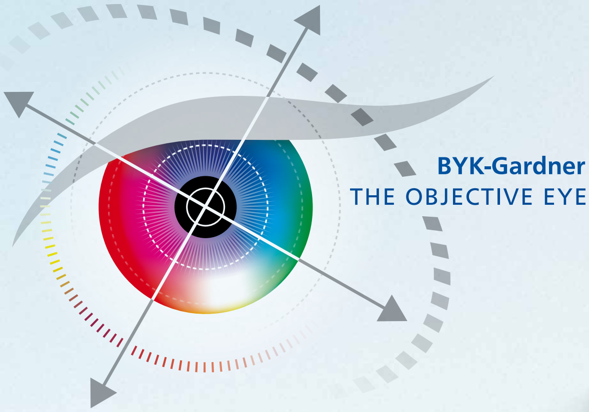
QC SOLUTIONS FOR TRANSPARENT PRODUCTS

Contents

The Objective Eye for a Clear View

Our modern high-tech world is no longer imaginable without transparent products. We are so used to their "invisibility" that we only notice them if defects diminish their transparency, and consequently, their final usage. If due to varying quality of the packaging film the same chocolates appear different on the shelf, the nice holiday photos appear hazy on the smart phone, or the motorcycle helmet's face shield easily gets scratched – then, all of this will affect our quality expectation and can even become a hazardous risk.

The perceived quality of transparent materials is dependent on its transparency, gloss and color. The human eye can recognize very fine variations in sharpness, contrast and appearance of a show window or transparent packaging film when goods are displayed behind it. Quality variations of the transparent product diminish the perceived appearance of the product. Therefore, a high and consistent transmission quality is a key factor in the sales decision. Depending on the end-use, a long lifetime in regards to non-yellowing, scratch resistance, and gloss stability is required.

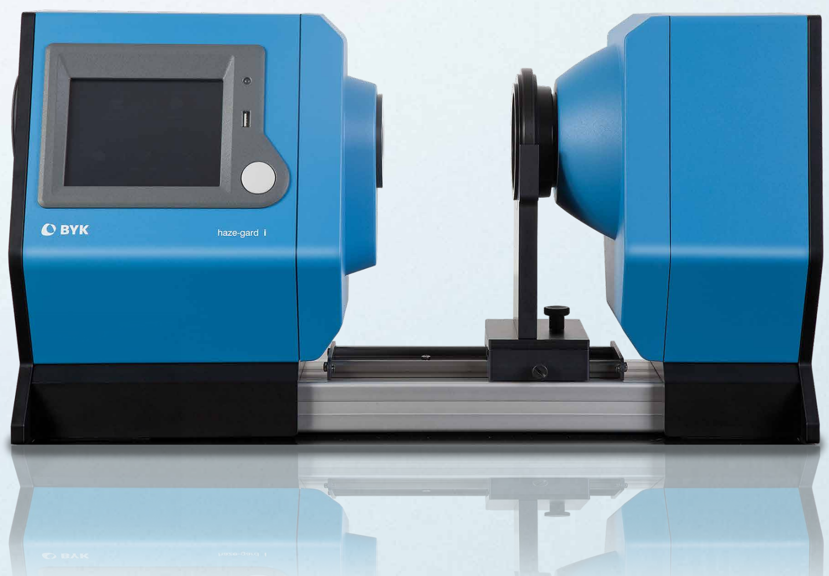


Each application asks for specific material properties and processing parameters. More than hundred different polymers are available for transparent end-uses. Many products consist of several components or multiple layers to combine different properties into one final, highly customized product. Besides the material selection, several production parameters influence the appearance and need to be optimized. Consistent transparency can only be guaranteed if the material and process factors are under control over the complete supply chain.

Visual perception is influenced by our individual preferences, which are dependent on personal factors like mood and age, environment (lighting, surrounding etc.), as well as our limited ability to communicate appearance differences. In order to guarantee consistent transparency under all possible situations, it is essential to define numerical parameters with customer relevant tolerances, which can be controlled in daily production and communicated among the entire supply chain of raw material and final product suppliers. A high quality production process should only be based on figures and facts and not emotions.

Consistent color and appearance needs an OBJECTIVE EYE!

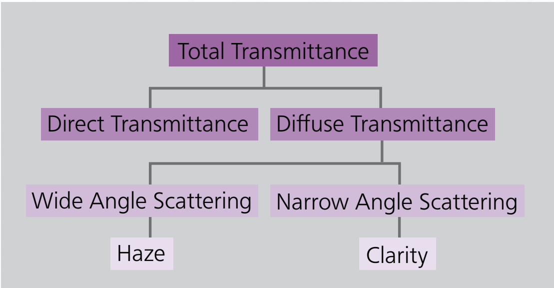
BYK-Gardner offers complete quality control solutions for your transparent products.



Transparency Measurement

Did you ever walk into a glass door? The challenge is to make the product "invisible", i.e. homogenous without any irregularities. Transparency is more than just the ability to transmit light. The perceived quality of a transparent product is dependent on how "good" we can see the objects behind it. It can appear crystal clear, hazy or unsharp. The human eye can perceive fine variations in sharpness as well as loss of contrast.

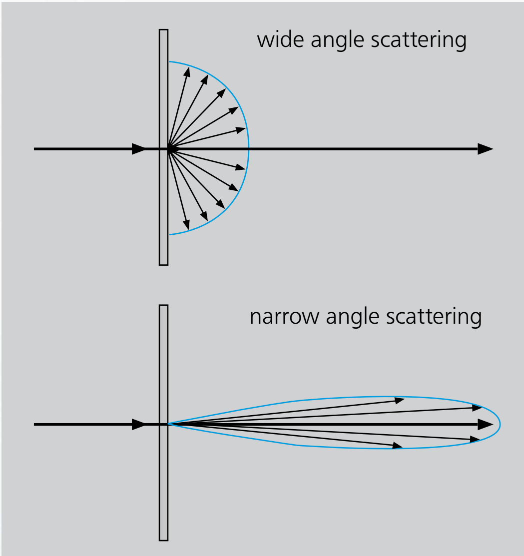
Transparency
For visual evaluation of the "see-through" quality, it is recommended to use a contrast rich object behind the specimen, e.g. a bright pattern on a dark background. The appearance of a transparent or translucent product is described by the following optical properties:



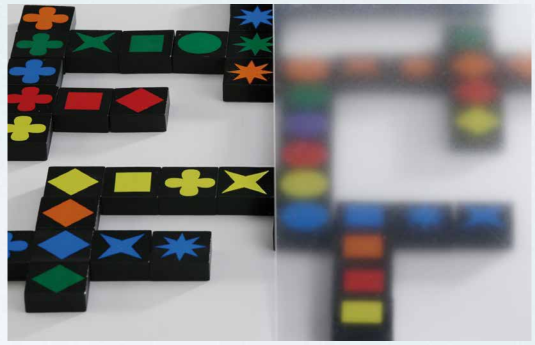
Total Transmittance (Tt)
The total transmittance is the ratio of transmitted light to the incident light. It is influenced by the absorption and reflection properties, e.g.:

Incident light	100 %
- Absorption	1 %
- Reflection	5 %
Total Transmittance	94 %

Depending on the application, a high Tt (eyewear) or low Tt (shopping bags) is needed. The totally transmitted light consists of the directly transmitted and the diffused components. The appearance of products viewed through the transparent product will be influenced by the scattering behavior of the diffused light.



