Foster Corporation

Introduction to Coloring of Plastics

August 2020

About Foster Corporation

- Founded in 1989 by CEO Larry Acquarulo
- Specializing in custom formulated compounds for medical device manufacturing and other specialty industries
- Established polymer distribution business in 2005
- Began drug & implant compounding in 2006
- Customers in 42 states and 27 countries
- ~130 employees between four facilities

Putnam, CT

Las Vegas, NV

Introduction to Coloring of Plastics

Color Basics

1. Perception of Color
2. Colorants (Organic, Inorganic, Dyes)
3. Color Options (concentrate or compound)
4. Color Development
    - A. Resin Type
    - B. Match Considerations (end use, fillers, dispersion)

Color Measurement / QC

1. Visual
2. Instrumental
    - A. CIE Las
    - B. CMC

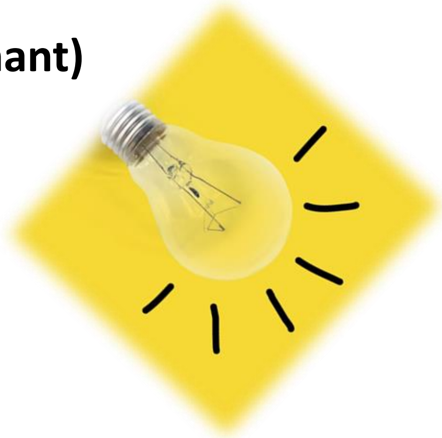
Color Match Formulation

1. What Does Lab Need?

Perception of Color

3. Observer (processor)

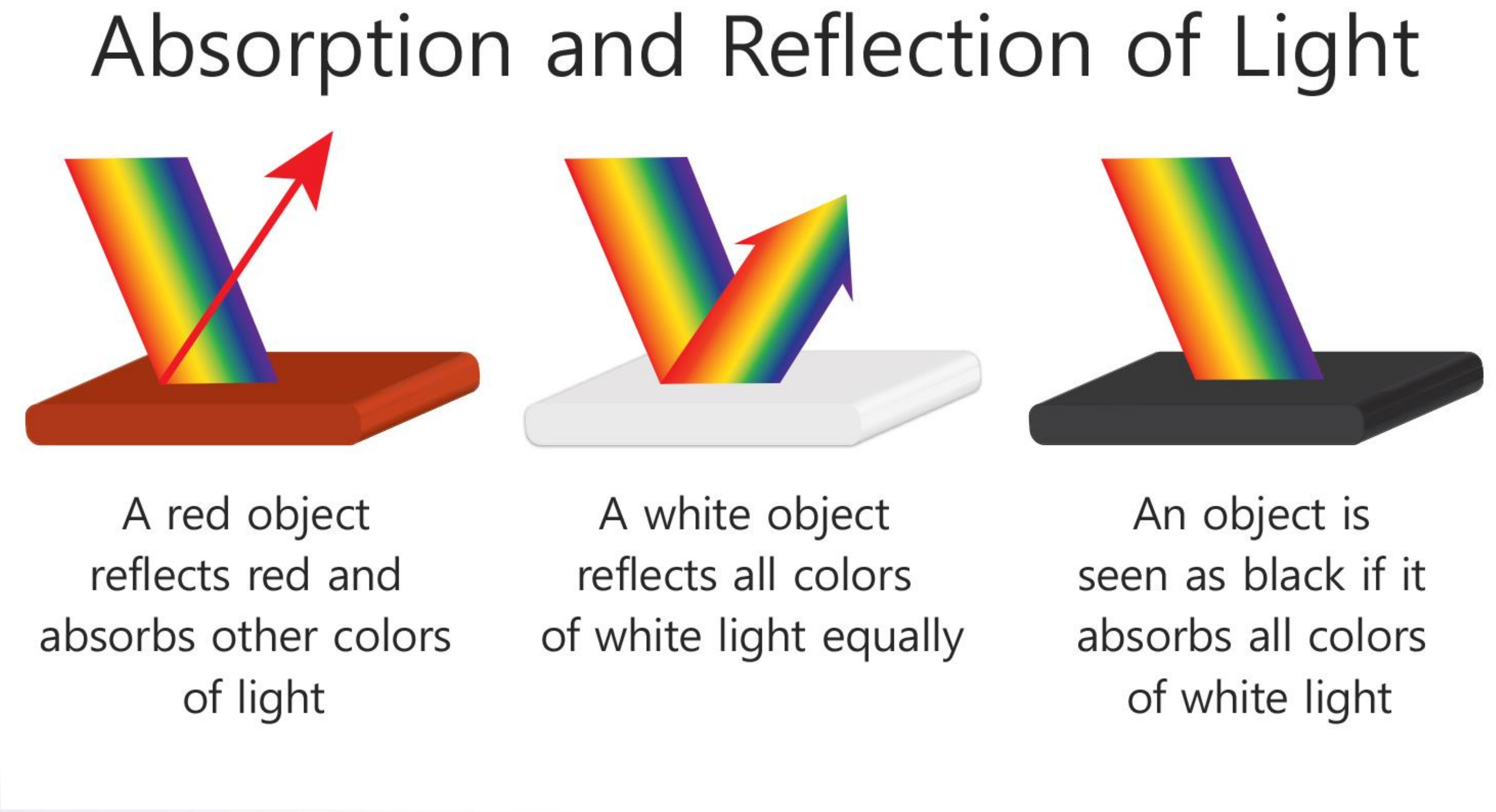
1. Light source (illuminant)



2. Object (sample)

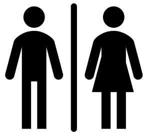
Three things must be present to see color

What Determines the Color We See?

