



Enhancing Plastics Manufacturing with Spectrophotometric Color Quality Control

Introduction

Color is more than a cosmetic attribute in plastics manufacturing – it is a critical quality indicator. Even slight color deviations can ruin product appeal, result in rejected batches, and erode brand reputation. Unlike other materials where color may be applied later, in plastics the color is often engineered directly into the resin or part. This means color consistency must be managed throughout processing, from raw polymer to finished product. Spectrophotometric color measurement provides precise, objective data far beyond what the human eye can discern. By quantifying color in standard color spaces (such as CIELAB) and metrics (ΔE color difference), manufacturers can detect subtle shifts early and ensure products meet exact color specifications. This white paper examines the role of color measurement in plastics – why it matters for quality and process control, how it's applied across the industry, challenges involved, global standards, and the best-in-class solutions with a focus on HunterLab instruments that enable effective color quality control.

Overview of the Global Plastics Market and Its Applications

The plastics industry is a massive global market, spanning all regions and industrial sectors. Worldwide plastic production has reached the order of 400 million metric tons annually, with a market value well into the hundreds of billions of dollars. Asia is the largest producer and consumer of plastics – as of mid-decade, Asia accounts for over half of global plastics output (China alone contributing roughly one-third). North America and Europe are also major producers, though European market share has been declining amid competitive pressures. Developing regions in Latin America, the



Middle East, and Africa are experiencing growth in plastics use as well, driven by industrialization and population needs.

Plastics are found in nearly every industry. **Packaging** is the single largest end-use segment, accounting for roughly 40% of all plastic usage. Plastic packaging (films, containers, bottles, etc.) is ubiquitous due to its light weight, durability, and cost-effectiveness. Beyond packaging, **building and construction** is another major sector (~15-20% of use) – for example, PVC pipes, insulation foams, and polymer-based building materials are common. The **automotive and transportation** industry relies on plastics (about 8-10% of usage) for interior parts, bumpers, panels, and under-the-hood components to reduce weight and improve fuel efficiency. **Electrical and electronic** products (circuit board materials, casings, wire insulation) account for around 5-10%. **Consumer goods and appliances** (from toys and household items to high-end electronics) use a broad range of plastics for aesthetic and functional parts. **Medical and healthcare** applications (syringes, IV bags, medical device components) also constitute a significant share, as do **textiles** (synthetic fibers like polyester and nylon). In summary, plastics are truly global and multi-industry: from food packaging in Europe, to automotive parts in North America, to consumer electronics in Asia – consistent color quality in plastics is a worldwide concern. Each application demands specific color specifications. For instance, a brand's signature packaging color must look identical across continents, and medical plastics may need to meet strict appearance standards to be deemed safe. This broad market scope underscores the importance of robust color measurement practices across all facets of plastics manufacturing.

The Importance of Color Measurement in Plastics Manufacturing

Color consistency is crucial in plastics manufacturing for both aesthetic and functional reasons. Unlike surface coatings or paints, the color in plastic is often integral to the



material – mixed in as pigments or dyes in the resin. As a result, any variation in color can indicate an underlying issue in material or process, and it directly affects the end product's appearance.

Brand and Customer Expectations: Many consumer products (e.g. beverage bottles, appliance housings, toy parts) have defined brand colors. A slight mismatch in color can be immediately noticeable and undermine consumer trust. Manufacturers risk customer complaints or returns if product color falls outside approved tolerances. Consistent color across production lots is therefore essential to meet customer and brand owner expectations for uniformity.

Quality and Scrap Reduction: Implementing precise color measurement in production helps catch off-color batches early, preventing large-scale waste. For example, if a plastic extrusion line begins drifting in color due to a metering issue, an on-line spectrophotometer can alert operators before hundreds of meters of material are produced off-spec. Timely color checks mean problems can be corrected immediately, not after hours of production. This reduces scrap and rework, directly improving yield and saving material and energy costs.

Process Control: Color data serves as a real-time process control parameter. Deviations in measured color (L^* , a^* , b^* values) often reflect changes in raw material or processing conditions. By monitoring color, operators can adjust processes (e.g. pigment feed rates, temperature settings) to maintain the target color, thereby keeping the process “in control.”

Regulatory Compliance: In certain industries like food packaging, medical devices and automotive, there are strict color and appearance specifications. Color can be tied to safety or identification (for instance, medical grade plastics might have color requirements). Spectrophotometric measurement provides documented evidence that products meet color standards, which can be important for regulatory compliance



and audits. Overall, robust color measurement practices boost manufacturing efficiency and ROI: by reducing waste, avoiding customer rejections, and ensuring smooth production with fewer interruptions, manufacturers can save significantly. Studies have shown that implementing spectrophotometric color QC leads to fewer off-spec batches and less downtime for adjustments, translating into tangible cost savings and higher profitability.

What Color Reveals About Plastics Quality and Process Control

In plastics production, color is often a telltale indicator of material quality and processing conditions. Subtle shifts in color can reveal problems before other quality tests detect them. For instance, an increase in the yellowness of a normally clear polymer usually signals **thermal degradation or oxidation**. PET (polyethylene terephthalate) resin, commonly used for bottles, will gradually become yellow (increase in b^* value) if it's overheated or exposed to moisture during processing. A spectrophotometer picking up a higher b^* or Yellowness Index can alert engineers to drying problems or excessive heat history in the resin, prompting adjustments (such as adding stabilizers or lowering melt temperature) before product quality is compromised. Similarly, a shift in the a^* axis (red-green tint) might indicate **contamination or mixing issues** – for example, an unintended pigment or another plastic contaminant in a batch can impart a slight green or red hue. If a batch of polypropylene shows an unexpected greenish cast, it could be due to trace contamination or incomplete pigment dispersion. By quantifying this color shift, quality control can trace it to a specific feeder or material lot.

Color measurements also correlate with **additive levels and aging**. Many plastics incorporate UV inhibitors, antioxidants, or colorants that affect color. A rising yellowness or darkening over time can measure how a material is aging or how effective stabilizers are. For example, polycarbonate sheets exposed to UV light will



show increasing yellowness; measuring the YI (Yellowness Index) periodically quantifies how much UV exposure has degraded the material. This helps in predicting product lifespan and scheduling maintenance or material replacement.

Haze and Clarity: In transparent or translucent plastics, color metrics combined with haze measurements provide insight into clarity. A spike in haze (%) might indicate the presence of particulate contamination, phase separation, or surface roughness in a polymer. If a normally clear film starts turning cloudy (high haze), it could mean moisture or filler incompatibility, or that the resin has crystallized differently. By measuring total transmittance and haze along with color, manufacturers can distinguish between a color change due to tint vs. a change in optical transparency due to scattering.

Process Variations: Continuous color monitoring in processes like extrusion can serve as an early warning system for equipment issues. For example, if color gradually drifts during a production run (ΔE values creeping upward), it might correspond with a mixing issue (e.g. pigment settling or screw wear in an extruder). A sudden color jump might occur if a chunk of material stuck to the extruder barrel comes loose ("surge"), temporarily altering the mix – the spectrophotometer would catch this as a sudden out-of-spec reading, prompting a line check. In summary, color data, including L^* , a^* , b^* values and indices like ΔE (total color difference), YI (yellowness), and Whiteness Index (WI), form an important dataset that reflects the state of materials and processes.

Manufacturers treat this data as a key part of Statistical Process Control (SPC). For instance, trending ΔE values can highlight gradual drift and trigger corrections before a batch goes out of tolerance. Thus, color measurement is a powerful diagnostic tool: it helps infer material composition and quality (detecting contamination, degradation, incorrect formulations) and ensures process stability by signaling when something in production has changed.



Applications of Color Measurement Across Plastics Production

Color measurement is employed at virtually every stage of plastics production and across all product forms. Key applications include:

- **Raw Resins and Pellets:** The color of base polymers and compounded pellets is checked before processing. Plastic resin pellets (whether natural, pigmented, or masterbatch concentrates) are often measured in a petri dish or sample cup using a spectrophotometer. Even materials that appear “natural” or colorless can have a slight tint – for instance, virgin PET resin can have a faint yellow or blue cast. By quantifying pellet color, suppliers and molders ensure that incoming material is within spec and will yield the correct final part color. If recycled content is used, pellet color measurements are critical; recycled pellets typically have a higher yellowness that must be compensated for in formulation. Consistent pellet color translates to consistent product color downstream.
- **Extrusion of Films and Sheets:** In film and sheet manufacturing, color (and haze) must be tightly controlled along the length of the product. Manufacturers use in-line or at-line color measurements to monitor extruded plastic **films** (thin flexible packaging films, plastic wrap, etc.) and **sheets** (thicker flat stock used for thermoforming or panels). For **transparent films**, transmission color and haze are measured to ensure clarity and correct tint. For **opaque or pigmented sheets**, reflectance color is measured. For example, a packaging film might be measured for its transparent green tint (to ensure brand consistency for a produce bag), whereas an extruded PVC sheet for consumer products or construction materials, will be checked in reflectance. In practice, sensors like the HunterLab SpectraTrend HT can be mounted on an extrusion line to continuously scan the moving sheet and alert if color drifts out of tolerance, enabling immediate adjustments. Offline, cut samples of film or sheet are also



measured in the lab for full QC reporting. Color control in extruded stock is crucial not just for appearance but for functionality too – e.g., films with UV-blocking additives must be the correct color (often slightly tinted) to indicate proper additive levels.