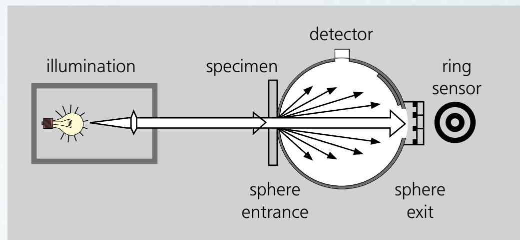
Luxury packaging or household dishes are often described as "Crystal Clear" with an appearance like glass. In technical terms, they should have a high Tt with no or very small amount of scattered light. Diminished optical properties can be caused by scattering at surface structures or by internal scattering at particles like e.g. voids, crystallites or poorly dispersed particles.



Haze
Scattering in a wide angle range (deviation from incident beam greater than 2.5°) will reduce the contrast of objects viewed through the transparent material. The transparent product will appear hazy.

Clarity
If the diffused component is scattered in a narrow angle range (deviation from incident beam less than 2.5°), fine details are blurred and the sharpness of the image is reduced. Unlike haze, clarity is distance dependent; the greater the distance between the specimen and the observed object behind, the worse the clarity effect. If the object is in direct contact with the specimen, the so called "contact clarity" is good.

Measurement principle
The sketch on the right shows the measurement principle of the haze-gard i in compliance with international standards. A light beam strikes the specimen and enters an integrating sphere. The sphere's interior surface is coated uniformly with a matte white material to allow diffusion. A detector in the sphere measures total transmittance and transmission haze. A ring sensor mounted at the exit port of the sphere detects narrow angle scattered light, a measure of clarity.

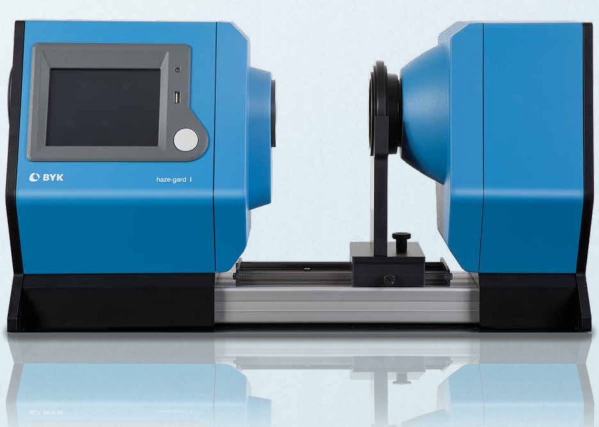


References

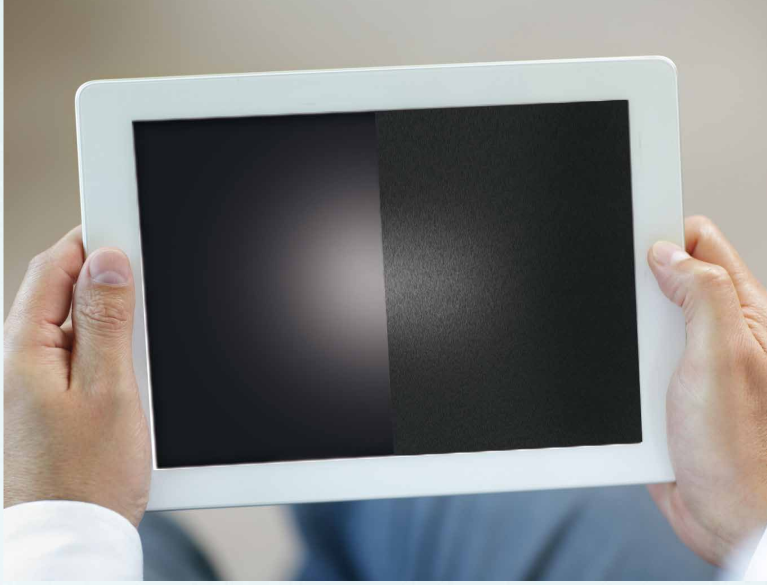
ISO 13468	Determination of the Total Luminous Transmittance of Transparent Materials
ISO 14782	Determination of Haze for Transparent Materials
ASTM D1003	Haze and Luminous Transmittance of Transparent Plastics

haze-gard i
The industry standard for transparency

- Three measurements in one:
  Total Transmittance – Transmission Haze – Clarity
- Repeatable results guaranteed due to reference beam and innovative LED technology
- Open design for small and large specimens
- Large touch display in color for onboard analysis
- Versatile sample holder for films and sheets
- ASTM and ISO: two standard methods in one unit

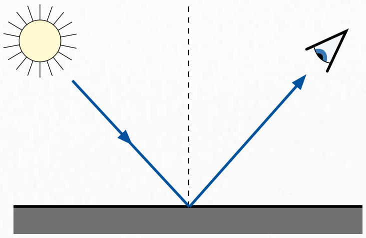


Gloss Measurement

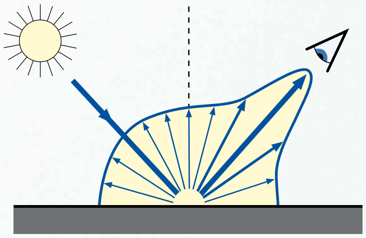


Many transparent products are recognized by their reflection properties rather than by their transmission behavior. Should a LCD screen be brilliant or diminish reflections? This depends on the application, but also on the customer's preference. However – once defined, the specified appearance needs to be supplied in a consistent and controlled quality.

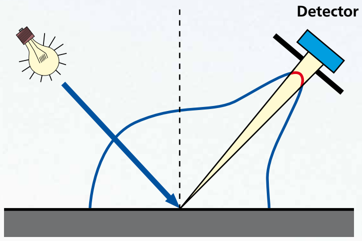
Gloss measurement
Gloss is a visual impression dependent on the surface condition. The more direct light is reflected, the more obvious the impression of gloss will be. A brilliant screen has a very smooth surface to create deep and saturated images, but at the same surrounding objects will be reflected. The incident light is directly reflected on the surface, i.e. only in the main direction of reflection. The angle of reflection is equal to the angle of incidence.