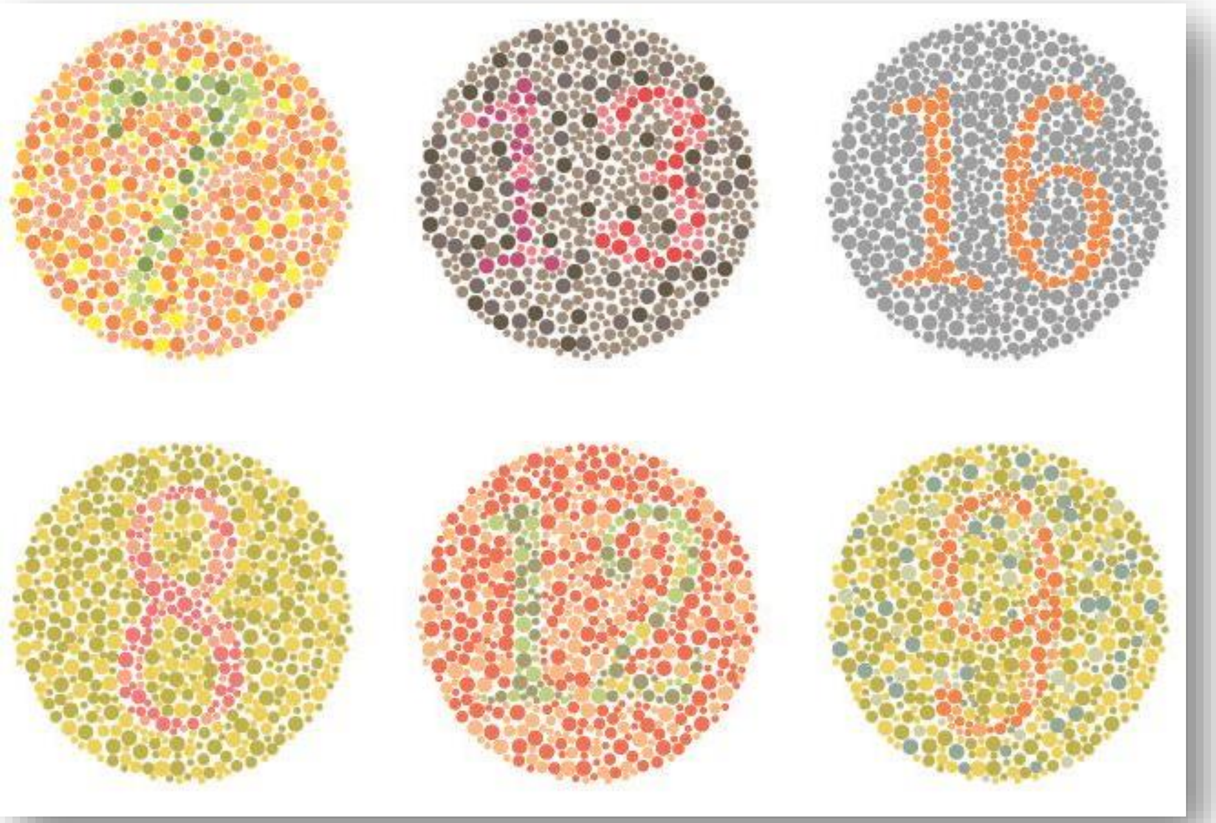


Color Blindness/ Color Deficiency

Cones in the eye are responsible for color determination



8% males
1% females



Are You Color Blind??

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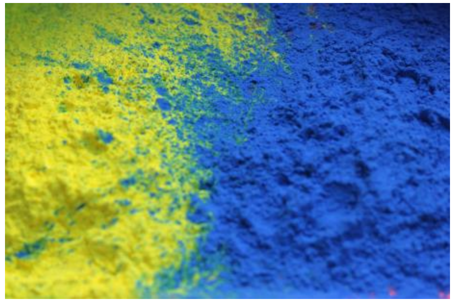
Primary Colorant Types used in Plastics



Pigments

A. Inorganic Pigments: Insoluble, associated with mineral or metal salts utilizing Iron, Cobalt, Zinc, Titanium, etc., also encompassing the use of regulated heavy- metal based pigments, such as Cadmium and Lead based. Good opacity and lightfastness.

B. Organic Pigments: Insoluble, synthetic molecules or metal complexes. High color strength. Dispersion concerns. Wide range of properties. Certain organic pigments can affect shrinkage and warpage may occur.

Dyes

Soluble in resin system. Specific resin compatibility. Excellent transparency.

