Coloring of Plastics
Color Education

Presented by: The Color and Appearance Division

Education Committee

Originally Created July 2007

Last Modification Dec 2020

Color Education

Purpose and Scope

This Color Education presentation provides fundamental concepts of color and appearance for use by anyone educating students, professionals, and organizations.

The scope of the presentation covers colorimetry with definitions and images selected by the Education Committee members of the Society of Plastics Engineers (SPE) – Color and Appearance Division (CAD) Board of Directors that best represents the theory and practice used in today's coloring of plastics industry.

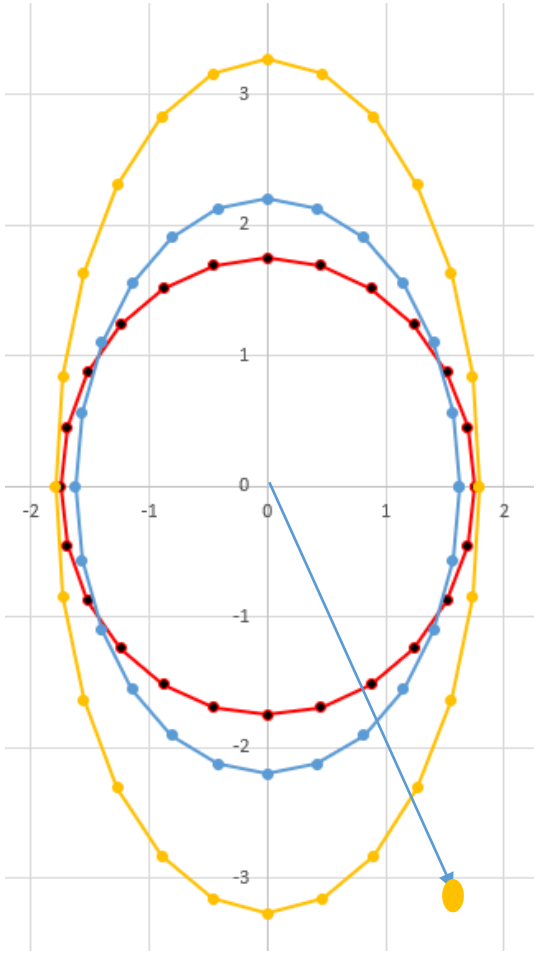
Color Education

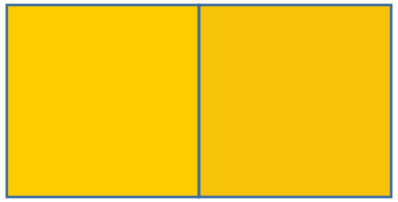
Sections I – VI

I. Color Science
II. Color and Appearance
III. Color Measurement and Test Methods
IV. Colorants
V. Plastics (Polymers)
VI. Definitions

Section III – Color Measurement and Test Methods

Color Measurement - *why*





STD Sample

What are the color values of my product?
communicate color

Is my product in-spec?
specifications or tolerance

What are the color differences?
adjustments

Does my product meet performance criteria?
suitability

Color Measurement - *who*

- Quality Control Laboratories
- Production Line Inspections
- Research and Development
- Analytical labs
- Designers
- Incoming raw material inspectors

- Certificate of analysis, COAs
  Statistical Process Control
- Next stage assembly process
  In-process quality control
- Product innovation, process repeatability
  Patents, counter-offers, performance
- Identification
  Spectral response
- Brand Owners
  Trademark color space, styling
- Approving raw materials

Colored Plastic Object - *what*

- Test methods can vary between plastics, coatings and inks

Color Measurement - *how*

Color Computer / Color Spectrophotometer

Table-top diffuse sphere , hand-held spectrometers

FIGURE 4 » d:8° geometry SPIN.

