pdf.aspx>

T 452 TAPPI - Brightness for Pulp Paper and Paperboard (1987)

This will deliver the same results as described in the official method TAPPI T 452 as published in 1977.

This will be used in the paper industry to evaluate the quality of non-processed pulp, paper and board.

This TAPPI T 452 (1977) is not recommended to be used to evaluate the appearance of white. Especially if fluorescent material is used you better should use a whiteness index.

Further information at:

<http://www.tappi.org/Downloads/unsorted/UNTITLED---0104T452pdf.aspx>

T 525 TAPPI - Diffuse brightness of paper, paperboard and pulp

This method will provide the diffuse brightness of pulp based on reflectance ($d/0^\circ$) measurement at 457 nm. It is used to evaluate the diffuse blue reflectance factor (diffuse brightness) of pulp, in which samples prepared according to T218 ("Forming Hand sheets for Reflectance samples of Pulp")

This TAPPI T 452 (1977) is not recommended to be used to evaluate the appearance of white. Especially if fluorescent material is used you better should use a whiteness index.

Further information at:

<http://www.tappi.org/Downloads/unsorted/UNTITLED---0104T525pdf.aspx>

TAPPI T 425 Opacity

Opacity of paper (15°/Diffuse illuminant A/2Deg, 89% Reflectance Backing and Paper backing)

This is an empiric measurement of the optical properties of paper, the quantity and type of filler, the degree of bleaching. This method will measure paper over a black and white backing. The measurement of paper over black will let the light pass through non opaque paper. The measurement over black backing will be compared with the over white backing. .

Two alternate methods of opacity measurements are used:

- Opacity (89% Reflectance backing)
- Opacity (Paper backing)

Further information about Tappi Methods at:

<http://engineers.ihs.com/document/abstract/LMXBJBAAAAAAAAAA>

TAPPI T 519 - Diffuse Opacity of paper (D/0-Backing)

This method provides a measure of diffuse opacity (paper backing) of white and near-white papers, previously known as “printing opacity.”

The method may be employed for colored papers on condition that their reflectance (paper backing) is greater than 20% and their diffuse opacity (paper backing) is greater than 45% (1).

The method is not suitable for highly transparent papers such as glassine.

This method employs d/0 geometry, illuminant C, and paper backing whereas TAPPI T 425 “Opacity of Paper” employs 15/d geometry, illuminant A, both 89% reflectance backing and paper backing.

This method is similar to ISO 2471.

Further information about Tappi T519i Method at:

<http://engineers.ihs.com/document/abstract/ERNRJBAAAAAAAAAA>

AATCC Gray-Scales

AATCC Gray-Scale-Tests for assessing changes in color (equivalent to ISO 105-A02-1978 (E))

Describes the gray scale for determining changes in color of textiles in color fastness tests, and its use. A precise colorimetric specification of the scale is given as a permanent record against which newly prepared working standards and standards that may have changed can be compared. The essential scale (5 steps) consists of pairs of non-glossy grey color chips (or swatches of grey cloth). In addition, an augmented scale includes four half-steps and, thus, 9 steps.

Further information you will find here:

http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=3785

AATCC Gray Scale for assessing staining (equivalent to ISO 105-A02-1978 (E))

Describes the grey scale for determining staining of adjacent fabrics in color fastness tests, and its use. A precise colorimetric specification of the scale is given as a permanent record against which newly prepared working standards and standards that may have changed can be compared.

The essential, or 5-step, scale consists of five pairs of non-glossy grey or white color chips (or swatches of grey or white cloth), which illustrate the perceived color differences corresponding to fastness ratings 5, 4, 3, 2 and 1. This essential scale may be augmented by the provision of similar chips or swatches illustrating the perceived color differences corresponding to the half-step fastness ratings 4-5, 3-4, 2-3 and 1-2, such scales being termed 9-step scales. The first member of each pair is white in color and the second member of the pair illustrating fastness rating 5 is identical with the first member. The second members of the remaining pairs are increasingly darker in color so that each pair illustrates increasing contrasts or perceived color differences which are defined color metrically. The full colorimetric specification is given below.