An anti-reflex screen uses a coating with a fine structured, rough surface, scattering the light diffusely in all directions. The more uniform the light is scattered, the less intense the reflection will be in the main direction. The surface will appear more and more matte.



Gloss meter
International standards define the measurement of specular reflection with a gloss meter. The light intensity is measured over a small range of the reflection angle.



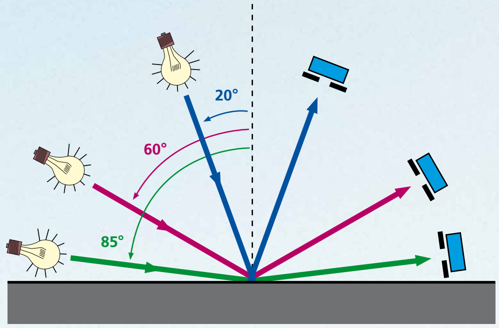
A light source, simulating CIE illuminant C, is placed at the focal point of a collimating lens. A receptor lens with an aperture in the focal plane followed by an illumination detector completes the basic optical design.

The intensity is dependent on the material and the angle of illumination. The measurement results are related to the amount of reflected light from a black gloss standard with a defined refractive index. The measurement value for this defined standard is equal to 100 gloss units. Materials with a higher refractive index can have a measurement value above 100 gloss units (GU).

References

ISO 2813	Determination of Specular Gloss of Non-Metallic Paint Films at 20°, 60°, 85°
ASTM D523	Standard Test Method for Specular Gloss
ASTM D2457	Standard Test Method for Specular Gloss of Plastic Films and Solid Plastics

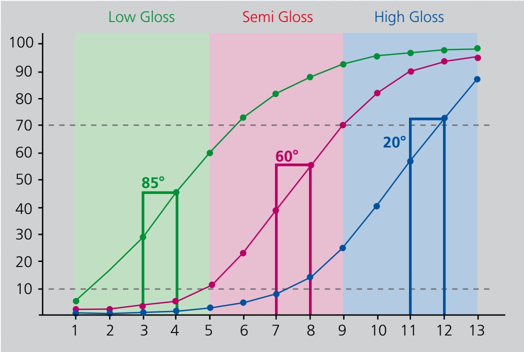
The angle of illumination is of high influence. In order to obtain a clear differentiation over the complete measurement range from high gloss to matte, three geometries, i.e. three different ranges, are standardized:



Gloss level	60° value	Recommended geometry
Semi gloss	10 to 70 GU	60° geometry
High gloss	> 70 GU	20° geometry
Low gloss	< 10 GU	85° geometry

In a case study 13 samples were visually ranked from matte to high gloss and measured with the three specified geometries. In the steep slope of the curves, the differences between the samples can be clearly measured, while in the flat part the measurement geometry no longer correlates with the visual perception.

Besides these three geometries, a 45° gloss meter is often used in plastic and film applications to measure medium to high gloss materials.



Why three different gloss ranges?

A single measurement geometry, such as 60°, may not provide instrument readings of gloss that correlate well with visual observations when comparing different gloss levels. This is why international standards provide for measurement at three different angles of incidence, namely 20°, 60°, and 85°. Each of the three geometries uses the same source aperture, but a different receptor aperture. The choice of geometry depends on whether one is making a general evaluation of gloss, comparing high gloss finishes or evaluating low gloss specimens for sheen. The 60° geometry is used for comparing most specimens and for determining when the 20° or 85° geometry may be more applicable. The 20° geometry is advantageous for comparing specimens having 60° gloss values higher than 70 GU. The 85° geometry is used for comparing specimens for sheen or near grazing shininess. It is most frequently applied when specimens have 60° gloss values lower than 10 GU.

micro-gloss

The new intelligence in gloss measurement

- Unsurpassed industry standard in gloss measurement
- 1- angle and 3-angle gloss meters for high gloss to matte finishes
- Automatic calibration check in holder
- Measurement modes for any task: Statistics – Difference – Pass/Fail
- Continuous mode for uniformity check of large surface areas
- Wireless data transfer

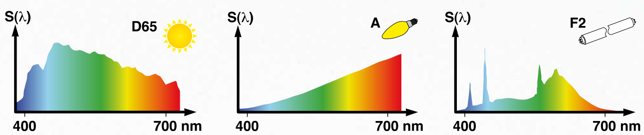
Color Measurement

Colored or uncolored – that is the question! Opaque, or hiding – that is another question! Transparent products require different properties according to the final application. How do you clearly define the color and opacity to guarantee consistent quality over time?

Our color perception is dependent on our individual "taste", which is influenced by our mood, gender, age, but also the light source used as well as our inability to exactly remember and communicate one specific color.

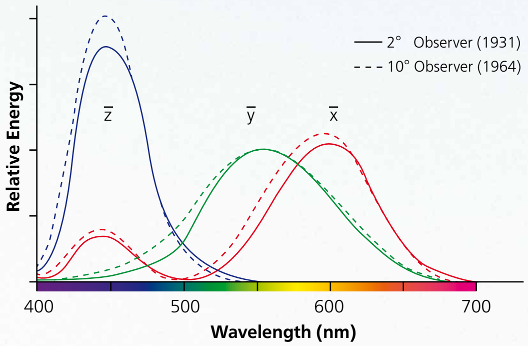
Standardized viewing conditions

For controlled visual and instrumental evaluation the light source, the surrounding and the observer are to be defined. The CIE (Commission Internationale de 'Éclairage) standardized commonly used **light sources**.



References	
CIE 15	Colorimetry
ISO 6504	Determination of hiding power

The **observer for visual appraisal** should have normal color vision and be trained in observing and classifying colors. Visual tests are recommended to check an observer's color vision periodically as it can change over time (see Guide ASTM E1499). The **observer for instrumental color control** was standardized with two different viewing fields: 2° standard observer and 10° standard observer. Today, mainly the 10° observer functions are used as the eye integrates over a larger area.