- **Injection Molding & Thermoforming (Molded Parts):** Finished molded parts – such as bottle preforms, containers, automotive components, appliance housings, toy parts – are routinely checked for color uniformity. Typically, a bench spectrophotometer (sphere or 45/0 geometry depending on surface) or a portable spectrophotometer is used to measure plaques, parts, or color chips from production. For **opaque molded parts**, instruments with 45°/0° (or the inverse 0°/45°) geometry are often preferred because they measure color as the eye sees it, including the effect of surface texture and gloss. For example, a series of polypropylene molded automotive interior panels will be measured with this device to ensure each panel, whether textured or smooth, matches the approved master sample color under standard lighting. For **transparent molded parts** (like light lenses or clear bottles), transmission measurements are used to ensure clarity and correct tint. Many manufacturers perform color checks at the start of a production run, at set intervals, and after any pigment changeover to guarantee consistency throughout. Handheld instruments can be used on large parts or on the factory floor for spot checks.

Spectrophotometers are also invaluable during **color matching and formulation** for molded plastics – a lab will measure trial color plaques and adjust pigment recipes to hit the target CIELAB values within a small ΔE (difference).

- **Recycled Plastics and Compounding:** With the increasing use of recycled plastic (regrind, PCR resin, etc.), maintaining color is a challenge because recycled material can introduce variability (gray or yellow tints, impurities). Color measurement is used when blending recycled and virgin materials to ensure



the final mix still meets color specs. For example, a PET bottle manufacturer might measure each batch of recycled PET (rPET) pellets for Yellowness Index and L* (brightness); if the rPET is too yellow, they know to add a bit more blue toner or optical brightener to counteract it in the blend. By monitoring color, producers can increase recycled content while still achieving the required appearance, supporting sustainability goals without sacrificing quality.

- **Coatings and Secondary Operations:** Some plastic parts are painted or coated after molding (for instance, automotive exterior parts or decorative film coatings). Color measurement is equally applicable here – spectrophotometers are used to ensure that the paint color on a plastic bumper matches the metal body, or that a hard coat on a polycarbonate lens doesn't alter the transmitted color beyond spec. Additionally, plastic packaging might have printed labels or decorations; while not the plastic's color per se, the overall appearance including print can be measured (using spectrophotometric color imaging instruments) to ensure the combined visual effect is correct.
- **Quality Documentation and Communication:** Across all these stages, color measurements are typically logged into a quality database or software (like HunterLab's EasyMatch). This produces **color QC reports** for each lot, showing the measured color values and whether they pass within tolerance. Such data is critical for maintaining standards internally and for communicating with customers or suppliers. Many supply agreements for plastic parts require color data to accompany shipments, demonstrating that the parts meet the agreed color spec (often defined by a master sample or a CIELAB target with ΔE tolerance). In global supply chains, a consistent color measurement program ensures that a part produced in different factories (or different countries) will match, since all are measured to the same standard.

In short, spectrophotometric color control is implemented from start (raw materials) to finish (final products) in plastics manufacturing. This end-to-end color monitoring not



only preserves aesthetic consistency but can also flag functional or material issues at each step, ensuring that by the time the product reaches the customer, it both looks correct and has been processed correctly.

Challenges in Applying Color Measurement (Visual vs. Instrumental Methods)

Implementing color measurement in plastics does come with challenges, both practical and perceptual. One fundamental challenge is overcoming reliance on **visual inspection**. Historically, many plastics producers relied on trained inspectors to compare plastic samples to color standards by eye. However, visual judgments are subjective and prone to inconsistency. Different observers might perceive color slightly differently (due to eyesight or even color vision deficiencies), and ambient conditions such as lighting type and intensity can dramatically affect what color is seen. For example, a plastic part might look like an acceptable green under factory fluorescent lights but appear off-color in daylight. This phenomenon, known as **metamerism**, means two samples can match under one light source but not another. Human vision cannot reliably detect small color differences (a ΔE of 1.0 or below is usually imperceptible to an untrained eye), whereas instruments can quantify those differences precisely. Thus, a big challenge is convincing stakeholders to trust instrument readings over the “gut feel” of visual checks. Training and demonstrating the correlation – for instance, showing how an instrument can catch a subtle yellowing that an inspector missed – is key to this transition.

On the technical side, **sample presentation and geometry selection** pose challenges in plastics. Plastics come in many forms (transparent, translucent, opaque, glossy, matte, granular pellets, etc.), and the appropriate measurement method can vary:

- **Transparent and Translucent Samples:** Measuring the color of clear or see-through plastics requires transmission geometry. One must cut flat specimens



(like a piece of a bottle wall or film) and place them in a spectrophotometer's transmission chamber. Any curvature (as in a whole bottle) or variable thickness can distort the reading due to path length differences or double refraction. Therefore, standards recommend using flat sample cut-outs of uniform thickness. Ensuring the sample is clean (no fingerprints) and parallel to the light beam is important. Additionally, transmission measurements are sensitive to stray light and alignment – instruments must be calibrated with no blocking of the light path (100% transmission) and perhaps with a black trap (0%) to standardize. For translucent materials that scatter light, integrating-sphere based transmission is needed (to capture all scattered light). If the sample is *partially* transparent (translucent), it can sometimes be measured in reflectance with a white backing as an alternative – but the user must decide which mode correlates best with visual perception for that product. These nuances make the proper method selection critical.

- **Opaque Samples:** Opaque plastics are generally measured in reflectance, but the surface finish (glossy vs matte, textured vs smooth) influences results. Here is where geometry matters: **45°/0° (or 0°/45°) geometry** instruments shine light at a 45° angle and measure the reflected light at 0° (perpendicular) or visa-verse. This geometry, especially when using annular illumination (illumination from a ring around the sample), captures color like how our eyes see it and excludes mirror-like specular reflection. It is ideal for opaque, solid-colored samples and is recommended by many standards for color quality control. However, if a sample has a lot of texture or gloss variation, a single 45/0 reading spot might not be representative. In such cases, multiple readings at different rotations or positions should be averaged to get a true picture (this is often done for molded parts that might have flow lines or color gradations). On the other hand, **sphere (diffuse d/8°) geometry** instruments illuminate the sample diffusely (with an integrating sphere) and collect reflected light at an 8° angle.



This geometry includes the specular reflection component unless a gloss trap is used. Sphere instruments are more forgiving with textured or non-uniform surfaces because the diffuse illumination “averages” out surface effects. They are also versatile enough to measure both reflectance and transmission in one device. The challenge is that sphere measurements may not correlate exactly with visual perception for high-gloss samples (they measure color including gloss unless configured otherwise). Therefore, companies must choose the right geometry for their needs: for instance, **color-critical visual match** applications often prefer 45/0°, whereas **multi-purpose or applications including haze** may prefer sphere. Using the wrong geometry can yield misleading data – e.g., measuring a glossy part on a sphere (SCI mode) might show it within color tolerance, but to the eye it looks off because of a gloss difference that the 45/0 method would have caught.

- **Special Sample Forms:** Measuring color of pellets, powders, or liquids introduces additional challenges. Pellets can be multi-faceted and translucent; they need to be measured in a tray with a backing – typically a sample cup with a white background behind it for reflectance (per ASTM D6290 for pellet color). One must fill the cup sufficiently to avoid seeing through gaps and often average several mixes of pellets to get representative data. Powders similarly must be evenly presented and leveled without pressing (to avoid altering optical properties). Liquid plastics or colorants are usually measured in transmission cells of specified path length – avoiding bubbles and choosing the right path length (thickness) to get a meaningful absorbance is important. All these require careful SOPs and trained technicians to ensure repeatability.
- **Environmental and Instrument Maintenance Factors:** To ensure reliable color measurement, instruments need regular calibration and stable conditions. Spectrophotometers are typically standardized each day (or more frequently) using reference white and black tiles. These standard tiles must be kept clean



and handled properly; any dirt or scratch on the calibration standard can throw off all measurements. Plastics plants can be dusty or have airborne particles – it's a challenge to keep the sample port and the instrument optics clean. Many labs implement a routine cleaning schedule and keep the instrument covered when not in use. Temperature and humidity can also affect instrument performance and samples (a hot plastic sample might change color as it cools). Thus, conditioning samples and operating the spectrophotometer in a lab-like environment is preferred. Instruments themselves must be maintained – for example, replacing lamps on schedule (for those with xenon flash or halogen bulbs) and verifying performance with secondary standards (like a colored tile whose values are known) to ensure the instrument hasn't drifted. Operator training is crucial so that measurements between different shifts or sites remain consistent (everyone uses the same settings, geometry, calibration routine, etc.).