Further information you will find here:

http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=3787

Metamerism-Index

The Metamerism-Index (MI) will show the probability that two samples will show the same color difference under two different illuminants (represented by the first and second illuminant)

MI =	$MI = \sqrt{(\Delta L^*_1 - \Delta L^*_2)^2 + (\Delta a^*_1 - \Delta a^*_2)^2 + (\Delta b^*_1 - \Delta b^*_2)^2}$
	<ul style="list-style-type: none">• ΔL^*_1 Δa^*_1 Δb^*_1 are the Delta CIELab* color coordinates between Standard and Sample for the first illuminant
	<ul style="list-style-type: none">• ΔL^*_2 Δa^*_2 Δb^*_2 are the Delta CIELab* color coordinates between Standard and Sample for the second illuminant

Interpretation:

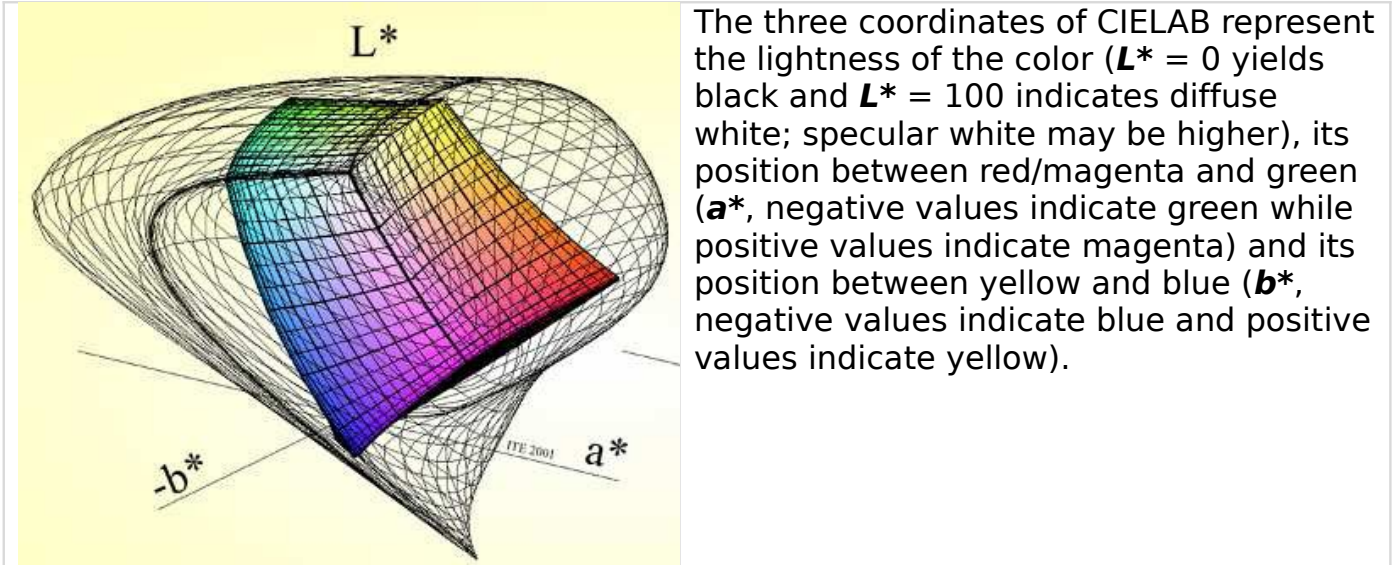
- If MI is low the color difference between the sample pair is the same for both illuminants. This does not mean that the two samples match, it means, that the two samples show the same difference for both illuminants
- If MI is high there is a different color difference between the two samples at two different illuminants. The samples might match under one illuminant, but not under the second. Or the sample 1 might be red under illuminant 1 and to green under illuminant 2

Color Inconsistency

This attribute indicates a color change in the sample (without any reference to the standard) under different illuminants. This property is sometimes known as "**flare.**" You may select to display a Color Inconstancy value for samples for the first and second illuminants, the second and third illuminants, and the first and third illuminants. This is a new index for which experimental data has not been gathered and therefore no hard and fast rules on acceptable tolerances have been established. Higher values of Color Inconstancy (over 1.0) probably indicate an unacceptable color difference; however, it would be wise to also examine the trial measurement in question in the Color Rendering View with the Multiple Illuminants option turned on to examine the color change visually rather than depending purely on the numeric value listed in the Multi-Trial View. Color Inconstancy is also an attribute on which you may sort formulas when in Color iControl's formulation mode and can be selected from that mode's Settings dialog.

CIE 1976 (L^* , a^* , b^*) color space (CIELAB)

CIE $L^*a^*b^*$ (CIELAB) is color space specified by the CIE International Commission on Illumination (French *Commission internationale de l'éclairage*). It describes all the colors visible to the human eye and was created to serve as a device independent model to be used as a reference.