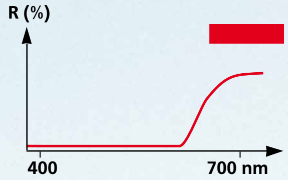
spectro2guide

The revolution in portable color control

- Color, gloss and new fluorescence measurement in one instrument
- Balanced and upfront design with large 3.5" color touchscreen
- Docking station with built-in standard for automatic calibration
- Live preview of measurement spot with zoom function
- Smart high tech LEDs with peak performance for Digital Standards
- Data analysis out-of-the-box with WiFi or USB connection

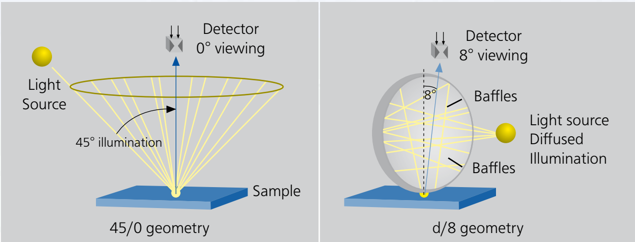
Standardized measurement parameters

For instrumental color measurement, the optical properties of the product need to be measured. A spectrophotometer measures the amount of light that is reflected by the object at different wavelengths in the visible range (400 – 700 nm). The reflectance curve shows the spectral data and acts as a "finger print" for the object color.



Standardized instrument geometries

International standards define the geometric conditions of spectrophotometers:



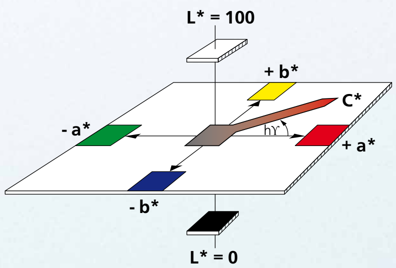
45/0 – Control color as you see it

For final QC of solid colors a 45° circumferential illumination is defined to achieve repeatable results on unstructured and structured surfaces.

d/8 – Control the hue of a color

If the color without influence of surface gloss or texture is to be controlled, diffused illumination is required.

Internationally standardized **color systems**, like the widely used CIELab system, combine data of standardized illuminant, standardized observer and spectral reflection data in three color components describing the lightness, hue and chromaticity of a color.



Tolerances are established either on each color component or on the total color difference ΔE*.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Yellowness Index

For near-white or near-colorless samples, a one-dimensional number is calculated from the spectral data, the so called yellowness index. This index quantifies the degree to which a sample's color shifts away from an ideal white. The larger the value, the more yellowish the sample appears.

Very often such samples do not strictly appear just yellow, but show a significant difference in hue and lightness. Therefore they require a three dimensional description of color: red/green, yellow/blue and light/dark.

References

ASTM E313	Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates
ASTM D1925	Yellowness Index of Plastics (withdrawn in 1995)
DIN 6167	Description of yellowness of near-white or near-colorless materials

Opacity Measurement

Opacity is the ability of a thin, transparent material to hide the surface behind. It is also sometimes referred to as contrast ratio and hiding power. Opacity is expressed as the ratio of the reflectance when the material is backed by a black substrate to the reflectance when it is backed by a white substrate.

$$\textbf{Opacity (\%)} = \frac{Y_{black}}{Y_{white}} \times 100$$

100% opacity means complete hiding: no difference can be seen between the transparent material over black and white.

Raw Materials

Plastic raw materials such as polypropylen (PP), polyethylene (PE) and polycarbonate (PC) are usually supplied as colorless granular bulk goods. In order to guarantee consistent color, gloss and transparency of the final product, a routine quality control system needs to be established at the very first production step. Otherwise the phrase "garbage in – garbage out" may become reality. As granular plastic pellets are of irregular shape, the key for repeatable measurement results is a standardized sample preparation.

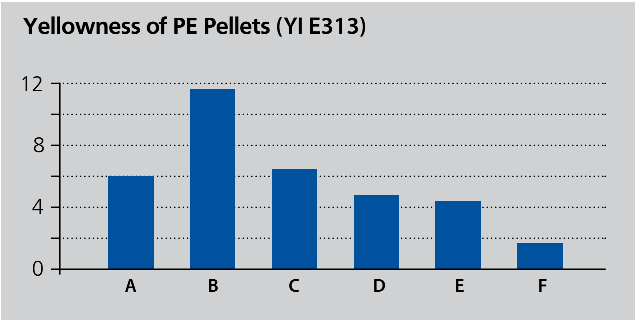
The basis for any plastic material is mineral oil which undergoes several fractionating steps to finally end up as straight-run gasoline (naphtha) which is then cracked and polymerized into different plastic resins. Dependent on the selection of the raw materials, the manufacturing process and the additives, different properties of the final plastic material can be achieved.

Consistent color

Plastic raw materials such as PP, which is often used for colored end-use applications, must be controlled for degree of yellowness. If the resin is not "white", the final color will be off specification. The degree of yellowness is influenced by contamination or impurities of the raw materials as well as process variations (e.g. temperature, amount of catalysts).

For quick and efficient quality control, it is necessary to mold the plastic pellets into plaques with a homogenous surface and defined thickness. The plaques can then be measured in reflection mode by the spectro2guide, a portable color spectrophotometer, which automatically calculates the yellowness index according to international standards. As the yellowness index is just a one-dimensional number, it sometimes does not completely describe the visual perception. Very often samples show additionally a significant difference in hue and lightness. Therefore, a three dimensional description of color using the commonly available CIELab color system is recommended. Within this system, the b* value can be used as an indicator for yellowness.

The molded plaques are usually not completely opaque. Thus, the background when taking the color readings has a crucial impact on measurement results. To achieve the best discrimination between different products a white backing material is recommended. The material should be long-term stable and agreed upon between the involved parties.



BYK-Gardner Solution

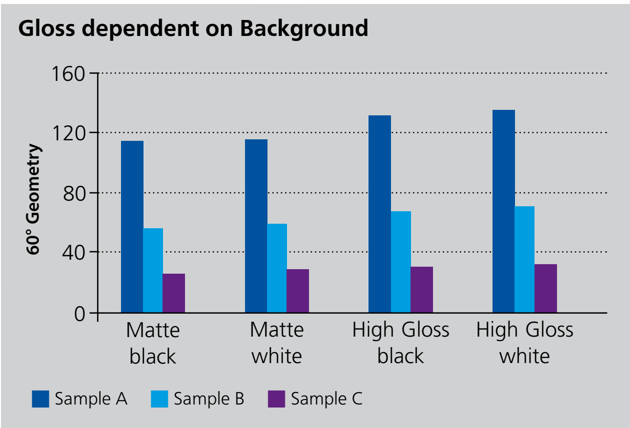
Solid Color & Gloss
spectro2guide

Gloss
micro-gloss

Drawdown Test Charts
byko-charts

Consistent gloss

As specular gloss is used primarily as a measure of the shiny appearance of the final product, plaques or films are extruded to ensure consistent quality for the end-user. These samples have in common that they are transparent or translucent. To avoid additional reflection from the background, which will result in erroneous gloss measurements, a matte black backing must be placed behind the film or sheet. Either a black paper board or matte test chart like the byko-charts can be used. The backing material should have a gloss value close to zero.