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Special Effect Pigments

Laser Mark Print : Foster Lazermed™ offerings

Laser Welding: IR transparent

Solar Reflective: heat reduction

Fluorescent: Bright "Dayglo", limitations on FDA for HDPE only.

Optical Brighteners: Fluorescent whitening agents mostly used into whites.

Phosphorescent (Glow-in-the-Dark): requires high loadings. High shear can harm pigment particles. Can cause excessive screw and barrel wear in extruders.

Thermochromic (thermal change)/Photothermic (light exposure change): limited color options, expensive, made to order, difficult to sample.

Granite(stone)/Swirl/Wood grain: Certain effects require two component system.

Translucent/Frost/Light Diffusion/Light filter: increased interest due to LED light cover applications.

Pearlescent/Metallic/Glitter: flat platelet shapes provide reflective properties. Inherent low opacity can force higher loadings which may affect physical properties and limit use in concentrate options. Smaller particle sizes can cause more noticeable knit/flow lines.

Color Basics: Coloring Options

Pre-Colored Compounds

Advantages:

Uniform and consistent color. Can accommodate higher loadings of fillers such as radiopacifiers Barium Sulfate, Bismuth Subcarbonate, etc. Also can incorporate glass fibers/beads, talc and other modifiers.

Disadvantages:

Inventory concerns, warehouse space considerations and consumption of remaining compound.

Larger quantities require longer run time in manufacturing

Color Concentrates(Masterbatch)

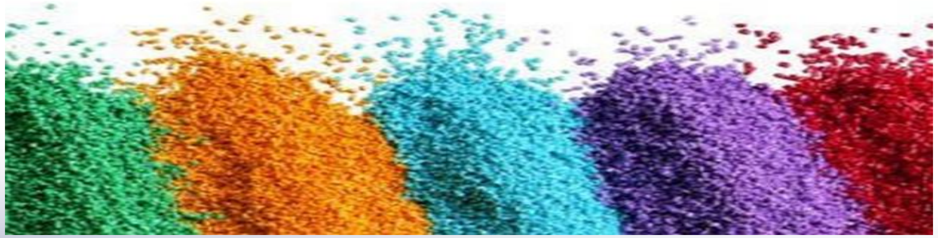
Advantages:

Cost advantages to customer. Inventory rationalization of letdown resin for multiple colors. Reduced shipping costs, quicker changeovers. May be possible to use single universal color concentrate into different end use resins or products.

Disadvantages:

Requires accurate and adequate mixing to ensure proper and uniform color distribution within a part.

Often steps required to improve mix can affect cycle times or cause increased degradation



Understanding Color Concentrate

Resin System using Proper Carrier Systems

"Let-Down" Resin:

This is the resin that will be used by the customer to produce the final product.

Carrier Resin:

This is the resin that will be used to make the color concentrate. The preference is to use a softer resin or one with the same or higher melt flow properties. This will allow a faster incorporation into the letdown resin

Let-Down Ratio (Percentage):

The ratio of "Let-Down" resin to Color Concentrate. Common ratios are 25:1("4%"), 50:1("2%"), 100:1 ("1%").

Example; 25:1 (25 parts customer letdown resin, 1-part color concentrate)

(Often use of concentrate determined as percentage.)

Resin Systems

- **Olefins –** Can accept higher pigment loadings depending on pigment type.
- **Styrenics –** Ability to use solvent dye formulations. ABS and HIPS have some inherent opacity and can affect surface gloss. Crystal PS and SAN have good clarity.
- **Polycarbonate –** Normally good clarity, solvent dyes accepted. Conventional TiO2 and pearls can decrease strength. Requires higher heat stable colorants.
- **Polyamide –** Careful selection of colorants with proper heat stability and compatibility. Glass and other fillers complicates coloring. Coloring options can vary greatly between different types of nylon.
- **Polyester –** PET, PETG, PCTG. Good clarity, FDA dyes available for PET only.
- **Elastomers, PEBAX,TPO,TPU –** Proper selection of carrier resin required for proper mix if using concentrates.
- **Fluoropolymers –** FEP, PVDF, ETFE, limited pigment compatibility.
- **High Temperature –** PEEK, PPS, PSU,PSF. Require high performance colorants.
- **Acetal –** limitations on high loadings and compatibility concerns.