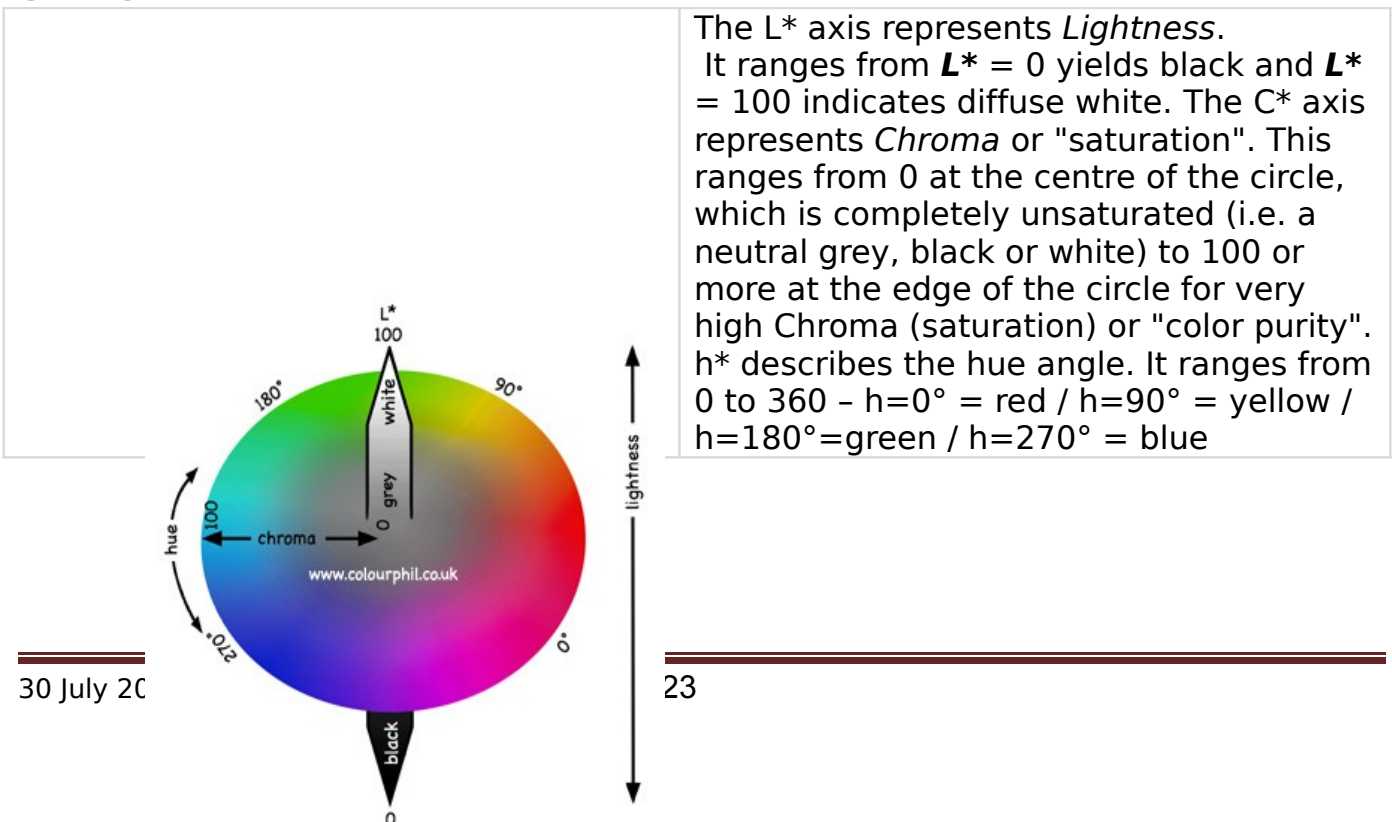


The three coordinates of CIELAB represent the lightness of the color ($L^* = 0$ yields black and $L^* = 100$ indicates diffuse white; specular white may be higher), its position between red/magenta and green (a^* , negative values indicate green while positive values indicate magenta) and its position between yellow and blue (b^* , negative values indicate blue and positive values indicate yellow).

The asterisk (*) after L , a and b are part of the full name, since they represent L^* , a^* and b^* , to distinguish them from Hunter's L , a , and b , described below. Since the $L^*a^*b^*$ model is a three-dimensional model, it can only be represented properly in a three-dimensional space.