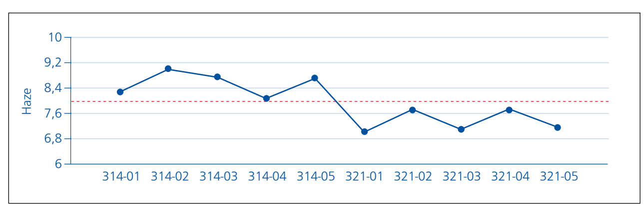
Consistent transparency

The appearance of a transparent product is defined by its application. Plastic containers used in the food industry should be very clear and transparent, while containers for cosmetic products (e.g. beauty cream) should be translucent and diffuse the light to ensure long-term stability of the content. Therefore, these parameters are tested on the final product by extruding plaques or films with defined thickness.

The haze-gard i is a versatile hazemeter which determines total transmittance and transmission haze according to the ASTM and ISO test method. The test sample must be large enough to cover the measurement port of the instrument and should be free of dust, or any other imperfections. The most critical parameter for plastic raw materials is the haze value. The goal is to achieve a haze value as low as possible – ideally close to glass. Otherwise additives used in the final product, so called clarifiers, cannot guarantee optimum transparency and coloring properties.

The challenge when measuring transmission and haze of plastic plaques is to place them flush and repeatable against the measurement port. Versatile sample holders were developed that can be easily mounted into the open measurement compartment.

For efficient process control Pass/Fail limits for different product specifications can be directly input in the haze-gard i. The new batch is then measured and automatically compared to the specifications. Green or red indicators instantly illustrate the results on the instrument display. Using smart-lab Haze software even facilitates showing production process stability using trend reports including data tables with statistics and line graphs with Pass/Fail coloring.



Transparency
haze-gard i

Thin Film Accessory
thin film Holder

Film and Sheet Accessory
sample holder

Films and Foils

Transparent films are used in thousands of different applications. Whether shrink film, blister or medical films – each application asks for specific behaviors in the material selection and processing conditions. Flower packaging should be very clear, protecting and presenting its content in the same way. Films for grocery bags are expected to diffuse the light. Consistent transparency can only be guaranteed if the key material and process factors are under control and a standardized sample preparation is used.

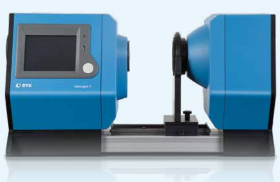
Influence of material and process parameters
Besides polymer selection, several decisions can influence the appearance, such as the choice of cast versus blown film production process. Cast film with its fast quench capabilities has better transparency and gloss, and can be controlled by the roll surface. Many parameters affect the final film quality e.g. density, mass distribution or melt index on the polymer side, as well as processing influences like melt homogeneity, cooling rate or blow-up ratio. Often additives to control properties like crystallinity or anti-blocking need to be adjusted to guarantee the desired effect.

Inner haze versus surface haze
A hazy appearance of films can be caused by internal scattering in the bulk material due to voids, crystallinity or other irregularities, referred to as “Inner Haze”. On the other hand, light can be scattered at surface structures, which is called “External or Surface Haze”.

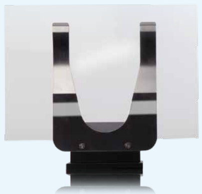
At cast films, surface roughness can often be reduced by the chill rolls surface and the temperature control in the cooling process. On blown film with its free-surface flow, the surface roughness is mainly caused by melt-flow phenomena and crystallization.

In the development and optimization of production parameters, it is important to know the source causing the scattering and which parameters offer potential for improvement. Thus, inner and surface haze are to be differentiated. A liquid with similar refractive index as the sample, is used to cover the surface structure, which allows minimizing the scattering by the film roughness during measurement. Appropriate liquids can be found in the optical laboratory supplies for refractometry and microscopy.

BYK-Gardner Solution



Transparency
haze-gard i



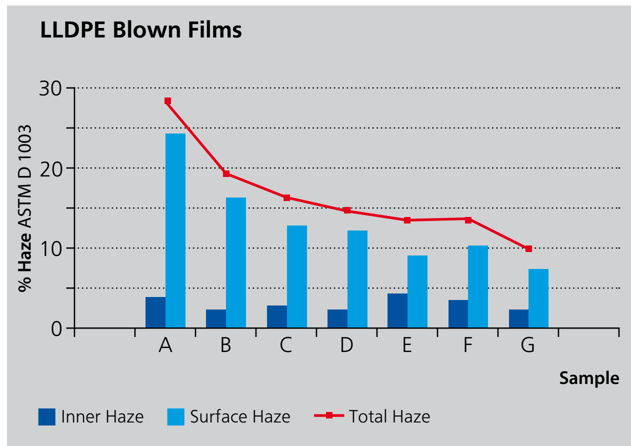
Film and Sheet Accessory
sample holder

Thin Film Accessory
thin film Holder

First, the sample is measured without the liquid to get its "total haze" value. Then, the sample can be placed in a cuvette containing the liquid, or often a thin film of the liquid is applied on both sides of the sample to measure its "inner haze". In this case, care has to be taken to apply a uniform layer without dirt or air bubbles. Finally, the difference between both values will provide the "surface haze":

Surface Haze = Total Haze – Inner Haze

The example graphs the haze results of different linear low density PE blown films. The data show a strong impact of surface related causes to the total haze quality, which is characteristic in blow film production. Influencing parameters besides the resins itself are e.g. the melt viscosity, blow-up ratio and process speed.



Accessories for Liquids
cuvette holder

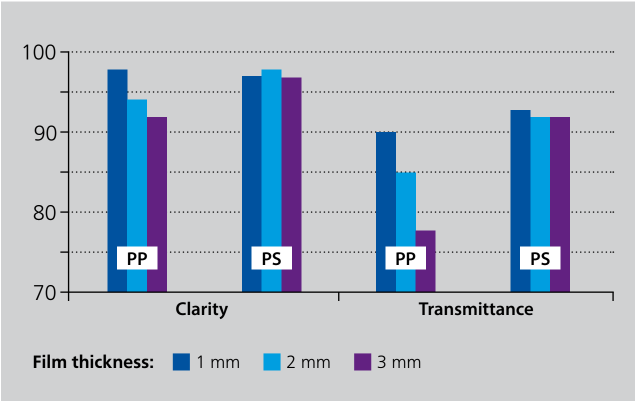
Accessories for Liquids
Cuvettes

Standardized sample preparation

Development of new film products and reliable QC of running production, both require objective measurement data. It is a prerequisite for meaningful evaluation of transparency to assure standardized sample preparation and measuring conditions. Besides defined sample thickness, it is important to take care that the sample is positioned flush against the measuring port. Depending on the product behavior this can be a challenge, especially for very thin films like shrink wrap. Due to its open measuring compartment, the haze-gard i enables usage and easy changing of film holders designed for different applications. The "Thin Film Holder" (cat. no. 4784) allows you to place films flat and crease-free at the instrument's opening.