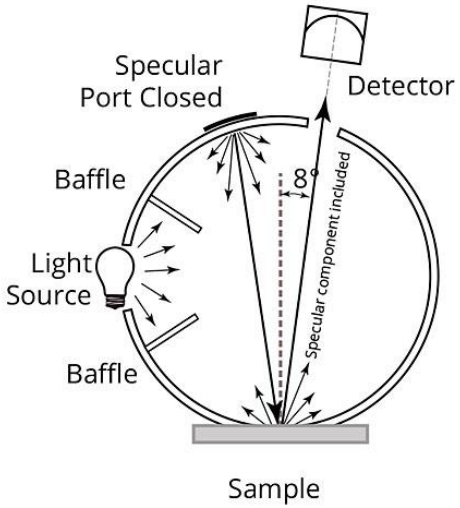
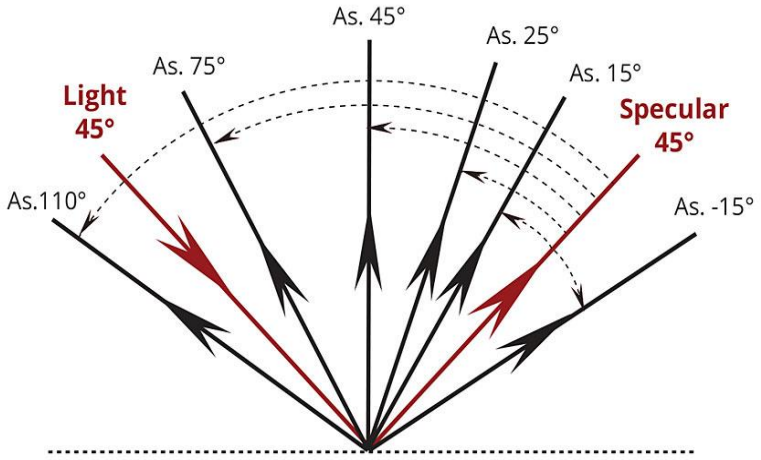


FIGURE 6 » 6 angle geometry.



Color Measurement - *considerations*

Method

- Proprietary (Internal)
- International (ISO, ASTM, DIN)
- Purpose
- Equipment
- Validity
  - Reference standard
  - Stored standard
  - Spectral data
- Output
  - Record retention
  - Traceability
  - SPC
  - Color coordinates CIELab
  - Adjusted Strength values

Sample

- Sample preparation
- Surface size and shape (area view)
- Concentrate, heat history, stabilized
- Coloration Level
  - Masstone
  - Tint
- Resin Type
  - Transparency - background
- Frequency
  - Specification: tested on every lot
  - Typical: Tested occasionally
- Pigment type

Colorimetric Methods

ASTM - formerly known as American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services.

ISO - International Organization for Standardization is an international standard-setting body composed of representatives from various national standards organizations.

DIN - German Institute for Standardization, national organization for standardization and is the German ISO member body

International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

Division 1: Vision and Colour
Division 2: Physical Measurement of Light and Radiation
Division 3: Interior Environment and Lighting Design
Division 4: Transportation and Exterior Applications
Division 6: Photobiology and Photochemistry
Division 8: Image Technology

http://www.cie.co.at/

Spectrophotometers and Colorimeters

ASTM E1348-15e1

Standard Test Method for Transmittance and Color by Spectrophotometry Using Hemispherical Geometry

This method describes steps to use spectrophotometers or colorimeters, hemispherical or bidirectional optical geometry, to measure transparent and translucent material. It is not intended for fluorescent materials

ASTM E1349-06 (2013)

Standard Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional (45°:0° or 0°:45°) Geometry

Provides instructions for spectrophotometers with bidirectional (45°:0° or 0°:45°) geometry

Operating Procedures and Calculations

ASTM E1164-12e1

Standard Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation

This method provides procedures for establishing operating conditions for spectrometers. It includes guidelines for instrument calibration

ASTM D2244-16

Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

This method explains the calculation of color differences and tolerances for specimens with small color differences in opaque specimens that are non-metameric.

Colorimetric Method Accuracy

ASTM E1345-98 (2014)

Standard Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements

ASTM E2480-12

Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method with Multi-Valued Measurands

precision of color measurement in colorimetric terms; e.g., CIELAB data

ASTM E2867-14

Standard Practice for Estimating Uncertainty of Test Results Derived from Spectrophotometry

protocol used to obtain the uncertainty of color measurement data

Coloration Levels

Masstone – dark coloration, maximum absorption saturation

Standard Depth – mid-tone level

The International Standard Depth is an arbitrarily chosen depth of shade for all hues

Constant TiO_2 content, pigment levels are adjusted

Colorants with high tinting strength require less loadings

Used to illustrate the relative color strength and performance of different pigment types.