Because the red/green and yellow/blue opponent channels are computed as differences of lightness transformations of (putative) cone responses, CIELAB is a chromatic value color space.

CIE $L^*C^*H^*$



The L^* axis represents *Lightness*. It ranges from $L^* = 0$ yields black and $L^* = 100$ indicates diffuse white. The C^* axis represents *Chroma* or "saturation". This ranges from 0 at the centre of the circle, which is completely unsaturated (i.e. a neutral grey, black or white) to 100 or more at the edge of the circle for very high Chroma (saturation) or "color purity". h^* describes the hue angle. It ranges from 0 to 360 - $h=0^\circ = \text{red}$ / $h=90^\circ = \text{yellow}$ / $h=180^\circ = \text{green}$ / $h=270^\circ = \text{blue}$

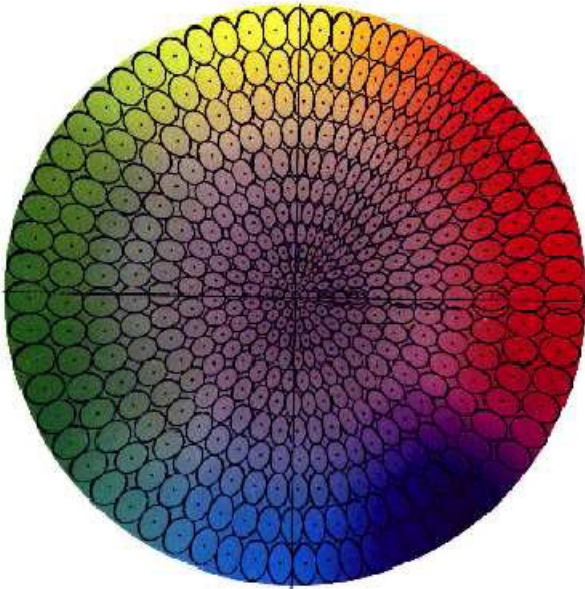
CieLab* Color Attributes

L*	Represents a standard or sample's position on the lightness axis in either CIELAB or CIELCH color space. This attribute is also available in Strength Adjusted form.
a*	Represents a standard or sample's position on the green/red axis in CIELAB color space, green being in the negative direction and red being in the positive direction. This attribute is also available in Strength Adjusted form.
b*	Represents a standard or sample's position on the blue/yellow axis in CIELAB color space, blue being in the negative direction and yellow being in the positive direction. This attribute is also available in Strength Adjusted form.
C*	Represents a standard or sample's chroma value in CIELCH color space. This attribute is also available in Strength Adjusted form.
h*	Represents a standard or sample's hue value in CIELCH color space. This attribute is also available in Strength Adjusted form.

CieLab* Color Difference Attributes

DL*	The delta value for the L* attribute. This attribute is also available in Strength Adjusted form.
Da*	The delta value for the a* attribute. This attribute is also available in Strength Adjusted form.
Db*	The delta value for the b* attribute. This attribute is also available in Strength Adjusted form.
DC*	The delta value for the C* attribute. This attribute is also available in Strength Adjusted form.
Dh*	The delta value for the h* attribute. This attribute is also available in Strength Adjusted form.
DE*	The distance a sample falls from the standard in CIE* color space using a simple, straight-line calculation. This attribute is also available in Strength Adjusted form.

CMC l:c (1984)



In 1984, the Colour Measurement Committee of the Society of Dyers and Colorists defined a difference measure, also based on the L*C*h color model. Named after the developing committee, their metric is called **CMC l:c**. The quasimetric has two parameters: lightness (l) and chroma (c), allowing the users to weight the difference based on the ratio of l:c that is deemed appropriate for the application. Commonly-used values are 2:1 for acceptability and 1:1 for the threshold of imperceptibility.

$$\Delta E_{CMC} = \sqrt{\left(\frac{\Delta L^*}{l \cdot S_L}\right)^2 + \left(\frac{\Delta C^*}{c \cdot S_C}\right)^2 + \left(\frac{\Delta H^*}{H_L}\right)^2}$$

SL = Funktion von L

- SL is a function of L
- Sc is a function of C
- l:c is the defined ratio of Lightness and Chroma

CMC* Color Difference Attributes

DL*cmc	The delta L* weighted by the CMC equation. This attribute is also available in Strength Adjusted form.
DC*cmc	The delta C* weighted by the CMC equation. This attribute is also available in Strength Adjusted form.
Dh*cmc	delta H* weighted by the CMC equation. This attribute is also available in Strength Adjusted form.
DEcmc (2.0:1)	This value also represents the distance in color space that a sample falls from the standard but is calculated using the CIE DEcmc equation which includes weighting functions that predict visual acceptability more accurately than the simpler DE* calculation. This attribute is also available in Strength Adjusted form.