In summary, while spectrophotometers greatly improve objectivity and precision in color QC, successful implementation requires addressing various challenges. Transitioning from visual to instrumental methods entails establishing proper procedures: using controlled lighting for any visual assessments, selecting appropriate instrument geometry, preparing samples consistently, and maintaining/calibrating instruments diligently. When these challenges are managed, instrumental color measurement yields highly repeatable results with far tighter tolerances than human vision could achieve, ultimately benefiting quality control programs.

Global Color Measurement Methods and Regulatory / Quality Standards

Color measurement in plastics is governed by a framework of international standards and methods that ensure measurements are consistent and meaningful across different labs and industries. Organizations such as ASTM (American Society for



Testing and Materials), ISO (International Organization for Standardization), and CIE (International Commission on Illumination) have established standard practices for how color and appearance should be measured. Adherence to these standards is critical for plastics manufacturers, especially those supplying to regulated industries or global customers, because they provide a common language and set of criteria for color quality.

Some key standards and methods relevant to plastics color measurement include:

- **ASTM D1003 – Haze and Luminous Transmittance of Transparent Plastics:** This widely used standard defines how to measure the percent haze and total light transmission of transparent materials (like plastic films, sheets, or lenses). It essentially quantifies clarity: haze (%) is the fraction of transmitted light that is scattered more than 2.5° from the incident beam (i.e., how cloudy the material is), and luminous transmittance (%) is the total amount of light that passes through. ASTM D1003 prescribes using an integrating sphere instrument or a hazemeter for these measurements, with Procedure A (using a hazemeter) and Procedure B (using a spectrophotometer with a sphere) defined. Plastics companies making clear packaging, for instance, often have internal specs like “haze < 5% per ASTM D1003” for a given product. Instruments like HunterLab Vista and UltraScan VIS/PRO, which can measure haze in transmission, are designed to comply with this standard, meaning they have the geometry and analysis to report haze per ASTM D1003.
- **ASTM E1164 / ISO 7724 (Parts 1-3) / CIE 15 – Spectrophotometric Measurement Geometries:** These are standards that describe recommended practices for color measurement by reflectance. ASTM E1164 (and the equivalent ISO 7724-2, and CIE Publication 15) specify instrument geometries (like 45/0 or d/8), the use of specific illuminants (like CIE D65 daylight or Illuminant A), and observer angles (2° or 10° standard observer). They also



address instrument calibration procedures. They ensure that if two different instruments claim to measure “color,” they do so under similar conditions. Many modern color instruments will cite conformance to these standards. For example, a spectrophotometer might specify that it uses 10° observer and D65 illuminant per CIE recommendations, or a 45/0 instrument will align with ASTM E1164 geometry requirements. Plastics measured under these standards will have CIE L^* , a^* , b^* values that are comparable anywhere in the world when the same parameters are used.

- **ASTM E308 / ISO 11664-4 – Calculation of Color Coordinates (XYZ, Lab):** These define how to transform raw spectral data into tristimulus values and then into CIELAB or other color scales. They ensure that every instrument or software uses the same math – for instance, given a 10 nm spectral reflectance curve, how to multiply by the standard observer and illuminant functions to get X, Y, Z, and then L^* , a^* , b^* . Compliance here is about the software side of color measurement. It’s important for plastics companies when comparing data – if one lab used a slightly different formula or omitted UV components differently, Lab values could differ. Following ASTM E308/ISO guidelines means color values and ΔE are computed consistently.
- **ASTM D2244 – Calculation of Color Differences (ΔE):** This standard (and its ISO equivalents in ISO 7724-3 or ISO 11664-6) outlines how to calculate the color difference between a sample and a standard. It typically refers to the CIELAB ΔE^* (as well as newer formulas like ΔE_{2000}). In plastics QC, it’s common to set acceptable tolerances in terms of ΔE – for example, ΔE^*_{ab} must be less than 1.0 for any production sample vs the standard. ASTM D2244 provides the framework for doing this objectively and is often referenced in QC documentation. If a plastic part fails ΔE per ASTM D2244, it is out of spec for color.



- **ASTM E313 – Yellowness and Whiteness Indices:** ASTM E313 defines the Yellowness Index (YI) and Whiteness Index for plastics (and other materials like textiles). YI is particularly useful for near-colorless or neutral materials, quantifying the degree of yellow tint. For example, a highly transparent polystyrene might have YI around 0.0 (water clear), whereas after heat aging it might be YI = 10.0 (noticeably yellow). Whiteness Index is used for white or near-white materials (like TiO₂-filled plastic) to quantify how close to a pure white it is. Plastics producers often use YI to monitor material aging or to compare virgin versus recycled resin clarity. The use of YI is seen in industry guidelines (for instance, a PET resin spec might say “YI < 2.0 per ASTM E313”). Many spectrophotometers can directly output YI and WI values according to ASTM E313.
- **ISO 7724-1 / ISO 7724-2 / ISO 7724-3:** The ISO 7724 series (equivalent in large part to the ASTM and CIE standards above) covers general color measurement of plastics – Part 1: General principles, Part 2: Color measurement (instrumental requirements), Part 3: Calculation of color differences. These are often referenced by European manufacturers or global suppliers to ensure harmonization of color measurement practices across borders. For example, ISO 7724 might be cited in an automotive plastics standard to indicate how interior trim color is to be measured and evaluated.
- **ISO 14782 – Haze for Plastic Sheets (and ISO 13468 – Transmittance for Plastics):** These are ISO’s versions of haze and clarity measurements, like ASTM D1003. ISO 14782 covers determination of haze for transparent plastics, and ISO 13468 deals with luminous transmittance for transparent materials (including plastic sheets or glass). If supplying to certain markets, a company might need to report haze as per ISO 14782 instead of ASTM D1003, but in practice the methods are comparable. Instruments that comply with one are typically usable for the other.



- **Industry-Specific Standards and Regulations:** Beyond general ASTM/ISO methods, certain industries have their own color standards. For instance, the **food and drug industry (FDA/USP)** has standards for color additives and may require color testing for packaging that contacts food or pharmaceuticals. The United States Pharmacopeia (USP) has tests for the color of liquids (like medical IV solutions in plastic bags), and those often require spectrophotometric verification of haze and color. The **European Union** regulations on food-contact plastics also specify using only certain approved colorants and may indirectly require checking that no unintended color appears (as that could indicate contamination). In **automotive**, automakers often have internal standards (like Ford, GM color standards) that reference ISO methods and require ΔE compliance under multiple illuminants (to check for metamerism). The **medical device** industry might refer to ISO 10993 or others where color change after aging is monitored as part of device stability. **Pharmaceutical** packaging might require measuring transmittance at certain wavelengths (for UV blocking) – e.g., a brown plastic bottle must meet USP criteria for light transmission to protect the drug.
- **Corporate and Brand Standards:** Many large consumer product companies have their own color quality manuals. For example, Coca-Cola has defined Lab values for their PET bottle tints and tolerances for each plant; these are based on ASTM/ISO methods but customized to their products. Similarly, a brand like LEGO® has famously strict color tolerances for their ABS plastic bricks, measured with spectrophotometers to ensure a red brick from the current year matches one from 1990 – these internal standards align with CIE color measurement practices.

In all cases, compliance with these standards means using the **correct instrument, calibration, and procedure** for the situation. If a spec indicates “color to be measured per ASTM D XYZ,” the lab must ensure they have the right geometry instrument, the



specified illuminant/observer settings, and follow any sample prep guidelines in that standard. Meeting global standards ensures that a color measurement in one lab will agree with the same measurement elsewhere – crucial when suppliers and buyers are verifying each other's results. It also provides traceability: results can be traced to NIST or other national standards via the calibrated tiles and procedures, which is important in regulated industries. In summary, plastics manufacturers should integrate these standard methods into their SOPs to ensure consistent and accepted color data. By following ASTM/ISO guidelines, and by using instruments that support them, companies not only comply with regulatory and customer requirements but also gain confidence that their color control is on par with international best practices.