Influence of sample thickness

As seen before, scattering can be caused by internal scattering or surface structures. Some resin types show stronger inner scattering than others. The graph below shows polypropylene and polystyrene sheets of different thickness. While the polystyrene samples don´t exhibit any significant thickness dependency, transmittance and clarity of the PP samples decrease with increasing thickness, as more scatterer come into play. Thus, in case of internal scattering, it is of strong importance to assure that only samples with the same thickness are compared, or in other words, the sample thickness is important additional information in the product specification sheet.



BYK-Gardner Solution

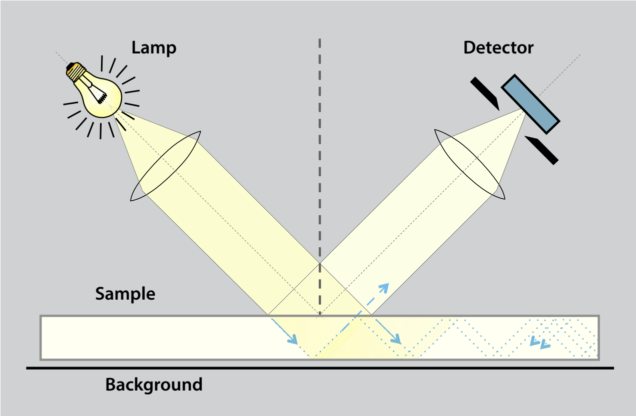
Transparency
haze-gard i

Solid Color & Gloss
spectro2guide

Drawdown Test Charts
byko-charts

Gloss of films

Besides transparency, high quality films require defined reflection properties, regardless if they are brilliant glossy packaging or non-glare films for LCD use. The internationally standardized method for measuring gloss illuminates the sample under a defined angle and detects the reflected light intensity. At transparent materials, a part of the illuminating light penetrates the surface. The transmitted light is reflected at the rear surface within the material and is partly transmitted into the direction of the sensor.



This additional reflection is dependent on the background used and has a significant impact on the measurement. To minimize this influence, it is recommended to use a black, matte background, e.g. paper board, and it is important to always use the same background.

It is additionally challenging when the samples are very thin and don´t form a really flat surface under the gloss meter. Therefore, often a vacuum plate is used to make sure no air bubbles or wrinkles distort the measured gloss results.

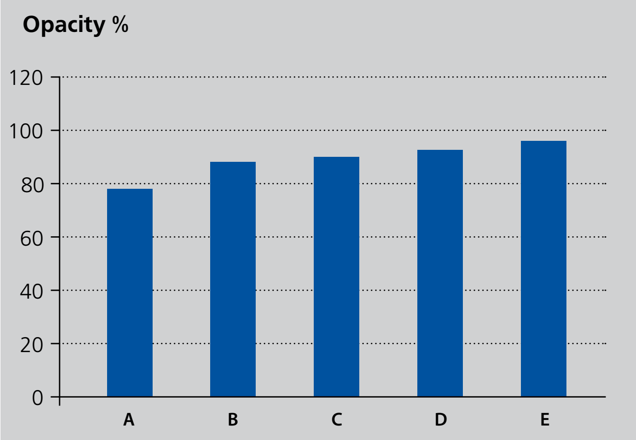
Opacity

In some applications the opposite of transparency is required, e.g. shopping bags or diaper backings, which need to keep its contents private. This behavior is called opacity and controlled by use of color measurement. The spectro2guide includes the respective index to automatically calculate opacity.

Opacity is the ability of a thin, transparent material to hide the surface behind. It is also sometimes referred to as contrast ratio and hiding power. Opacity is expressed as the ratio of the reflectance when the material is backed by a black substrate to the reflectance when it is backed by a white substrate.

$$\textbf{Opacity (\%)} = \frac{Y_{black}}{Y_{white}} \times 100$$

100 % opacity means complete hiding: no difference can be seen between the transparent material over black and white. For reproducible results, it is important to use always the same backing, therefore BYK-Gardner offers opacity charts which assure defined measurements. In the following graph the opacity of different types of sheet protectors were compared.



Gloss
micro-gloss

Transparency Accessory
black chart

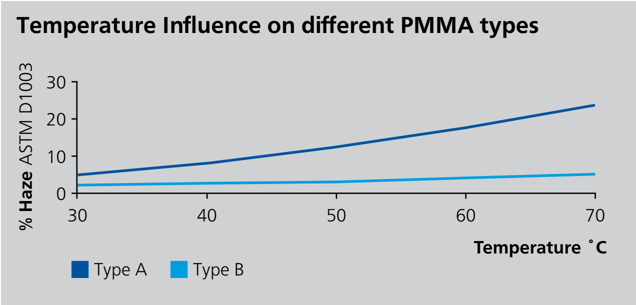
Transparent Sheets

Light weight and high design flexibility make transparent plastic sheets attractive for use as "organic glass" in many different applications e.g. noise barriers, green houses, sport arenas, sky domes, solar panels or bus stop shelters. In addition, rigidity and impact resistance of acrylic (PMMA) and polycarbonate (PC) sheets were optimized expanding its usage for safety and architectural glazing as well as for automotive, aircraft, yacht or caravan applications. Depending on the application, the transparency requirements will be very different and need to be objectively controlled – often within very tight specification.

Influence of material properties

Sheets for outdoor use need to withstand extreme weather conditions and require high rigidity over a long lifetime. As an example, PMMA typically shows increasing haze with higher temperatures and therefore, limits its use in e.g. automotive glazing where low haze is a crucial safety requirement. Material development has further allowed this behavior to improve and resulted in an optimized PMMA material with low temperature dependency ideal for automotive applications like rear windows.

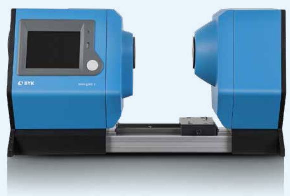
Automotive glazing is tested and approved in accordance to international regulations like e.g. ECE R43 or ANSI Z 26.1 in regards to mechanical, chemical and fire resistance, and last but not least transmission properties.