Tint – white reduction, lower saturation, pastel

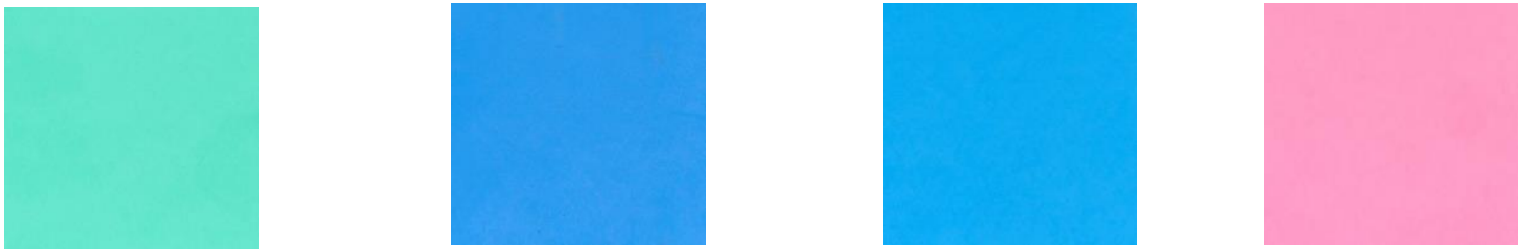
Used for shade and strength assessment

Used in performance testing

Masstone Level
0.50% pigment

1/3 Depth Levels (1% TiO_2)

Tint 0.1%p 1.9%W



PG7 PB15:1 PB15:3 PV19

Masstone 0.5%	L*	a*	b*	C*	h°
PG7	**27.55**	-9.04	-2.39	9.35	194.79
PB15:1	**26.41**	6.65	-15.97	17.3	292.62
PB15:3	**27.38**	10.67	-23.5	25.81	294.42
PV19	**43.04**	47.87	21.06	52.3	23.75
1/3 Depth	**L***	a*	b*	C*	h°
PG7	**60.83**	-47.59	2.1	47.64	177.47
PB15:1	**56.69**	-13.35	-40.54	42.68	251.78
PB15:3	**58.69**	-20.97	-39	44.28	241.74
PV19	**55.65**	53.29	0.21	53.3	0.22
0.1%P / 1.9% w	**L***	a*	b*	C*	h°
PG7	**77.84**	-35.5	-0.27	35.5	180.44
PB15:1	**64.43**	-15.27	-35.46	38.61	246.69
PB15:3	**66.83**	-23.07	-33.71	40.85	235.62
PV19	**70.45**	40.68	-6.01	41.12	351.59

Standard Depth Strength

DIN 53235 Testing of Pigments

Part 1 – Tests on specimens having standard Depth of Shade

Part 2 – Adjustment of Specimens to standard depth of shade

Procedure explains how to calculate the 1/3, 1/9, 1/25 and 1/200 standard color depths

ISO 787-16

General methods of test for pigments and extenders — Part 16: Determination of relative tinting strength (or equivalent coloring value) and colour on reduction of coloured pigments — Visual comparison method

ISO 784-24

General methods of test for pigments and extenders -- Part 24: Determination of relative tinting strength of coloured pigments and relative scattering power of white pigments -- Photometric method

Tint Strength

DIN 55603

Testing of pigments; determination of relative tinting strength and of colour difference on reduction of inorganic pigments using the lightness method

DIN 55978

Testing of dyestuffs; determination of the relative tinting strength in solutions; spectrophotometric method

DIN 55986

Testing of pigments; determination of relative tinting strength and colour difference after colour reduction; colorimetric method

Establishing Visual Assessments

ASTM E1499-16

Standard Guide for Selection, Evaluation, and Training of Observers

ASTM E1808-96 (2015)

Standard Guide for Designing and Conducting Visual Experiments

Guide that can be used to identify techniques that will contribute to visual observations that can be correlated with objective instrumental measurements of appearance attributes of material. It provides guidelines to identify viewing conditions and analysis to achieve reliable visual data.