Recommended HunterLab Solutions for Color Measurement in Plastics

To address the diverse color measurement needs in plastics manufacturing, HunterLab offers a range of spectrophotometric instruments. Each instrument is designed with specific geometries and capabilities suited to different material types and use cases, from laboratory QC to in-line process monitoring. Below are the recommended HunterLab solutions and their key features for plastics color quality control:

- **Vista™** – *Transmission Color & Haze spectrophotometer*: The HunterLab Vista is a compact benchtop spectrophotometer engineered specifically for **transparent and translucent plastics**. It measures transmitted color **and** haze simultaneously in one measurement. Vista uses an integrating sphere (diffuse d/0° geometry in transmission) and complies with ASTM D1003 Procedure B for haze measurement, meaning it can report total transmittance and percentage haze according to the standard. Key capabilities include providing CIE L*, a*, b* color values for the sample and computing haze % at the same time. For example, a clear PET film sample can be placed in Vista's large transmission



chamber, and in one pass Vista might report $L^* 92$, $a^* +0.2$, $b^* +1.5$ (indicating a slight warm tint) along with 15% haze. This allows a technician to immediately judge if both color and haze are within spec. The Vista's design accommodates various sample formats – from film strips and plaques to cuvettes of liquids – making it versatile for packaging films, bottle preforms, lenses, and other see-through materials. With its array-based spectrophotometer (400–700 nm range at high resolution) and user-friendly touchscreen interface, Vista enables quick, objective evaluation of transparency-critical plastics. In summary, Vista is ideal whenever **transparent or translucent plastic color** must be measured, providing objective haze values (eliminating subjective visual haze checks) and accurate transmitted color readings in one convenient instrument.

- **Agera L2** – $0^\circ/45^\circ$ Reflectance Color with Integrated Gloss, Imaging, and True D65 Illumination: The HunterLab Agera L2 is a reference grade benchtop spectrophotometer optimized for precise color and appearance measurement of opaque plastics and solid materials. It uses a **$0^\circ/45^\circ$ circumferential geometry**, widely recognized for evaluating color as the human eye perceives it on solid surfaces. The instrument illuminates the sample at 0° and views at 45° around the full 360° circumference, capturing reflected color while minimizing specular glare, making it highly sensitive to visual color differences even on glossy or textured plastic parts. Agera L2 uniquely integrates a **60° gloss sensor**, allowing *simultaneous measurement of color* (L^* , a^* , b^* , ΔE) and surface gloss in a single reading—important because gloss strongly influences perceived color. The instrument also includes an **integrated high-resolution camera** that captures the measurement area, helping users verify proper sample placement and identify surface features that could affect results. A key advancement is **True CIE-calibrated D65 illumination**, which replicates standardized daylight to improve correlation between instrument data and human visual evaluation. Agera L2 measures across the **360–700 nm spectral**



range, enabling detection of materials containing optical brighteners or UV absorbers commonly used in plastics. The instrument also features **Dark Performance Mode**, an enhanced optical measurement mode designed to improve accuracy and repeatability when measuring very dark plastics and low-reflectance materials by optimizing signal detection and reducing measurement noise. With improved optics, sealed design, and the **EasyMatch software platform**, Agera L2 delivers excellent repeatability, measurement confidence, and modern QC workflow capabilities. Typical applications include resin and pellets, injection-molded housings and enclosures, vinyl siding, appliance components, consumer electronics plastics, and automotive interior parts, where both color and surface appearance must meet specification. By measuring color, gloss, and imaging simultaneously, Agera L2 allows manufacturers to ensure that plastic products match the intended color standard and appearance as the eye sees it, while improving production consistency and quality control.

From a technical standpoint, Agera L2 covers a broad spectral range (360–700 nm using LED illumination) including near-UV, which means it can detect optical brighteners or UV absorbers present in plastics. The LEDs and optics provide excellent repeatability and inter-instrument agreement.

- **Use cases:** any opaque or slightly translucent plastic part where precise color matching is required – e.g., colored ABS panels, polypropylene bottle caps, vinyl siding samples, injection-molded electronics housings. It's especially valuable when **appearance** (gloss/texture) needs controlling alongside color (such as an automotive interior part where both color and gloss must meet spec). By using Agera L2, manufacturers can ensure that an opaque plastic product's color matches the standard



as the eye sees it, and that its surface gloss is consistent, all in one convenient measurement.

- **ColorFlex® L2** – *Benchtop 45°/0° spectrophotometer (Compact and Versatile):*

The ColorFlex L2 is a compact, easy-to-use benchtop spectrophotometer employing **45°/0° annular geometry** to replicate human visual perception of color. It provides a cost-effective yet powerful solution for routine color QC on a wide variety of sample types. The 45°/0° design means it's excellent for opaque and semi-opaque materials – it captures color while accounting for how lightness and hue appear to an observer (including the effect of surface finish). The ColorFlex L2 is built with versatility in mind: it can measure not just solid plastic parts, but also powders, granules, pellets, and even liquids (with appropriate sample dishes). For instance, a user can measure powders by filling a sample cup, or measure slurry, or liquid colorant in a Petri dish, making the L2 useful for colorant suppliers and compounders. Its optical system uses annular 45° illumination (meaning it illuminates from all directions in a ring, reducing directional biases) and 0° viewing, ensuring consistent measurements even on samples with slight texture. The device is designed to be **standalone** – it has an integrated touchscreen and can operate without a PC if needed, storing standards and tolerances internally. This is useful on the production floor or in a plant lab where quick checks are needed. The ColorFlex L2 supports all the common color scales and indices (it can report CIELAB, Hunter L,a,b, ΔE, YI, whiteness, Gardner color, etc.), making it suitable for multiple industries.

- **Typical use cases:** verifying the color of injection molded parts (like a batch of bottle caps), measuring powders for paint or plastic additives, or even measuring the color of opaque liquids like plastic syrups or dispersions. In summary, ColorFlex L2 offers **45/0 precision in a small footprint**, delivering lab-quality color data with the flexibility to handle various sample forms. It's often the workhorse for routine color QC in



plastics plants, ensuring each lot of material meets the visual color standard.

- **SpectraTrend HT™** – *In-Line Non-Contact Spectrophotometer for Continuous Monitoring*: The SpectraTrend HT is HunterLab's solution for **real-time color monitoring on production lines**. It is an in-line spectrophotometer that mounts above or adjacent to a moving product (such as extruded plastic sheet, film, or siding) and measures color without contacting the material. The SpectraTrend HT uses a **0°/30° geometry** with dual sensors: one for color and one for distance (height) feedback. The STHT measures up to 5 per second as product passes under it. Crucially, the built-in distance sensor adjusts for any variations in gap or product flutter, maintaining accurate focus and measurement even if the plastic sheet wobbles or changes thickness. This makes the device unique in being able to handle the realities of a production environment (vibrations, slight movements) and still give reliable color data. SpectraTrend HT is housed in a rugged, IP66/NEMA 4 rated enclosure to withstand dust, heat, moisture, and splashes in industrial settings. The instrument continuously streams color values (typically L*, a*, b* and ΔE to a target) to a software interface (HunterLab's software or a PLC system). If color begins to drift out of the predefined tolerance, it can trigger alarms or alerts.
 - **Use cases:** continuous processes like plastic **sheet extrusion, film production, fiber spinning, vinyl siding extrusion, or even painted/coated plastic coil production** – anywhere you have a continuous web or flow of material and want to ensure color uniformity along its length. By catching color shifts immediately, manufacturers using SpectraTrend HT significantly reduce scrap and rework. It brings laboratory precision to the production floor in real time, closing the loop for color control. In summary, SpectraTrend HT is recommended for manufacturers who



need **around-the-clock color assurance** during production runs, enabling automatic color trend analysis and rapid intervention to maintain quality.

- **MiniScan® 4000L – Portable Sphere ($d/8^\circ$) Spectrophotometer:** The MiniScan 4000L is a portable, hand-held spectrophotometer that uses **diffuse/ 8° sphere geometry** for color measurement. This means it has an integrating sphere inside (like a lab bench sphere instrument) but in a compact battery-powered unit. The $d/8^\circ$ geometry with specular component included (SCI) allows it to measure color of a wide range of surfaces, including textured or non-uniform ones, with good repeatability. Being a sphere, it's also forgiving when measuring curved surfaces (like a plastic pipe or bottle) since it collects light diffusely. The "L" in the model number indicates a large area view; MiniScan 4000L typically offers a larger measurement aperture (25mm is standard) which is useful for averaging color over heterogeneous samples or avoiding the influence of small flaws.
 - **Use cases:** The 4000L is great for field or factory-floor measurements where bringing samples to the lab is impractical. For example, a quality engineer might carry it to various injection molding machines to check color on parts right as they come out, or a technician might use it to audit incoming plastic components at assembly lines. It's also used in warehouse incoming inspection or by sales reps who need to verify color at a customer site. The sphere geometry makes it suitable for both matte and glossy samples (it includes the specular reflection in the measurement). The device stores hundreds of measurements and can compare standards with pass/fail indications. It has a large LCD display for immediate reading of results. The MiniScan 4000L brings laboratory-grade sphere measurement capability into a portable format. By measuring in the same geometry as many bench units, it ensures consistent results – so a part measured by the portable can be correlated



to lab data. This instrument is particularly helpful for measuring color on products that are too large or bulky to bring to a bench device (e.g., a large plastic appliance panel or a car bumper at an assembly plant).