BYK-Gardner Solution

Solid Color & Gloss
spectro2guide

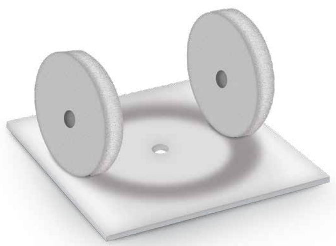
Gloss
micro-gloss

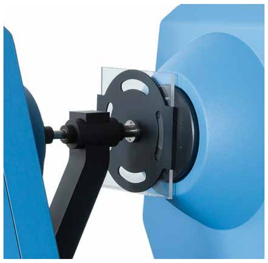


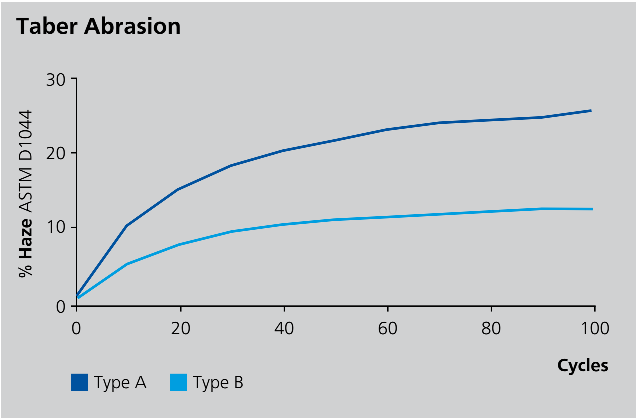
Transparency
haze-gard i

Abrasion resistance

A critical behavior of plastic materials has been their limited abrasion resistance, which in many applications requires additional efforts, such as modifications of the polymer or use of appropriate coatings. A widely used method for abrasion testing is the so-called Taber test according to ASTM D1044, where the sample is turned under abrasive wheels at defined conditions. After a certain number of cycles transmission haze is measured. To guarantee repeatable and representative readings, a special holder is available, which allows placement of the scrub mark exactly in the optical path of the haze-gard i.







As an example, the graph above shows the abrasion results of different uncoated PMMA types used for public and sport glazing.

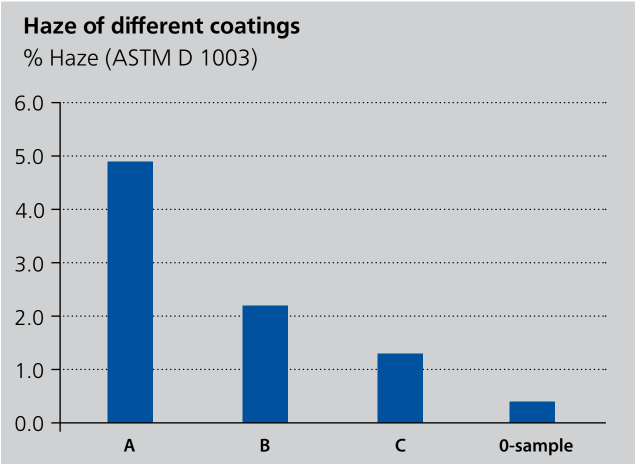
Film and Sheet Accessory
sample holder

Sheet Accessory
Taber abrasion holder

Wiper resistance test
In specific applications it is necessary to adapt a test method to the typical stresses during its real-world use. The wiper resistance test was developed to simulate accelerated abrasion by automotive windshield wipers under controlled laboratory conditions. Instead of rotating abrasive wheels, a linear back and forth motion of a wiper blade is applied to the sample under test. The test specimen is placed in a box filled with a defined suspension according to ISO 12-103-1 A4 at ambient temperature.

The complete test should be done for 20.000 cycles. After the test, the samples are to be cleaned with water.

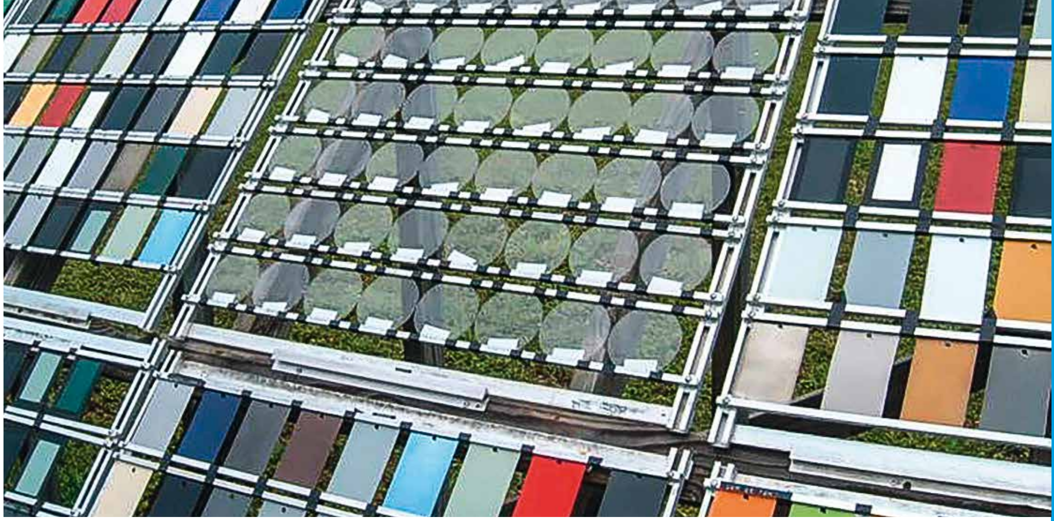
For the final evaluation, the transmission haze is measured with the haze-gard i. In order to generate a representative reading for abrasion resistance, the sample is measured at 9 positions within the center.



BYK-Gardner Solution

Abrasion Scrub Test
Wet Abrasion Tester

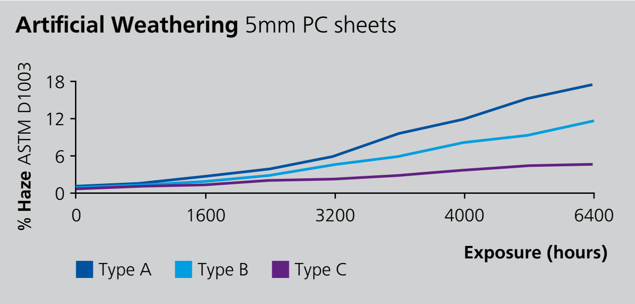
Abrasion Accessory
Modification Kit



Weathering stability

Outdoor applications like noise barriers, solar panels or automotive glazing are expected to reach a lifetime of several decades. Harsh weather conditions affect the stability and the transparency of plastic glazing. Today a wide range of plastics is available from photo stable types to UV stabilized polymers. Nevertheless, natural and artificial, accelerated weathering tests are necessary to evaluate the impact of heat, UV light and humidity to the products quality. Therefore, transmission haze and gloss are measured after certain exposure periods.