CIE94

The 1976 definition was extended to address perceptual non-uniformities, while retaining the L*a*b* color space, by the introduction of application-specific weights derived from an automotive paint test's tolerance data.^[7]

ΔE (1994) is defined in the L*C*h* color space with differences in lightness, chroma and hue calculated from L*a*b* coordinates. Given a reference color^[8] (L_1^*, a_1^*, b_1^*) and another color (L_2^*, a_2^*, b_2^*), the difference is:^{[9][10][11]}

$$\Delta E_{94}^* = \sqrt{\left(\frac{\Delta L^*}{K_L}\right)^2 + \left(\frac{\Delta C_{ab}^*}{1 + K_1 C_1^*}\right)^2 + \left(\frac{\Delta H_{ab}^*}{1 + K_2 C_1^*}\right)^2}$$

Where the K-values depend on the application

	graphic arts	textiles
K_L	1	2
K_1	0.045	0.048
K_2	0.015	0.014

CIE DE 2000* Color Difference Attributes

DE2000	DE value using CIE DE2000 evaluation equation (this equation was not formerly adopted and is provided here only for reference).
DL*00	The delta value for the L* attribute from a proposed new color space. This attribute is also available in Strength Adjusted form.
DC*00	The delta value for the C* attribute from a proposed new color space. This attribute is also available in Strength Adjusted form
DH*00	The delta value for the H* attribute from a proposed new color space. This attribute is also available in Strength Adjusted form.

Hunter Lab

The Hunter Lab color scale was developed in the 50's and 60's. There were several permutations of the Hunter Lab color scale until the current formulas were released in 1966.



The Hunter Lab color space is organized in a cube form. The L axis runs from the top to the bottom. The maximum for L is 100 (for a perfect reflecting diffuser) while the minimum is 0. The a and b axes have no specific numeric limits. Positive a is red and negative a is green. Positive b is yellow and negative b is blue.

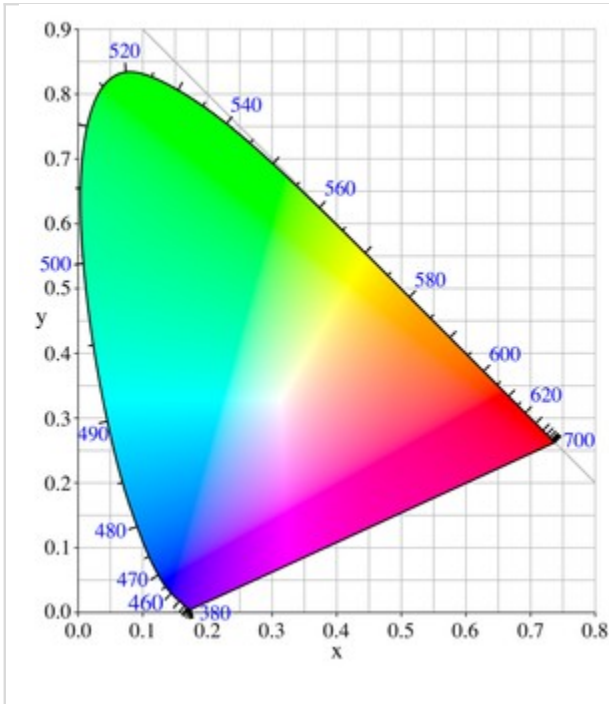
Hunter Lab Color Space attributes

L	Represents a standard or sample's position on the lightness axis in Hunter color space. This attribute is also available in Strength Adjusted form.
a	Represents a standard or sample's position on the green/red axis in Hunter color space. This attribute is also available in Strength Adjusted form
b	Represents a standard or sample's position on the blue/yellow axis in Hunter color space. This attribute is also available in Strength Adjusted form.

Hunter Lab Color Difference attributes

DL	The delta value for the L component of Hunter color space.
Da	The delta value for the a component of Hunter color space.
Db	The delta value for the b component of Hunter color space
DEh	The distance a sample falls from the standard in Hunter color space

CIE xyY Color space



The CIE 1931 color space chromaticity diagram. The outer curved boundary is the spectral (or monochromatic) locus, with wavelengths shown in nanometers.