- **MiniScan® 4500L** - *Portable 45°/0° Spectrophotometer*: Complementing the 4000L, the MiniScan 4500L is a portable spectrophotometer that uses **45°/0° directional geometry**. This model is designed for situations where you want the measurement to mimic visual inspection (excluding gloss), but in a handheld format. With 45/0 geometry, it's particularly useful for solid colors where surface finish matters to the visual match. The 4500L's advantage is that it allows on-site color checks that align with how a reference 45/0 bench unit (or human eye) would see the color. For instance, a plastic paint chip or a molded part's color can be measured on the production floor, and the results correspond to visual standards. The device features a large easy-to-read display and the ability to store standards/tolerances (up to 100 custom tolerances configurations), so an operator can quickly measure a sample and get a "Pass/Fail" message if it's within tolerance. It's often used in applications like checking the color of molded plastic pieces on a manufacturing line (especially if they're glossy and one wants to ensure the measurement isn't skewed by the gloss - the 45/0 inherently takes care of that by design). Another use is in field comparisons - for example, matching a repair piece's color to an existing plastic component (in automotive repairs or building products on-site). By having a portable 45/0, quality personnel can maintain consistency between lab and production as well; e.g., the ColorFlex L2 (bench 45/0) could be the lab standard, and MiniScan 4500L used on the line for quick checks, both correlating closely. Overall, the MiniScan 4500L provides **handheld convenience with laboratory accuracy**, enabling flexible quality control in environments where samples are large, immovable, or testing needs to be done at multiple points quickly.



- **UltraScan® VIS** - *Universal Integrating Sphere Spectrophotometer (360–780 nm)*: The UltraScan VIS is a high-performance benchtop spectrophotometer with a 6-inch integrating sphere, designed to handle **both reflectance and transmission measurements** across the full visible spectrum (plus near-UV). It operates in **diffuse/8° (d/8) geometry** and can include or exclude the specular component (gloss) via a gloss trap mechanism. UltraScan VIS is essentially an all-in-one lab workhorse: it can measure opaque solids in reflectance mode (with options for SCI or SCE to either include gloss or mimic eye response) and measure transparent materials in total transmission and haze mode. Notably, it has an extra-large transmission compartment, allowing for not just standard cuvettes but even larger samples like whole sheets or bottle preform sections up to 100 mm thick to be measured in transmission. The spectral range of 360 nm to 780 nm means it covers the near UV (critical for fluorescent brightener evaluation) through the entire visible range. With a photometric resolution of 10 nm (and excellent wavelength accuracy and repeatability), the UltraScan VIS provides “reference grade” accuracy suitable for research or high-precision applications.
 - **Use cases:** Because of its versatility, UltraScan VIS is used when a lab deals with many types of samples. For example, a plastics supplier’s central lab might handle color QC for opaque masterbatches (reflectance), clear packaging film (transmission and haze), and translucent samples (could be done in either mode). Rather than needing separate instruments, UltraScan VIS can do all of these. It’s particularly recommended when measurements need to comply strictly with multiple standards – e.g., measuring haze per ASTM D1003, YI per ASTM E313, and color in reflectance per ASTM E1164 – since the UltraScan VIS can perform all those modes properly. Its large sphere and multiple aperture sizes (often it comes with several masks like 25mm,



13mm, etc.) allow measuring small parts or averaging over larger areas. Many customers use UltraScan VIS as their primary **color standard instrument** – for instance, they might use handhelds on the production floor but use UltraScan VIS in the lab to certify the color of a “golden sample” or for interlaboratory comparisons. In summary, UltraScan VIS provides top-tier accuracy and unmatched flexibility for any plastic color measurement task (except extended UV/IR, which is where the UltraScan PRO is positioned). It’s often referred to as a “workhorse” or “reference” instrument in color labs.

- **UltraScan® PRO** – *Ultra-Wide Range Spectrophotometer (350–1050 nm, Research Grade)*: The UltraScan PRO is HunterLab’s premier spectrophotometer, designed for the most demanding color measurement applications. It extends the capabilities of the UltraScan VIS by covering an even broader spectral range – from the near-ultraviolet at **350 nm through the visible and into the near-infrared up to 1050 nm**. This broad range allows the UltraScan PRO to characterize samples that standard visible-range instruments cannot. For example, it can assess UV transmittance (critical for UV-blocking plastics) and NIR properties (which might be relevant for certain optical filters or plastics used in IR applications like remote controls or sensors). The UltraScan PRO uses a diffuse/8° integrating sphere geometry like the UltraScan VIS, with automated specular inclusion/exclusion. It also boasts higher spectral resolution (typically 5 nm reporting, with data acquired at even finer steps) for extremely precise color discrimination. The design is a dual-beam, high-stability system that ensures excellent inter-instrument agreement and low noise – the PRO is often used as a reference instrument in round-robin tests or at standards labs.
 - **Use cases:** advanced color analysis and research, or high-precision quality control where the absolute best accuracy is needed. This can include applications like measuring the color and clarity of display



components (e.g. covers for smartphone displays, which might require checking IR transparency at 950 nm for facial recognition systems), or quantifying the UV-blocking performance of a plastic film (by measuring in the 350–400 nm range). In the plastics context, UltraScan PRO is perfect for R&D labs that work on new materials – for example, developing a plastic with a special IR-blocking additive would require measuring how it transmits in the IR, which the PRO can do. It's also chosen by companies that want the *benchmark* instrument – knowing that if the PRO says ΔE 0.5, it's as close to the true value as one can get, giving confidence when setting tight tolerances. The UltraScan PRO, like VIS, can handle reflectance and transmission (including haze calculation). It comes with multiple aperture sizes (often including very small ones for tiny samples like fibers or pellets). Many users treat UltraScan PRO as the final arbiter of color: production devices might do the routine work, but anything in question or any new color standard is measured on the PRO. In summary, UltraScan PRO offers **the widest range and highest precision**, enabling comprehensive color and appearance characterization (from UV through NIR) in one instrument. It is truly best-in-class when no compromises can be made on data quality.

Each of these HunterLab solutions addresses specific needs within plastics color QC, from speedy on-line checks to laboratory-grade analysis. They share a common platform of robust calibration, easy-to-use software (like EasyMatch and EasyMatch Essentials, which provides standard indices, color difference calculations, and trend analysis), and traceability to standards – ensuring that whichever instrument is used, the data can be trusted for making quality decisions.

Competitive Technology Comparison and HunterLab's Advantages



Color measurement technology for plastics has evolved over decades, and various instrument designs exist. Understanding the differences (filter vs. spectrophotometer, directional vs. sphere geometry, etc.) is important when comparing solutions. Here we outline some key comparisons and highlight why HunterLab's approach is considered best-in-class.

Filter Colorimeters vs. Spectrophotometers: Basic color measurement devices (often called colorimeters) use a few broad filters – typically red, green, blue sensors – to mimic the human eye's response. They output tristimulus values or maybe Lab values, but they do not capture the full spectral information. Such filter colorimeters are lower cost and can be sufficient for simple comparisons, but they lack precision. They might report two colors as "the same" because their crude sensors can't discern a subtle metameric difference. Spectrophotometers, on the other hand, measure the full spectrum (often 400 nm to 700 nm in 10nm increments) and then compute color values. This allows them to detect fine color differences and metamerism – e.g., they can tell if two yellows have different spectral curves that could look different under another illuminant. HunterLab exclusively designs **full spectrophotometric** instruments (with either diode array detectors or scanning gratings), ensuring high accuracy. Competitor offerings include some filter-based handhelds (which may be marketed as "color analyzers") that are not as sensitive. In practice, plastics companies that tried to upgrade to a spectrophotometer once they experienced readings that don't catch small drifts. Additionally, spectrophotometers can report indices like yellowness or haze that simple colorimeters cannot. The benefit of HunterLab's spectrophotometers (like ColorFlex or Vista) is evident in consistency – for instance, where a 3-filter device might miss a slight yellow tint, a HunterLab spectrophotometer quantifies it, avoiding potential quality escapes.

Directional (45°/0°) vs. Sphere (d/8°) Geometry: Both geometries are recognized and have their place. 45/0 (and 0/45) measure color in a way that correlates strongly with



visual perception, especially for opaque, solid colors. It ignores mirror-like reflections, so two samples that are the same color, but different gloss, will measure differently - matching how a human would compare color by eye under controlled lighting.