Visual Assessment Methods

ASTM D1729-16

Standard Practice Visual Appraisal of Colors and Color Differences of Diffusely-Illuminated Opaque Materials

ASTM D2616-12

Standard Test Method for Evaluation of Visual Color Difference With a Gray Scale

ASTM D4449-15

Standard Test Method for Visual Evaluation of Gloss Differences Between Surfaces of Similar Appearance

Techniques for the training of selected observers are outlined along with precautions for them and the experiments involved. It also identifies several color vision tests such as Farnsworth-Munsell Hue 100 Test and HVC Color Vision Skill Test.

Visual Assessment Methods

ASTM E1478-97(2015)

Standard Practice for Visual Color Evaluation of Transparent Sheet Materials

ASTM D4086-92a(2012)

Standard Practice for Visual Evaluation of Metamerism

Commonly Reported Colorimetric Data

CIELAB Color Space

L*, a*, b* , C, h	(absolute values)
DL*, Da*, Db*	(delta values, cartesian coordinates)
DL*, DC*, DH_{ab}*	(delta values, polar coordinates)
DE*	(total delta)
$DE_{CMC\ (l:c)}$, DE'_{2000}	(color tolerance)

Illuminant and Observer: D65, 10^{o} Observer Function

Measurement geometry (equipment model or type)

- Hemispherical/Diffuse Sphere; such as, D:8^{o}
- Bi-directional; such as, $45^{o}/0^{o}$

YI, WI, Opacity and Metamerism

ASTM E313-15e1

Standard Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates

The method is intended for use with specimens made of the same material and same general appearance. It defines when Yellowness (YI) and Whiteness (WI) are suitable parameters to describe general appearance of specimens. It does not explain how to prepare exhibits.

ASTM D2805-11

Standard Test Method for Hiding Power of Paints by Reflectometry

The method provides an instrumental method to measure opacity

ASTM D5382

Standard Guide to Evaluation of Optical Properties of Powder Coatings

The method identifies various practices and test methods for the evaluation of color, color difference, gloss, and metamerism by both visual and by instrumental means.

Instrumental Methods for Gloss

ASTM D523

Standard Test Method for Specular Gloss

ASTM D3134-15

Standard Practice for Establishing Color and Gloss Tolerances

ISO 2813:2014

Paints and varnishes -- Determination of gloss value at 20 degrees, 60 degrees and 85 degrees

Multiangle Color Measurement

for gonio apparent materials

ASTM E2175-01 (2013)

Standard Practice for Specifying the Geometry of Multiangle Spectrometers

ASTM E2194-14

Standard Test Method for Multiangle Color Measurement of Metal Flake Pigmented Materials

Physical Performance Testing

- Heat Buildup/Total Solar Reflectance (TSR)
- Light fastness
- Weatherability
- Heat stability (thermal stability)
- Migration
- Chemical resistance
- Warpage, distortion, shrinkage
- Filter Pressure Value

Heat Buildup/Total Solar Reflectance (TSR)

ASTM D4803

Standard Test Method for Predicting Heat Buildup in PVC Building Products

ASTM D7990-15

Standard Test Method Using Reflectance Spectra to Produce an Index of Temperature Rise in Polymeric Siding

ASTM E903

Standard Test Method for Solar Absorbance, Reflectance, and Transmittance of Materials Using Integrating Spheres

ASTM C1549

Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer

Weather and Light Fastness

ISO 105-B01:2014

Textiles — Tests for colour fastness

Part B01 Colour fastness to light: Daylight

(assessed on the wool blue scale DIN EN ISO 105-B 01)

ISO 4892-2:2013

Plastics — Methods of exposure to laboratory light sources

Part 2: Xenon-arc lamps (in the presence of moisture)

(assessed on the gray scale DIN EN 20105-A02)

Heat Stability (thermal stability)

DIN 12877-1

Colouring materials in plastics - Determination of colour stability to heat during processing of colouring materials in plastics

Color Migration

DIN 53775-3

Testing of colorants in plastics; testing of colorants in plasticized polyvinyl chloride (PVC-P); determination of bleeding of colorants