Challenges Presented by Use of Medical Grade Fillers

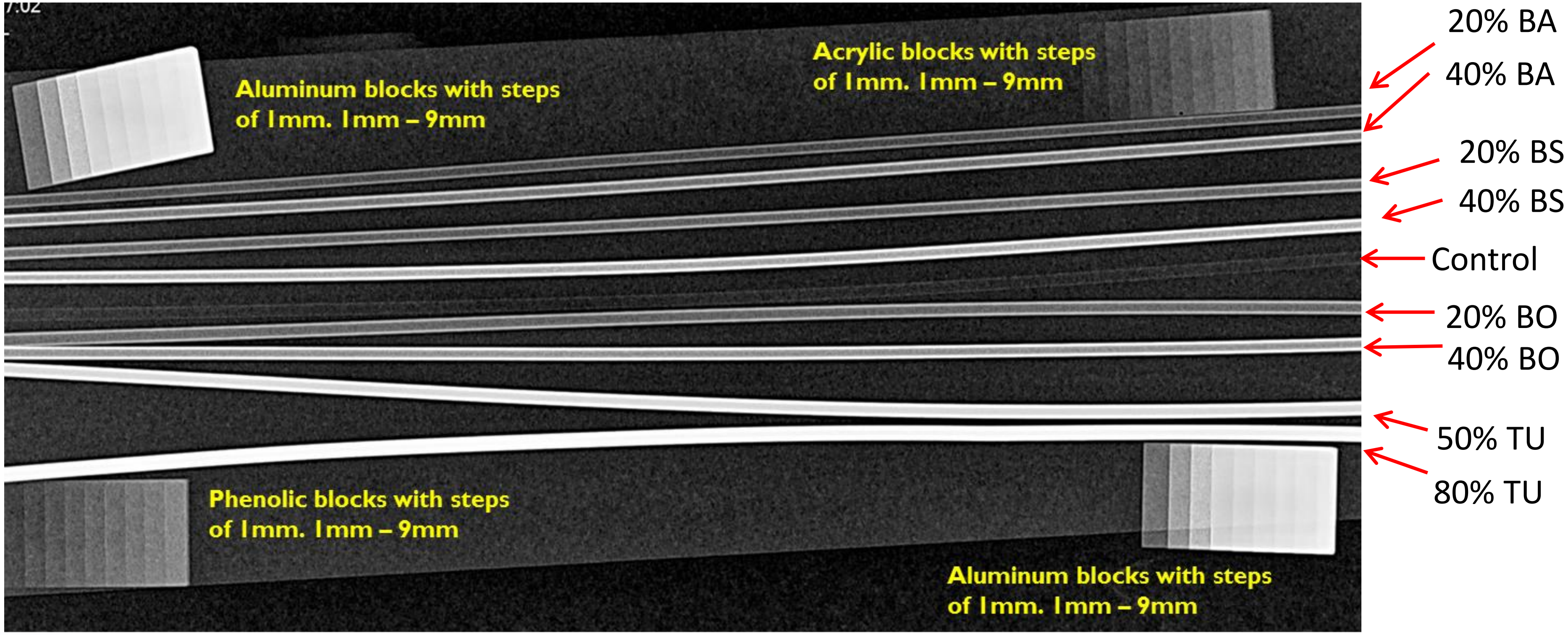
Common Radiopaque Fillers

Barium Sulfate
Bismuth Subcarbonate
Bismuth Trioxide
Bismuth Oxychloride
Tungsten

X-ray Comparison of Fillers

The degree of opacity is an important factor in achieving desired color match

Pebax® 7233



This slide shows the added opacity due to filler type and concentration

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Factors Involving Medical End Use Applications

- Limited number of pigments approved for specific medical applications as listed in Food and Drug Administration Title 21, Code of Federal Regulations parts 73 and 74 Subpart D. accepted)
- Foster's MediBatch line have been tested for biocompatibility to maximize the probability of FDA qualification.
- Radiopaque fillers often requested. Higher loadings require an increased pigment loading which could cause dispersion issues.

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Pigment Selection-End Use Requirements

Medical versus FDA Food grade Formulation: Same Orange Color Target

Medical grade pigments Formulation:
Could not achieve desired color target

*Limited number of colorants acceptable for medical use

FDA Food Grade pigments Formulation:
Better color match

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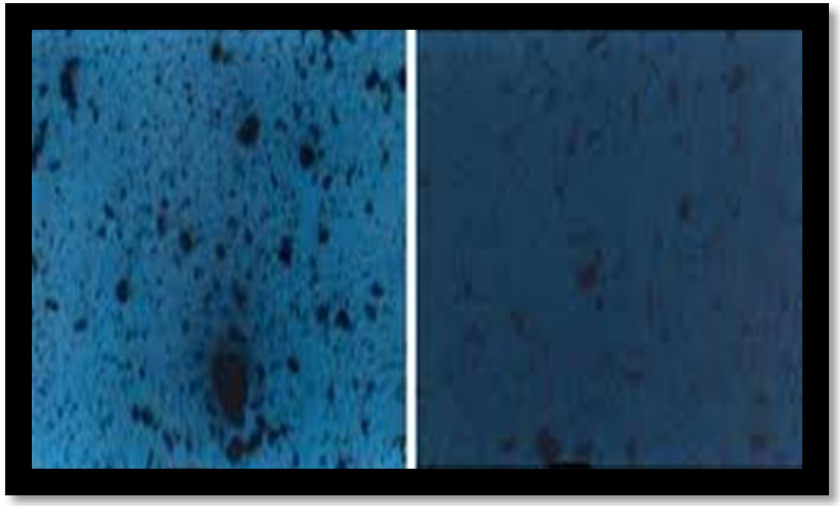
Dispersion

The combination of optimized processing conditions, proper pigment selection, and potential dispersing agent can help achieve good dispersion



Results of Poor Dispersion

- Color inconsistency, loss in color strength, batch-to-batch shade differences.
- Detrimental effects to the physical and mechanical properties of the final product such as loss of electrical properties in wire and cable applications.
- Negative processing effects can cause filter blockage, breaking of the fiber or undesired splitting of blown films.