Sphere geometry illuminates diffusely and includes the surface reflectance unless set to exclude it. Sphere instruments are more versatile - they can measure glossy, matte, translucent, etc. - and they allow for SCI/SCE modes to either include or exclude gloss as desired. However, a sphere will see a glossy dark sample as "lighter" than a 45/0 would (since gloss adds to the collected light). Many competitors offer only one geometry or the other in each instrument series. HunterLab distinguishes itself by providing **both geometry options across its product line** and even integrating them where useful. For example, Agera is 0/45 (great for visual matches on opaque parts), whereas UltraScan VIS/PRO is d/8 (great for universal use including transmission). By having both, users can choose the instrument that fits their application best - not all competitors have that breadth. Additionally, HunterLab ensures that its sphere instruments have features to minimize geometry drawbacks: e.g., UltraScan VIS has a gloss exclusion feature and large sphere for good averaging, and Agera (0/45) has circumferential illumination to avoid directional shadowing as with some directional 0/45 devices.

Integrated Capabilities (Gloss, Haze, UV) vs. Separate Devices: Traditionally, if you needed to measure gloss, you'd use a gloss meter; for haze, a haze meter; for color, a colorimeter/spectrophotometer. This can be cumbersome - multiple instruments, multiple measurements, and potential alignment issues (measuring exactly the same spot with different devices). HunterLab has taken an innovative path of integrating functions: the Agera includes a 60° gloss measurement built-in, which is fairly unique (most competitor spectrophotometers do not measure gloss - you'd need a separate gloss meter). Similarly, Vista and UltraScan measure haze in the same device as color, removing the need for a separate haze tester. The advantage of integration is clear - one setup, one sample, one instrument yields all the needed data, improving



efficiency and ensuring the color and haze data correspond to the exact same sample condition. Many competitors' high-end sphere spectrophotometers can measure both reflectance and transmission, but not all can measure haze to ASTM standards without an accessory - and most do not include gloss measurement. HunterLab's approach of feature integration provides **time savings and consistency** with no switching devices or worrying if the sample orientation changed between tests.

Instrument Design and Innovation: On the hardware side, differences include light sources and optical design. Some competitor instruments use tungsten halogen lamps, which can run hot and have more drift, requiring warm-up periods plus frequent calibration and replacement. HunterLab has favored **xenon flash lamps and LEDs** in newer designs, which offer instant-on stability and consistent output. For example, Agera's full-spectrum LED illumination runs cool and lasts much longer than a typical halogen lamp, and it allows UV control without filters (because LED modules can be switched on/off in UV range). This is an advantage in measuring fluorescent materials - UV inclusion/exclusion is easier and more precise. Some older competitor designs using tungsten lamps might struggle with UV fluorescence accuracy unless carefully filtered. Another design point: **aperture size and viewing area**. HunterLab often provides large-area view options (like 25 mm diameter) which are important for plastics that aren't uniform (resins and pellets). Not all competitor instruments have such large sample viewing areas or uncomplicated ways to swap apertures. The Agera, for instance, can handle up to 2-inch sample areas, and UltraScan has various ports and an expansive sample chamber for large samples. This attention to practical usability sets HunterLab apart in accommodating real-world plastic samples (which might not always be flat tiny chips). Additionally, the SpectraTrend HT's dual sensor (color + height) design is a unique innovation - many on-line color sensors in the market lack active distance compensation, meaning any flutter or distance change can alter readings. HunterLab's incorporation of a height sensor in SpectraTrend HT



ensures consistent results in a production environment where conditions are not perfectly steady.

Inter-Instrument Agreement and Reference Role: When a company has multiple instruments (lab, production, different sites), it's important that they all agree closely. HunterLab instruments are known for excellent **inter-instrument agreement**, often due to high-quality components and thorough calibration protocols. The UltraScan series in particular is regarded as **reference-grade** – many companies use an UltraScan as the master to which other instruments (even from other brands) are compared. The UltraScan PRO, for example, is often used by standards labs and in round-robin tests because of its stability and accuracy. Competitors do have high-end instruments too, but UltraScan VIS/PRO tend to edge out others due to features like expanded range (PRO's 350–1050 nm versus many others 400–700 nm) and the ability to handle large samples easily. This means a lab can trust that if they measure color on an UltraScan and share those values, another lab with a similar unit will replicate them – crucial for supply chain color agreements.

Software and Data Integration: Modern color quality control is not just about the instrument; it's also about how data is collected, analyzed, and integrated into quality systems. HunterLab provides software that allow networking of data from **lab to line**. For example, a company can link in-line SpectraTrend HT readings with bench spectrophotometer readings in one central database to see the full picture of color across production and QC. HunterLab's focus on **application-specific solutions** – such as pre-loaded indices for plastics (APHA color, Gardner scale for liquid resins, etc.) – shows in their software as well. Many competitors have generic software which might need customization to get the same level of plastics-specific utility. Moreover, HunterLab offers thorough support and documentation (like the applications knowledge articles that inform this paper), reflecting deep expertise in plastics color issues. This expertise is an advantage when a customer faces an unusual measurement



problem – they can consult HunterLab’s team who often have encountered similar challenges with other clients and can advise on methodology (like how to measure a very dark, glossy plastic without interference, or how to handle fluorescent samples). Companies sometimes find that with general instrument vendors; such experienced technical support is harder to get.

In summary, while there are numerous color measurement tools on the market – from simple handheld color checkers to sophisticated spectrophotometers – HunterLab’s instruments stand out for their **combination of technical excellence and practical features**. They cover all necessary geometries (rather than forcing one approach), integrate additional appearance measurements (gloss, haze) that others require separate devices for, and maintain high accuracy and agreement that instill confidence. This “no compromise” design philosophy means users don’t have to trade accuracy for convenience or vice versa. HunterLab’s decades-long singular focus on color science (especially in industries like plastics) has yielded solutions that truly cater to the needs of plastics professionals, making them a top choice for companies where color quality is non-negotiable.

Summary - HunterLab Solutions Features and FABs

Below is a summary table of each recommended HunterLab solution, highlighting its key **Features**, the corresponding **Advantages** those features provide, the **Benefits** to the user/manufacturer, and key **Specifications** for each instrument:

Vista

Features:

- Transmission spectrophotometer with built-in haze measurement.
- Diffuse d/0° integrating sphere transmission geometry.



- Full visible spectrum sensing (400–700 nm).
- Simultaneous color, haze, and transmittance measurement.
- EasyMatch Essentials L2 embedded software platform.

Advantages

- Measures transparent and translucent materials accurately in transmission.
- Captures both color and clarity characteristics in a single measurement.
- Provides objective spectral analysis across the visible wavelength range.
- Eliminates the need for separate haze meters or clarity instruments.
- Offers intuitive QC workflows with optional connectivity to Quality Central.

Benefits

- Ensures transparent plastics meet both color and clarity specifications.
- Improves consistency of bottles, films, sheets, and packaging materials.
- Speeds up quality control by measuring multiple properties in one test.
- Reduces equipment costs and measurement complexity in production labs.
- Supports digital QC workflows and centralized color management.

Key Specifications

- **Geometry:** Diffuse d/0° transmission integrating sphere.
- **Spectral Range:** 400–700 nm (visible spectrum).
- **Appearance Metrics:** %Haze, %Transmittance, clarity measurement.
- **Color Outputs:** L*, a*, b*, ΔE, YI, WI, and additional color indices.
- **Software:** Onboard EasyMatch Essentials L2 with optional EasyMatch Quality Central integration.



Agera L2

Features

- 0°/45° circumferential geometry (annular illumination).
- True CIE calibrated D65 illumination.
- Integrated 60° gloss sensor and imaging camera.
- Dark Performance Mode for low-reflectance materials.
- EasyMatch Essentials L2 embedded software platform.

Advantages

- Captures color as the eye perceives it.
- Improves visual correlation with standardized daylight conditions.
- Measures color and gloss simultaneously while verifying measurement area.
- Enhances measurement stability and accuracy on dark plastics.
- Provides intuitive QC workflows with optional network connectivity to Quality Central.

Benefits

- Achieves precise color match on opaque plastic parts, even with texture or surface variation.
- Ensures color measurements align with real-world daylight appearance.
- Controls overall product appearance (color & gloss) in one measurement, improving efficiency.
- Improves repeatability and confidence when measuring very dark materials.
- Enables modern digital QC workflows, traceability, and centralized data management.



Key Specifications

- **Geometry:** 0° illumination / 45° circumferential viewing.
- **Illumination:** True CIE calibrated D65 LED illumination (360–700 nm).
- **Measurement Modes:** Standard mode and Dark Performance Mode for low-reflectance materials.
- **Appearance Measurement:** Integrated 60° gloss measurement and measurement-area imaging.
- **Software:** Onboard EasyMatch Essentials L2 embedded interface with optional EasyMatch Quality Central connectivity.

ColorFlex® L2

Features

- 45°/0° benchtop spectrophotometer with annular 45° illumination.
- Versatile sample handling for solids, powders, pellets, and liquids.
- Full visible spectrum sensing (~400–700 nm).
- Interchangeable apertures and accessories for flexible sample presentation.
- EasyMatch Essentials L2 embedded software platform.