Warp, Shrinkage, Distortion

ASTM D955 – 08 (2014)

Standard Test Method of Measuring Shrinkage from Mold Dimensions of Thermoplastics

Analytical Test – *special mention*

- Ash (inorganics)
- Conductivity
- Density
  - True DIN EN ISO 787-10
  - Specific gravity
  - Bulk DIN ISO 171
- Moisture Content
- pH
- Particle size
  - Pigment
  - Pellet
- NIAS
  - Solubles
  - Heavy Metals
- Spectroscopy
  - FTIR
  - UV-vis
  - X-Ray
- Volatiles

Heavy Metals and NIAS

(non-intentionally added substances)

- Toxicological assessments and regulatory compliance statements.
- Not typically reported on individual lots of general use or industrial-grade pigments.
- Vary by material (pigments, additives, extenders)

- Heavy Metals
  - Lead (Pb)
  - Arsenic (As)
  - Mercury (Hg)
  - Cadmium (Cd)
  - Chrome (Cr)
- NIAS
  - Primary Aromatic Amines (PAA)
  - Aromatic Amine Sulfonic Acid (AASA)
  - Chlorinated Benzenes (HCB, PCB)

pH (hydronium ion concentration)

- Colorant pH may be checked by dispersing the pigment into DI water then checking the pH of the filtrate.
- Polymers such a cPVC or POM may be affected by pH that is not in a desired range

Moisture Content

- Many pigments are recovered from water slurries by filtering and then drying.
- Typical residual moisture contents may be >1% for organic pigments
- Moisture is measured when the pigment is packaged and may not reflect actual moisture content, especially for hydrophilic pigments.
- Some pigments have a water of hydration associated with them, and an aggressive test for drying may find between 2 and 3% moisture. This moisture serves a purpose however, and over-drying to remove the water of hydration may ruin desirable properties of the pigment.
- Different manufacturers may treat moisture as a lot to lot reportable variable or may only occasionally check moisture content.
- Moisture can interfere with polymer clarity, appearance, and stability.

Particle Size Measurement

- **Visual/Light Microscopy**
  - Visual assessments, larger than 25um in different light sources
  - Light Microscopy with colorants larger than 0.5 um use oil immersion
- **Dynamic Light Scattering**
  - Photo correlation spectroscopy is a non-invasive process, submicron size
- **Laser Diffraction**
  - Standard method for correlation and characterization of particles
  - Particles are passed through a laser beam and scatter a light proportional to particle size
- **Image Analysis (TEM, SEM)**
  - Characterizes the individual shape and size of the particles
  - High resolution characterization, size range nano - micron
- **Acoustic Spectroscopy**
  - Ultrasound waves, particles suspended in a solution

End Section III – Color Measurement and Test Methods

Return to Index

Disclaimer

The information in this presentation is furnished in good faith based on current technology, experience and knowledge thought to be true. The Color and Appearance Division (CAD) of the Society of Plastics Engineers (SPE) makes no warranty or assumes no responsibility of any kind, expressed or implied, regarding this information. CAD and/or the SPE does not assume any responsibility for any subsequent processing or compounding of any resources or materials in order to produce compound(s) or any finished article(s). Nor does CAD or SPE imply this information may suggest any legally binding assurance of certain properties or suitability for any specific purpose. It is the responsibility of those using this information to ensure their actions complies with any proprietary rights and/or existing laws or legislation.

Credits

Past Chairs/Contributors

Robert Charvat, Colorants – Pigments and Dyes

Steve Goldstein, Inorganic - Organic Pigment Particles

Jack Ladson, Color Science Consultancy

Betty Puckerin, Ampacet Corporation

Education Committee

- Earl Balthazar, Datacolor
- Breeze Briggs, BASF Colors and Effects
- Steve Esker, Paramount
- Jack Ladson, Color Science Consultancy
- Bruce Mulholland, Celanese
- Alex Prosapio, Sudarshan
- Betty Puckerin, Ampacet Corporation
- Elizabeth Serdar, Omya
- Mark Tyler, Silberline
- Brian West, Techmer PM
- Kimberly Williamson, Techmer PM
- Michael Willis, Sun Chemical, ***Education Committee Chair***