Mixing

Distributive

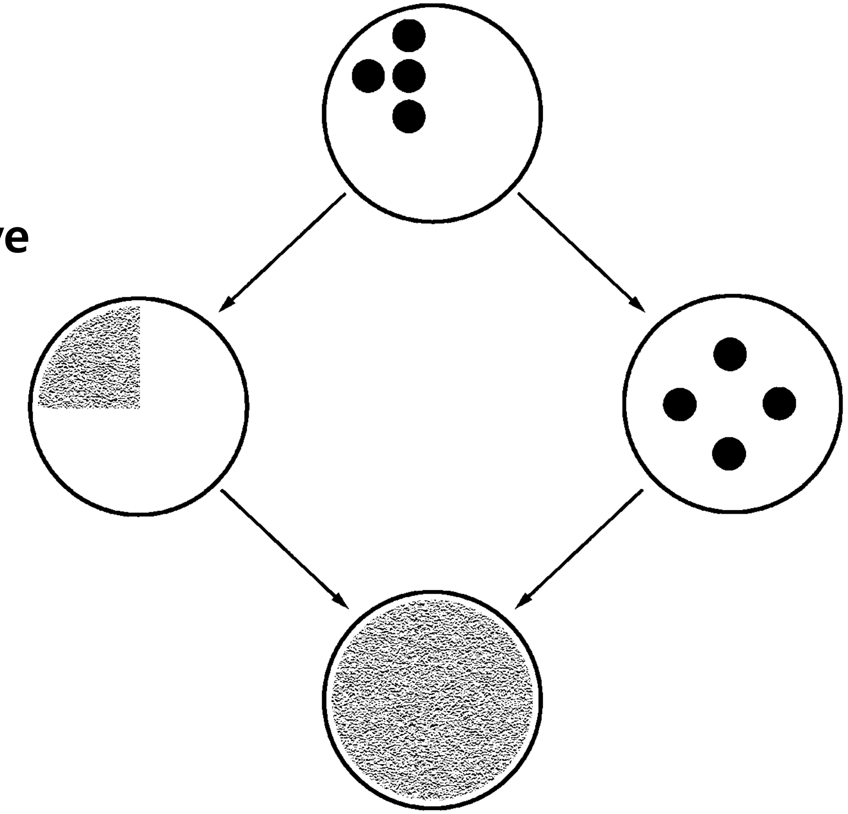
- Uniformly distributes ingredients without using high shear stress.
- Example of poor distributive mixing noticed at time when color concentrate used at low percentage into filled compounds.

Dispersive

- Intensive process that utilizes high shear techniques to break up agglomerated solids
- Examples of poor dispersion result in dark specks observed by magnification.

Mixing Differences

Example dispersive mixing



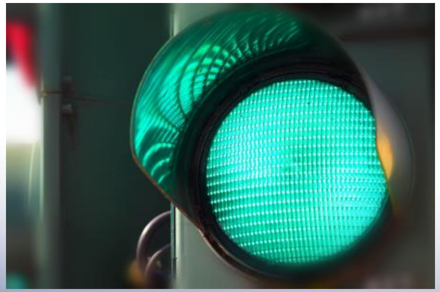
Homogenous compound

Example distributive mixing

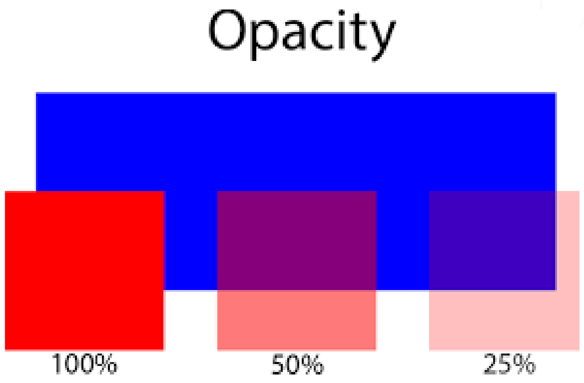
Other End Use Considerations

- Injection Molding (Hot runner system-longer residence time)
- Blow Molding
- Rotational Molding

  (Pulverizing, Dry color)
- Film (Clarity, dispersion-free from agglomerates)
- Extrusion
- Optical (laser eye protection, welding eye protection)



Additional Factors



Opacity:
For **Opaque** colors, the degree of "hiding" or opacity has a direct correlation on the amount of colorant required. The concentration is limited by resin acceptance of high pigment loadings. Matches that require use of organic pigments will have limitations regarding opacity due to dispersion requirements. The earth tones: Tan, Beige, and Brown types often exhibit much better opacity characteristics.
The thickness of the end use application has to be considered in relation to the desired opacity.