Advantages

- Replicates human visual color perception using industry-standard 45°/0° geometry.
- Handles a wide variety of sample types with one compact instrument.
- Provides accurate spectral color measurement across the visible range.
- Adapts to different sample sizes and containers using multiple aperture options.



- Offers intuitive QC workflows with optional connectivity to EasyMatch Quality Central.

Benefits

- Ensures consistent color quality control for opaque and translucent materials as seen by customers.
- Reduces the need for multiple instruments to measure powders, pellets, liquids, and solids.
- Improves color consistency in plastics, foods, chemicals, and industrial materials.
- Simplifies laboratory workflows with flexible measurement configurations.
- Supports digital QC processes, traceability, and centralized color management.

Key Specifications

- **Geometry:** 45°/0° annular reflectance.
- **Spectral Range:** ~400–700 nm (visible spectrum).
- **Outputs:** L*, a*, b*, ΔE, YI, WI, and additional color indices.
- **Apertures:** Multiple measurement apertures (e.g., 25 mm and smaller masks) with accessories for cups, cells, and sample holders.
- **Software:** Onboard EasyMatch Essentials L2 embedded interface with optional EasyMatch Quality Central connectivity.

SpectraTrend HT

Features

- In-line non-contact spectrophotometer with 0°/30° measurement geometry.



- Dual-sensor system combining color measurement with distance (height) sensing.
- Real-time continuous color monitoring for production environments.
- Rugged industrial design for installation directly on manufacturing lines.
- Connectivity to process control systems and QC software platforms.

Advantages

- Measures product color without contact, eliminating contamination or sample handling.
- Automatically compensates for product height variations to maintain measurement accuracy.
- Provides continuous real-time color data during production.
- Designed to withstand harsh plant environments and operate reliably in-line.
- Integrates directly with PLC or QC systems for automated monitoring and control.

Benefits

- Detects color drift immediately on the production line, enabling instant corrective action.
- Improves product consistency by maintaining color targets throughout production runs.
- Reduces scrap, rework, and off-spec material through continuous process monitoring.
- Eliminates delays associated with manual lab sampling and offline testing.
- Enables automated quality control with alarms, trend monitoring, and process feedback.

Key Specifications



- **Geometry:** 0° illumination / 30° reflectance viewing (non-contact).
- **Measurement Distance:** ~65–140 mm operating range with automatic height compensation.
- **Speed:** Up to 5 measurements per second for continuous monitoring.
- **Enclosure:** Industrial NEMA 4 / IP66 sealed housing.
- **Connectivity:** Outputs to QC software or PLC systems for alarms, trend charts, and process.

MiniScan 4000L

Features

- Portable integrating sphere spectrophotometer with diffuse d/8° geometry.
- Large area view aperture for improved measurement averaging.
- Battery-operated handheld design for mobile color measurement.
- Specular included/excluded measurement capability for appearance evaluation.

Advantages

- Provides accurate color measurement on textured, curved, or irregular surfaces.
- Measures color with sphere geometry that minimizes surface effects.
- Allows operators to perform measurements anywhere on the production floor or in the field.
- Captures color with or without gloss influence using specular control.
- Supports seamless data transfer to QC software for centralized analysis.

Benefits



- Enables on-site QC for large or immobile plastic parts without removing them from production.
- Improves flexibility for quality audits, supplier inspections, and incoming material verification.
- Maintains consistent color readings comparable to laboratory measurements.
- Reduces delays caused by transporting samples to lab instruments.
- Supports efficient color verification across manufacturing, warehouse, and field locations.

Key Specifications

- **Geometry:** Diffuse d/8° integrating sphere.
- **Spectral Range:** ~400–700 nm (visible spectrum).
- **Aperture:** Large area view measurement port.
- **Operation:** Portable handheld unit with rechargeable battery.
- **Connectivity:** Data transfer to QC software for analysis, reporting, and color control.

MiniScan 4500L

Features

- Portable handheld spectrophotometer with 45°/0° directional geometry.
- Large LCD display with onboard memory for standards and tolerances.
- Designed for rapid pass/fail color comparison in production environments.
- Directional measurement geometry for strong visual color correlation.
- Battery-powered portable design for shop floor and field measurements.

Advantages



- Measures color using 45°/0° geometry that closely replicates human visual perception.
- Allows operators to store and quickly access multiple standards and tolerance setups.
- Provides immediate color comparison results directly on the instrument display
- Excludes gloss influence to focus on perceived color differences.
- Enables portable color verification.

Benefits

- Allows fast color verification directly on production lines or inspection stations.
- Ensures manufactured parts match master color standards as seen by customers.
- Improves response time for quality decisions with instant pass/fail feedback.
- Reduces delays associated with sending samples to laboratory QC equipment.
- Supports efficient color checks during manufacturing, incoming inspection, and supplier audits.

Key Specifications

- **Geometry:** 45°/0° directional reflectance.
- **Spectral Range:** ~400–700 nm (visible spectrum).
- **Aperture:** Large area view measurement port.
- **Operation:** Portable handheld unit with rechargeable battery.
- **Connectivity:** Data transfer to QC software for analysis, reporting, and color control.

UltraScan VIS

Features



- Lab-grade integrating sphere spectrophotometer with diffuse d/8° geometry.
- Measures both reflectance and transmission with haze capability.
- Specular included/excluded measurement modes for appearance analysis.
- Large 6" integrating sphere for improved measurement averaging.

Advantages

- Handles opaque, translucent, and transparent samples with one instrument.
- Supports both reflectance and transmission measurements for maximum versatility.
- Evaluates color with or without surface gloss influence using specular control.
- Provides highly stable and repeatable measurements through large sphere optics.

Benefits

- Centralizes color testing for solids, liquids, films, and transparent materials.
- Reduces the need for multiple instruments and calibration procedures in the lab.
- Improves confidence in color decisions using reference-grade spectral measurements.
- Supports compliance with industry standards for haze, YI, ΔE , and color tolerancing.
- Enables consistent global color control across laboratories and production facilities.

Key Specifications

- **Geometry:** Diffuse d/8° reflectance integrating sphere.
- **Spectral Range:** 360–780 nm (UV-Visible spectrum).
- **Spectral Resolution:** 10 nm dual-beam spectrophotometer.



- **Measurement Modes:** Reflectance (specular included/excluded), Total Transmission, and Haze (ASTM D1003).

UltraScan PRO

Expanded range integrating sphere spectrophotometer with diffuse d/8° geometry.

- Extended spectral coverage across UV-Visible-NIR wavelengths.
- Ultra-high-resolution dual-beam optical system.
- Automated aperture system for flexible sample measurement.

Advantages

- Captures full optical behavior beyond the visible spectrum.
- Measures reflectance, transmission, and haze with one instrument.
- Provides exceptional spectral precision and inter-instrument agreement.
- Automatically adapts measurement aperture for different sample sizes.
- Supports advanced QC and R&D workflows.

Benefits

- Enables detailed characterization of plastics, coatings, films, and materials requiring UV or IR evaluation.
- Supports research, formulation, and advanced quality assurance with highly reliable spectral data.
- Provides trusted “master instrument” performance for global color standardization.
- Reduces uncertainty in tight color tolerances and critical customer specifications.
- Centralizes complex optical measurements in a single high-precision platform.

Key Specifications

- **Geometry:** Diffuse d/8° integrating sphere with automated SCI/SCE control.



- **Spectral Range:** 350–1050 nm (UV-Visible-Near Infrared).
- **Spectral Resolution:** 5 nm reported (~2 nm sampling interval).
- **Apertures:** Automated 25 mm, 13 mm, and 7 mm measurement apertures.
- **Measurement Modes:** Reflectance, transmission, and haze in one instrument.

Hypothetical Case Studies: ROI and Quality Improvement through Color Measurement

To illustrate the impact of implementing spectrophotometric color control, consider the following hypothetical (but typical) scenarios that demonstrate return on investment (ROI) and quality gains:

Case Study 1 – Injection Molding Plant Reduces Scrap and Rework: A manufacturer of plastic packaging caps and closures was experiencing frequent color rejects. Caps produced in different shifts sometimes did not match the approved color standard, leading to entire batches being set aside for regrind or re-coloring. They relied on operators to do visual comparisons against a sample board under fluorescent lights. By the time a color discrepancy was noticed, a large quantity of caps (tens of thousands) might already be produced. This company invested in a **bench 45/0 spectrophotometer (ColorFlex L2)** at the molding line and instituted color checks every 30 minutes. They set a tight ΔE tolerance of 1.0 for any sample vs the master color. If ΔE exceeded 1.0, the machine would be adjusted (pigment feeder or machine settings) immediately. The result: color issues were caught within at most 30 minutes of onset, as opposed to sometimes 4–8 hours later previously. Over the first year, the scrap rate due to color nonconformance dropped by an estimated 80%. Where the company used to scrap about 5% of production for color defects, now it was under 1%. For a plant making millions of caps, this translated to significant material savings. In fact, the savings in resin and avoided rework labor equated to about \$50,000 in that year, more than paying back the cost of the spectrophotometer and training. Additionally, customer complaints about color virtually disappeared, strengthening



the supplier's reputation and avoiding potential penalty clauses for out-of-spec shipments. This case underscores how a relatively small investment in on-site color instrumentation yields returns via reduced waste and improved process efficiency (problems are corrected immediately, not after producing tons of scrap).