CIE XYZ Color Coordinates

X	Represents a standard or sample's X tri-stimulus value for the 1931 CIE XYZ color space
Y	Represents a standard or sample's Y tri-stimulus value for the 1931 CIE XYZ color space
Z	Represents a standard or sample's Z tri-stimulus value for the 1931 CIE XYZ color space.
sx	Represents a standard or sample's position on the horizontal axis in the chromaticity diagram
sy	Represents a standard or sample's position on the vertical axis in the chromaticity diagram

CIE XYZ Differences

DY	The delta value for the Y element of the chromaticity diagram.
Dx	The delta value for the x element of the chromaticity diagram
Dy	The delta value for the y element of the chromaticity diagram.

FMCII (Friele - MacAdam - Chickering) Color Difference

The FMCII unit of color difference is based on just noticeable, or threshold, color difference data.

It has been published in 1942. Friele used the data in his suggested color-difference formula, which was modified later by MacAdam, and then by Chickering. The FMC-2 Scale is a color difference scale only and was designed for Illuminant C and 2° standard observer conditions only. It has been successfully used for non-saturated colors under illuminants D65 and A as well as 10° standard observer conditions.

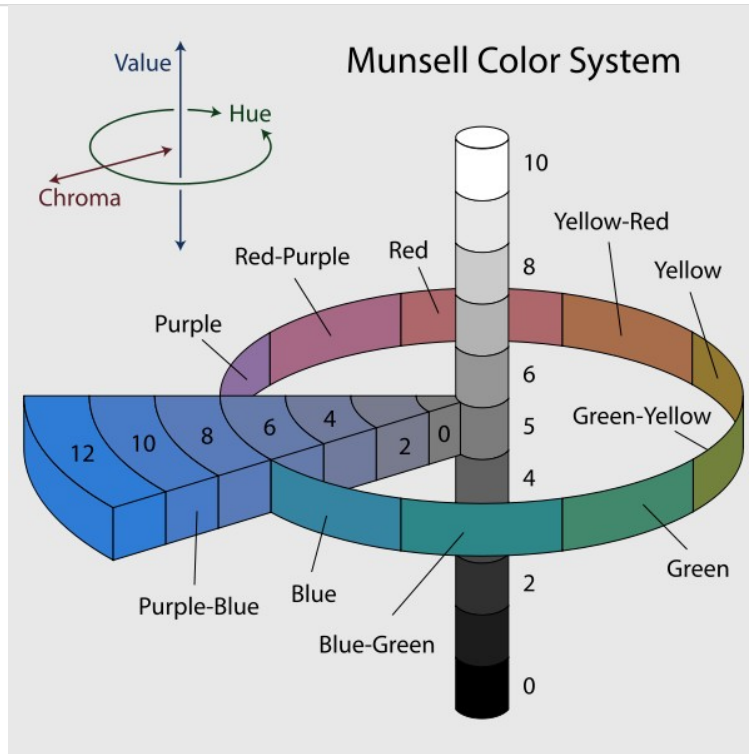
Red-green (DRG FMCII) differences, yellow-blue (dYB FMCII) differences, total lightness differences (dL), and total color differences (dE FMCII) between standard and sample are computed according to the Friele-MacAdam-Chickering metric (*JOSA*, February 1968, p. 292 and August 1969, p. 986).

FMC-II Color Difference attributes

DLf	The delta value for lightness in FMC-II color space.
DRGf	The delta value for the red/green value in FMC-II color space.
DYBf	The delta value for the yellow/blue value in FMC-II color space.
Def	The delta E value for the FMC-II color space.

Color Notations

Munsell



In colormetry, the **Munsell color system** is a color space that specifies colors based on three color dimensions: hue, value (lightness), and chroma. (color purity). It was created by Professor Albert H. Munsell in the first decade of the 20th century and adopted by the USDA as the official color system for soil research in the 1930s.

Munsell HVC Notation

This will display the Munsell Hue Value Chroma notation for the sample.

sRGB Color Notation

sRGB is a standard RGB color space created cooperatively by HP and Microsoft in 1996 for use on monitors, printers, and the Internet. sRGB uses the ITU-R BT.709 primaries, the same as are used in studio monitors and HDTV, ^[1] and a transfer function (gamma curve) typical of CRTs. This specification allowed sRGB to be directly displayed on typical CRT monitors of the time, a factor which greatly aided its acceptance.

sR, sG, sB

These attributes allow you to display RGB values as given in sRGB color space.