For **Transparent** colors, the wall thickness of final application is critical.
The Increased clarity of random copolymer polypropylene has led to development of organic pigments with improve transparency.
Translucent colors may include use of additives to create a frosted or haze effect.
These would allow some light to pass through in varying degrees

Part Thickness Importance

Coloring Considerations

General guidelines that that can apply to the intended color target:

- Highly chromatic colors (such as intense Blues, Greens, Red, Yellow, Orange, etc.) will typically have associated factors that can be anticipated. Often these colors will require the use of more expensive colorants, especially when used in more demanding applications.
- The organic pigments have associated higher costs and may also present dispersion concerns that may limit the attainable letdown ratio. Poor dispersion is noticed as pigment agglomerates that may appear as colored or black specks.
- Matches that involve White, Gray, or Earth Tones such as Tan and Brown can be expected to result in lower cost while exhibiting much better dispersion characteristics

Color Quality Control

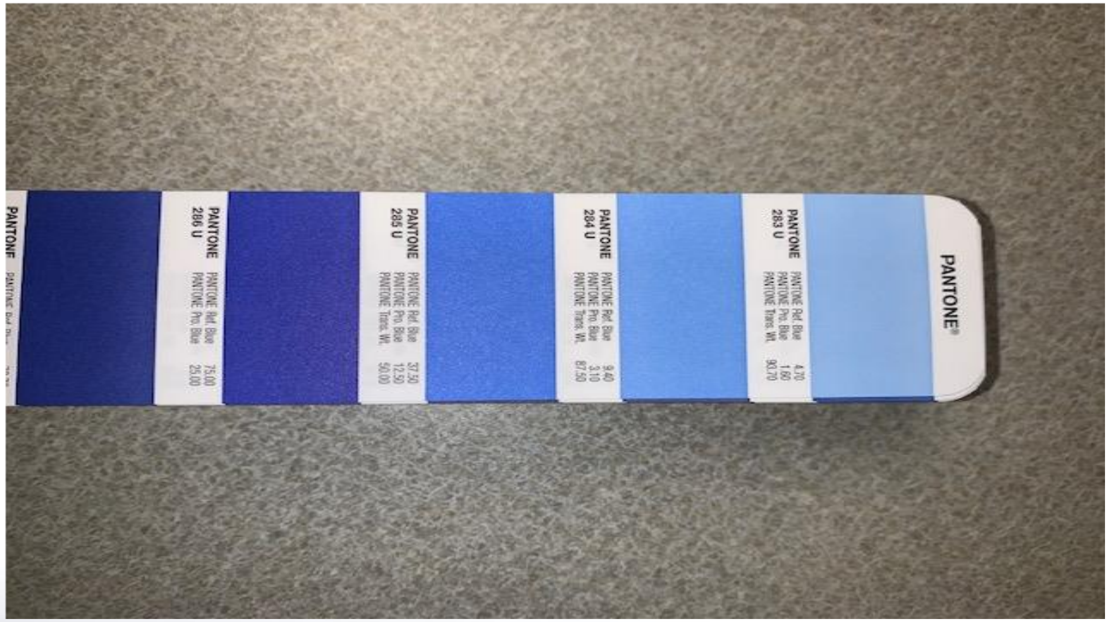
An acceptable color match can be determined using two methods:

1. Visual inspection- This method requires a physical target or standard for comparison. Requires a trained observer and can be subjective. This is also the preferred method for special effect and fluorescent matches.

2. Instrumental-Spectrophotometers enable the establishment of numerical tolerances. The target or standard measurements can be saved in the software. The set-up and measurements conditions must be controlled to ensure equivalent analysis. The two most prominent color equations used today are CIELab and CMC. The desired light source must be identified to ensure proper matching of a target for the intended use. A commonly encountered problem is Metamerism. This is caused by matching a target using different colorant formulations. The result is in an acceptable color match under some light sources, and a mismatch when view under other lighting conditions

Pantone Visual Assessment

- Close Color Match : Customer to provide sample or Pantone
- 1st time run will be less than +/- 1 Pantone
- Normal production inspection will be +/- 1 Pantone



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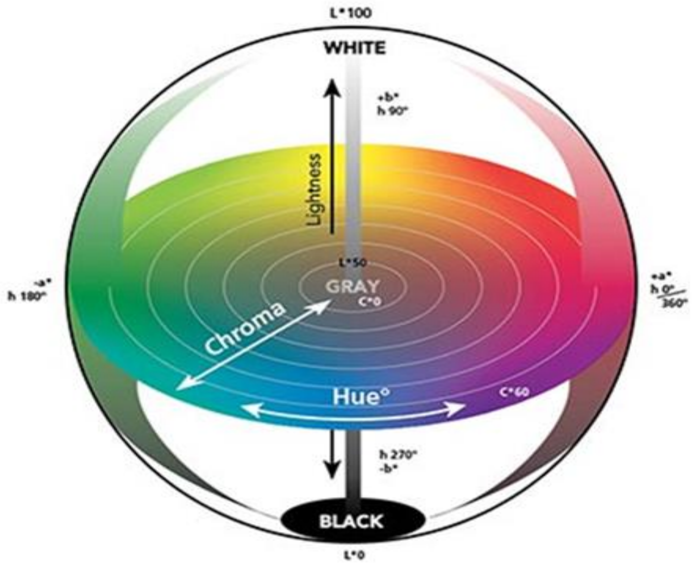
Instrumental Measurement - Spectrophotometer

- Critical Color Match : Customer pre-approval required
- 1st time run will be within Delta E <= 1
- Normal production Inspection will be within Delta E <= 2

Instrumental Evaluation

- Most common color tolerances will be communicated as **DE**. This is a total color **difference,** or the distance between two colors.
- A common industry commercial tolerance would be 1.0 units CIELab. A critical color match might be at 0.5 DE max. A non-critical match might be established at 1.5 DE.
- The CMC method is more effective at agreement with visual assessment. This method has become more widespread.