Case Study 2 – Extrusion Line Implements In-Line Color Monitoring: A company extruding colored vinyl sheet (for flooring applications) had challenges with color consistency along the length of rolls. Lab sampling was done every hour, but occasionally a dye pump would malfunction, or a mix inconsistency would occur and not be caught until the next lab test – by which point a few hundred meters of off-color material might have been produced. The manufacturer installed a **SpectraTrend HT in-line spectrophotometer** above the moving sheet, integrated it with their process control system. Now, the color is measured continuously and any drift beyond preset ΔE triggers an alarm and a slow-down of the line. In one incident, the system alerted operators 5 minutes after a pigment hopper ran low (causing a light color drift) – they paused and fixed the issue, saving most of the roll. Previously, that entire roll might have been downgraded. Over several months, continuous monitoring helped catch multiple small issues (pigment settling, temperature-induced color shifts, etc.) that would have otherwise gone unnoticed between manual checks. The reduction in off-spec output was quantified: scrap due to color defects went down by ~60%. Considering the high material cost of vinyl and the expense of reprocessing or landfilling defective rolls, the company estimated an annual savings of \$100,000 in waste reduction. Moreover, production became more **efficient** – fewer line stoppages for color adjustments since issues were corrected faster and didn't accumulate. The quality consistency also expanded new business – they were able to confidently guarantee color uniformity for longer roll lengths, which attracted a customer in the high-end flooring market. The ROI on the SpectraTrend HT system was achieved in under a year thanks to the material savings and increased product value.



Case Study 3 – Managing Recycled Content with Color Data (Sustainability

Improvement): A PET bottle producer aimed to use 25% recycled PET in their bottles to meet sustainability goals. However, recycled PET (rPET) tends to have a slight yellow tint compared to virgin, and initially the bottles made with rPET had noticeable color variation and a slight off-clear look, leading to some rejection from a brand customer. The producer implemented rigorous color measurements at three points: incoming rPET pellets, the PET melt (using a sample cup measurement of molten polymer in reflectance), and the final blown bottle (using Vista to measure transmitted color and haze). By analyzing Yellowness Index on incoming rPET batches, they began **sorting and blending** rPET sources – if one batch had high YI, they would mix it with a batch of lower YI or adjust the ratio of virgin added. They also introduced a small addition of blue toner masterbatch when YI of the mix exceeded a threshold to neutralize yellowing. The spectrophotometer data was essential in quantifying these adjustments. Over a few months, they tuned their process such that the average bottle color (L^* , a^* , b^* and YI) with 25% rPET was nearly indistinguishable from 100% virgin bottles. The initial problem of variability was solved: CIELAB ΔE between batches dropped from around 2.0 (visible difference) to below 0.5 (virtually no visible difference). This success in color control enabled the company to confidently increase recycled content further – they moved to 40% rPET in the bottles the next year, doubling the recycling impact. The **benefits** here were both economic and environmental: they saved on virgin resin costs and met the client’s sustainability criteria, securing a multi-year contract. In terms of ROI, while it’s hard to put a dollar on it, one can say the spectrophotometer (and the procedures around it) allowed the company to use cheaper recycled material without compromising quality, which improved margins. It also prevented costly scrapped batches that occurred during initial trials (where off-color bottles had to be rejected). This case demonstrates how color measurement can be a tool not just for quality, but for innovation – enabling use of sustainable materials by providing the data needed to adjust and ensure quality.



Case Study 4 – Automotive Plastics Supplier Improves Batch Consistency and Wins

Business: A supplier of molded plastic interior parts for cars (e.g., dashboard components, door trim) was trying to win a contract with an automaker that had extremely strict color harmony requirements. The automaker required that any supplied parts must match the master color within ΔE 0.7 (very tight) under two different illuminants (D65 daylight and A incandescent, to check for metamerism). The supplier had decent visual color control but occasionally parts from different production lots showed slight differences, which would not pass the automaker's incoming inspection. To tighten their control, the supplier invested in an **UltraScan PRO** in their lab for high-precision color analysis, and a couple of **MiniScan 4500L** units on the shop floor for quick checks during production. They developed color formulas and adjustments using the UltraScan PRO, taking advantage of its ability to measure under multiple illuminants and its high precision to ensure metamerism issues were resolved (if a pigment combination looked good in daylight but not under interior light, the PRO's data caught it). During production, they used the MiniScan 45/0 devices to validate color on random parts from each batch, ensuring nothing had shifted from the approved standard. Over time, the ΔE values between batches consistently stayed below 0.5 (often around 0.3-0.4). This gave the automaker confidence, and the supplier not only secured the contract but also reduced internal rejections dramatically. Before, they used to over-produce parts by ~5% to account for any that might be rejected due to color at final assembly. Now with consistent color, that extra production (and cost) was not needed. The investment in the instruments was on the order of \$50,000, but it enabled a contract worth several million, clearly a massive ROI. Additionally, the supplier now has a differentiator – they advertise their advanced color quality control in marketing to other clients. Having an UltraScan PRO (a known reference instrument) in their lab even impressed auditors during ISO/TS quality audits, as it signaled their commitment to top-notch quality control.



These case studies, while hypothetical composites, reflect real-world outcomes reported by plastics manufacturers who adopt spectrophotometer color measurement. In general, the **return on investment** comes from multiple angles: **scrap reduction**, **fewer customer returns/complaints**, **improved efficiency** (less trial-and-error, faster startups and color changeovers), and **ability to meet stricter requirements** (which can open new business opportunities). In many cases, companies find that a color quality program pays for itself within a year or two just from waste reduction and labor savings. Intangible benefits are present too: enhanced reputation for quality, greater confidence in scaling up production (since color can be reliably managed), and alignment with sustainability (as color monitoring helps incorporate recycled content and reduce waste). All these studies reinforce why, in a modern plastics plant, color measurement is not an optional add-on but a fundamental part of the quality and process control system.

Conclusion

Color measurement plays an indispensable role in the plastics industry, moving color control from a subjective art to a precise science. As we have explored, the global plastics market is vast and varied – yet across all regions and applications, the mandate for consistent color and appearance is a common thread. Achieving this consistency is critical: it ensures brand integrity in consumer products, indicates proper material composition and processing, and helps meet regulatory and safety standards. Spectrophotometric color measurement allows plastics professionals to quantify color and appearance attributes (like haze and gloss) with accuracy and repeatability that human vision alone could never guarantee. By integrating these measurements at every stage – from raw resin to finished part – manufacturers can detect issues early, adjust processes on the fly, and document quality with confidence.



Implementing a robust color quality control program yields tangible benefits. It reduces scrap and rework by catching off-spec product before it accumulates, thereby improving yields and cutting costs. It shortens troubleshooting time, since color data often points directly to the source of a problem (such as a lot of material that's off-color or a machine setting drift). It provides objective evidence of quality for customers and auditors, which is increasingly important in a world of tightened specifications and supply chain transparency. Moreover, as we saw in the case examples, effective color control can enable innovation – whether using more recycled content or achieving ultra-tight color tolerances for high-end products – thus providing a competitive edge.

HunterLab's suite of solutions (Vista, Agera, ColorFlex L2, SpectraTrend HT, MiniScan devices, UltraScan VIS/PRO, etc.) offers plastics manufacturers best-in-class tools to implement this color control with scientific rigor. Each instrument addresses specific challenges, but all share the goal of delivering reliable color data that correlates with human visual assessment and standard criteria. With these tools, users can cover the full spectrum of needs: laboratory analysis, quick at-line checks, and in-line continuous monitoring. When combined with proper procedures and adherence to international standards, the result is a color quality system that ensures every hue, shade, and tint is exactly as intended.

In conclusion, color measurement is no longer merely a quality box to check – it is a strategic function in plastics manufacturing. It safeguards aesthetic quality and brand consistency, reduces costs, and can even drive sustainability efforts by optimizing the use of materials. The scientific and technical advancements in instrumentation, exemplified by HunterLab's offerings, make it easier than ever to control and communicate color with high precision. For any plastics professional or quality engineer, leveraging these color measurement technologies is key to achieving manufacturing excellence and customer satisfaction in today's color-conscious market.