The following example shows the haze results of different polycarbonate samples after artificial weathering.



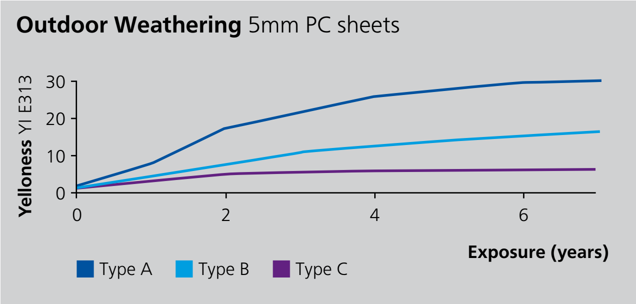
As the degradation is usually not homogenous within one sample a statistical evaluation of several measurements is highly recommended. Additionally, only samples of the same thickness should be compared.

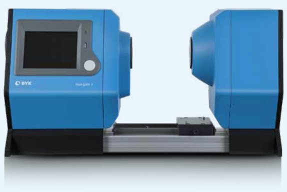
Yellowness

Another critical aspect of weathering is the tendency of polymers to change its color mainly turning yellowish, which is typically caused by a reduced transmission in the blue spectral range. Yellowing is evaluated by measuring the color in reflection mode with a white background. It is recommended to always use the same backing and only samples of the same thickness.

The spectro2guide – a portable spectrophotometer which easily can be used at the outdoor weathering station, measures the spectral distribution and the CIELab color coordinates. Often only the yellowness index according to ASTM YI E313 or YI D1925 is used as a quick check.

In the following example, different modifications of polycarbonate were exposed to natural weathering for several years.





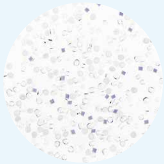
Transparency
haze-gard i

Film and Sheet Accessory
sample holder

Solid Color & Gloss
spectro2guide

BYK-Gardner Solutions for Transparent Products

Raw Materials - Granulate



Molded plaques/films

Very thin films

Accessory
- Film and Sheet Holder
- Thin Film Holder
- byko-charts for opacity check

Films and Foils

Films and foils

Very thin films

Accessory
- Cuvette table with cuvettes for "Inner Haze" control
- Film and Sheet Holder
- Thin Film Holder
- byko-charts matte for gloss measurement
- byko-charts for opacity check

Transparent Sheets

Sheets and plates

Accessory
- Film and Sheet Holder
- Taber Abrasion Holder
- byko-charts matte for gloss measurement
- byko-charts for Yellowness check

Transparency Accessories

Film and Sheet Holder
Cat. No. 4788

Thin Film Holder
Cat. No. 4784

Cuvette Table
Cat. No. 4786

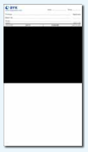
Cuvettes
Cat. No. 6180 - 6183

Haze Standard Set
Cat. No. 4795

Clarity Reference Standard
Cat. No. 4777

Transmittance Standard Set
Cat. No. 4783

byko-charts for opacity check
Cat. No. 2813

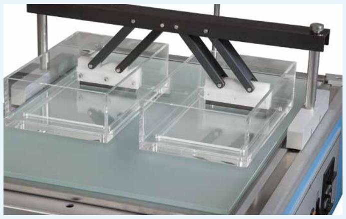


Uncoated byko-charts, matte
Cat. No. 2832

Black Scrub Panel
Cat. No. 5015

Taber Abrasion Holder
Cat. No. 4785

Wet Abrasion Tester
Cat. No. 5000



Modification Kit
Cat. No. 5094

For a live demo please view our videos on **www.byk.com**

BYK-Gardner Solutions for Transparent Products

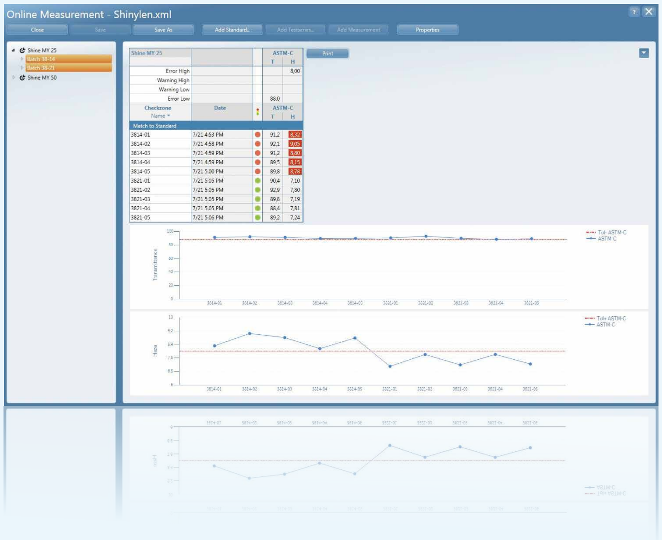
BYK-Gardner Objective Eyes

haze-gard i

The Objective Standard for a Clear View.

Cat. No. 4775

BYK-Gardner Software



smart-lab Haze

Online Measurement. Instant Data Analysis.

Cat. No. 4865

micro-gloss

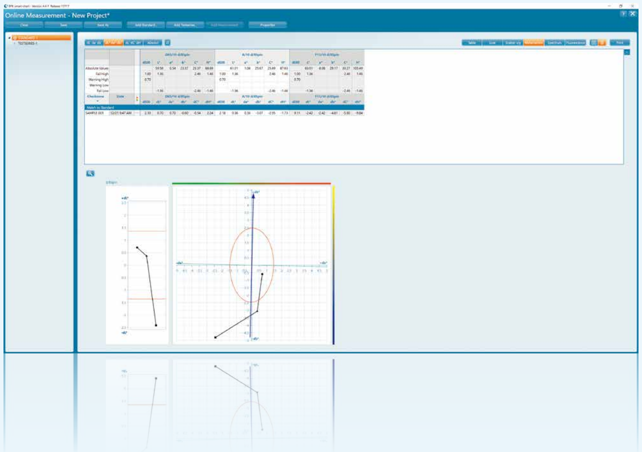
The New Intelligence in Gloss Measurement.

Cat. No. 4446 micro-TRI-gloss

spectro2guide

The revolution in portable color control.

Cat. No. 7070 spectro2guide, d/8 | Cat. No. 7075 spectro2guide, 45/0



smart-lab Color

Professional Standard Management and Documentation.

Cat. No. 7083

For a live demo please view our videos on **www.byk.com**

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