- **ΔL*** = difference in +lightness/-darkness
- **Δa*** = difference on +red/-green axis
- **Δb*** = difference on +yellow/-blue axis
- **ΔC*** = difference in chroma (intensity of the color)
- **ΔH*** = difference in hue (dominant color)
- **ΔE*** = total color difference value



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Color Equation

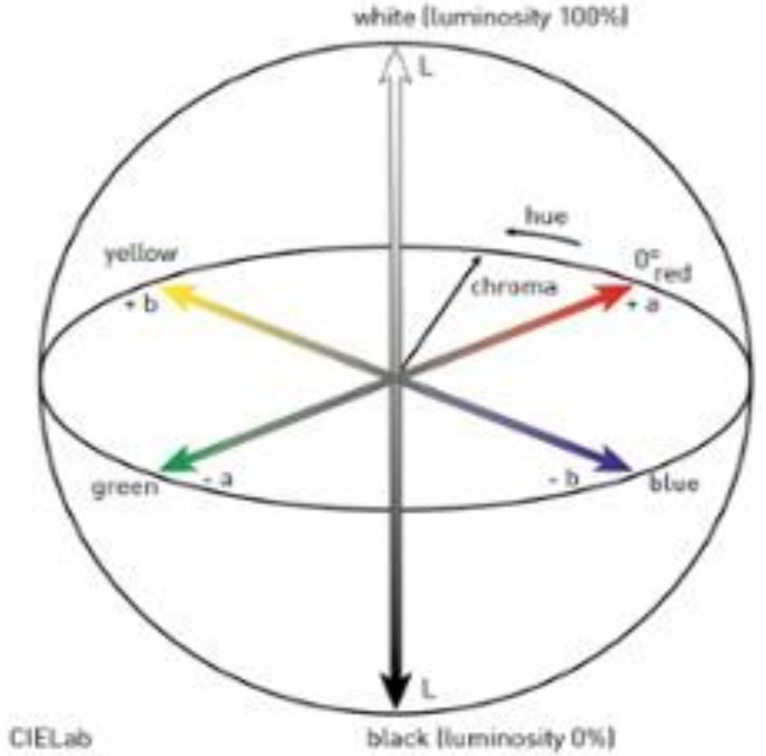
CIE LAB

The L axis represents differences in dark colors versus lighter colors, with absolute white at 100 and absolute black at 0.

The coordinates a and b represent the color axes, with red at positive a and green at negative a; yellow at positive b and blue at negative b.

The intermediate hues are between the major color hues of red, yellow, green and blue.

Δ L* being the lightness difference.
Δ a* being the red/green difference.
Δ b* being the yellow/blue difference.



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DE CMC

The CMC calculation identifies an ellipsoid around the standard color, the volume of the ellipsoid represents an acceptable color variation.

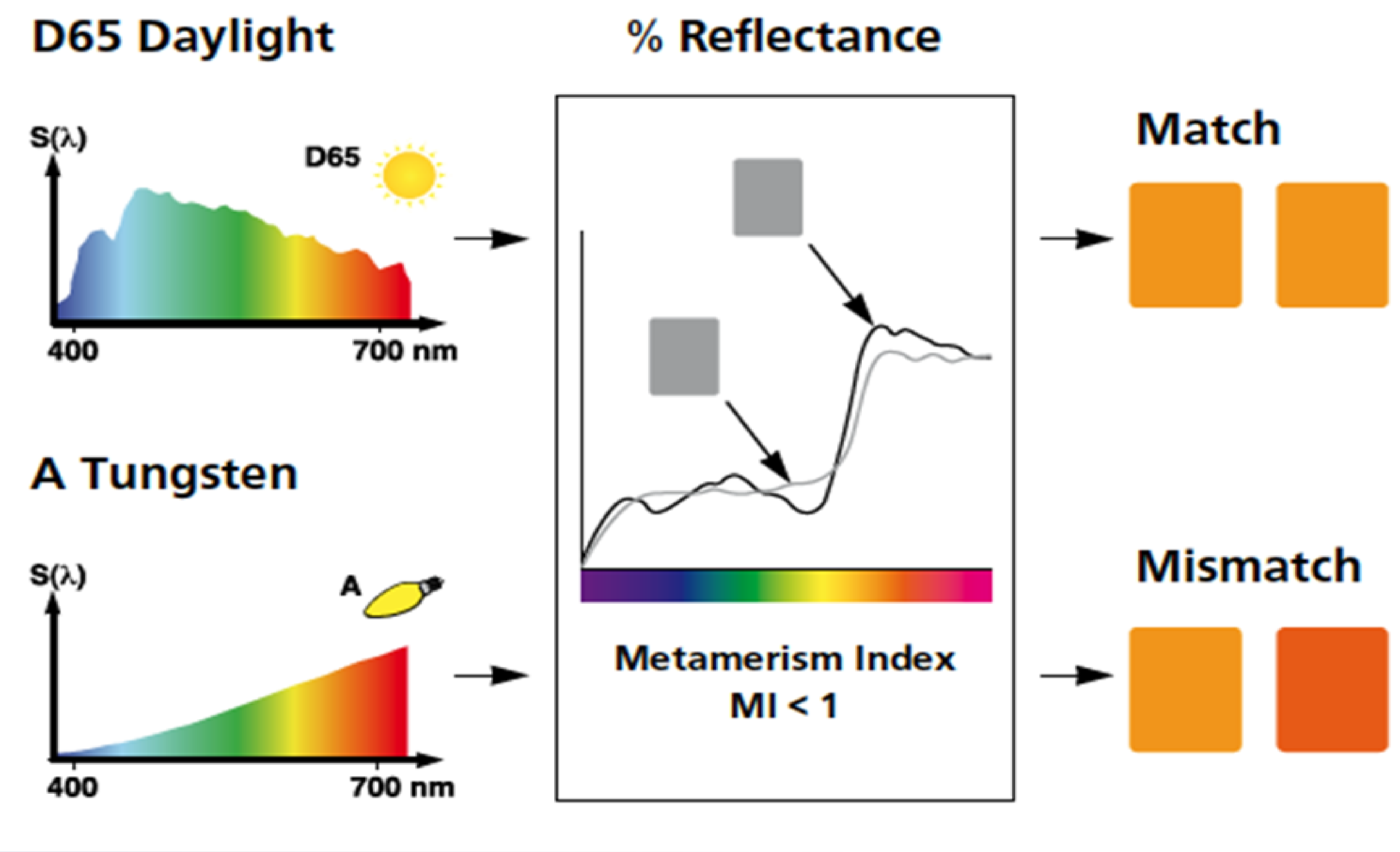
The shape and size of the ellipsoid will automatically change depending on the location in color space.

Colors in the orange area of color space will be more sensitive to changes in hue, this results in narrower ellipsoids, while colors in the green area have larger ellipsoids due to their lower sensitivity to hue.

Also, lightness will decrease hue and chroma tolerances as it increases or decreases from standard.

DE CMC facilitates assignment of same tolerance over a range of colors

Metamerism



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Precolored Compound Match

What Does Lab Need?

1) **Resin Type and Grade:**
   a) In stock
   b) Customer supplied (arrange for resin delivery)
2) **Color Target:**
   a) Customer supplied part/plaque/pellets
   b) Spectral numbers (L a b)
   c) Pantone
   d) Part Thickness: Opaque/Transparent/Translucency
3) **Market/Pigment Regulatory Considerations**
   a) Industrial
   b) FDA 21 CFR 174-178
   c) Medical grade 21 CFR part 73/74, Subpart D
4) **Additives/Fillers**
   a) Radiopaque (type/loading)
   b) Other functional additives
5) **Measurement conditions/Tolerance**
   a) Light source
   b) Visual critical (additional cost)
   c) Concept/Best effort- No charge
   d) Spectrophotometer limit (DE)

Color Concentrate Match

What Does Lab Need?

1) **Resin Type and Grade:**
   a) In stock (Concentrate carrier resin must be considered as well)
   b) Customer supplied letdown resin(arrange for resin delivery)
2) **Color Target:**
   a) Customer supplied part/plaque/pellets
   b) Spectral numbers (L a b)
   c) Pantone
   d) Part Thickness: Opaque/Transparent/Translucency
3) **Letdown Ratio (LDR)**
4) **Market/Pigment Regulatory Considerations**
   a) Industrial
   b) FDA 21 CFR 174-178
   c) Medical grade 21 CFR part 73/74, Subpart D
5) **Additives/Fillers**
   a) Radiopaque (type/loading)
   b) Other functional additives
6) **Measurement conditions/Tolerance**
   a) Light source
   b) Visual critical (additional cost)
   c) Concept/Best effort- No charge
   d) Spectrophotometer limit (DE)

Color Target

Proper target is critical to success of color match

Best options:

1. Physical part from customer
   If actual end use part, this provides both color and part thickness

2. Color plaque or pellets from customer
   This enables match to current supplied material.

L*=43.31
a*=47.63
b*=14.12

3. Spectral numerical readings, L a b.
   Numerical data important where critical DE required.

4. Pantone color number
   Suitable for less critical match.

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Information Resources

https://www.siyavula.com/read/science/grade-8/visible-light/12-visible-light?id=toc-id-5

https://www.mddionline.com/sites/mddionline.com/files/images/martinfig1.gif

https://encrypted-tbn0.gstatic.com/images?q=tbn%3AANd9GcRDpRptKhhO7jHid9SkoZ0fbcBIeOZf--2zlg&usqp=CAU

www.allaboutvision.com/eye-exam/color-blind-test.htm

x-rite.com, X-Rite color blog

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Thank you!

For more information contact us at:
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