

### EVALUATION OF WEATHERING EFFECTS

#### Visual Inspections and Instrumental Measurements

It is important to properly quantify the results of any exposure testing program. Typically, the researcher is interested in the amount of change that his material experiences during the exposure. Change in some properties, like color or gloss, can be measured instrumentally. Other changes, like cracking, peeling, chalking, blistering, or rusting, can be evaluated visually and rated according to standard rating scales from ASTM or other technical organizations.

#### Frequency of Evaluations

Typically, the property of interest is measured or rated prior to exposure. Thereafter, periodic inspection and evaluation is necessary to quantify the progress of the test. Evaluations are commonly performed on a monthly or quarterly basis. Periodic evaluations can and should be used to chart the degradation over time. All of this is a crucial part of the comprehensive testing program.

#### Visual Evaluations

Although Visual Evaluations are subjective, they are extremely vital, for it is often the individual end user's perception that will determine whether a material's appearance is satisfactory. Visual Evaluations must be repeatable, and must be consistent with other people's perception. Because consistency is critical, visual evaluations must be done by a trained, experienced, specialist inspector.

When a customer requests a Visual Evaluation of a test specimen, the inspector will check for all observable defects, including those listed below. The inspector will rate the change according to the applicable scale.

<u>Possible Defect</u>	<u>Applicable Evaluation Methods</u>
Chalk (velvet)	ASTM D4214, ASTM D659
Blistering	ASTM D714
Cracking	ASTM D661
Checking	ASTM D660
Flaking/scaling	ASTM D722, ASTM D610
Erosion	ASTM D662
Mildew	ASTM D3274
Dirt Retention	ASTM D3274
Gray Scale Color Change	ASTM D2616, DIN 54001, ASTM D1729 AATCC EP1
Adhesion	ASTM D3359
Corrosion, Filiform	ASTM D2803
Corrosion, Rust Creep from Scribe	ASTM D1654
Corrosion, Rust Surface	ASTM D610, ASTM D1654

Visual evaluations of weathering effects are reported using the standard ASTM 10 to zero rating system. The scale is shown below:

The intermediate odd numbers may be used when the effect is obviously somewhere in between the other ratings.

Visual ratings are performed under standard lighting conditions, using the naked eye. Microscopic evaluations up to 10x are used for confirmation, or when necessary, as in the case of micro-checking.

<b>Quality</b>	<b>Rating</b>	<b>Change</b>
Excellent	10	As Received (no change)
		9 Very Slight Change (trace)
Very Good	8	Slight Change
Good		6 Moderate Change
Fair		4 Pronounced Change
Poor		2 Severe Change
Very Poor	0	Complete Failure

Note: A rating of 9 indicates the first noticeable change.

The pictorial standards depicted in the Federation of Societies for Coatings Technologies (FSCT) book, *Pictorial Standards of Coatings Defects*, are used to directly compare the defects on the test specimen with a defined numerical value. This assists our inspectors in producing repeatable evaluations and aids the client in visualizing the reported defect.

### **Instrumental Measurements of Appearance Properties**

Appearance is a critical attribute for many products and materials. The customer's perception of quality is often based on gloss, color, brightness, smoothness or some other appearance characteristic. Useful service life is often determined by the same characteristics. A product that is otherwise perfectly serviceable will often be discarded when its appearance fails to meet the customer's aesthetic requirements.

Since, by definition, appearance is a visual or aesthetic characteristic, it seems to be a contradiction to use instruments to measure it. However, appearance is usually a property of the surface (smoothness, reflectivity, color, etc.). Over the years instruments have been refined to closely agree with the human observation.

Objective measurements of appearance have several advantages over the subjective evaluations. Instrumental measurements provide a quantifiable measure of performance. They preclude the possibility of human bias because a machine will produce the same numeric values every time - if all conditions are repeated. Additionally, the numbers produced by these instruments form a continuous scale to which a number of statistical operations can be applied.

There are three main electro-optical instruments that are used in the weathering industry: Gloss, Distinctness of Image and Color. These are used to monitor the surface appearance properties of unexposed and exposed materials to gauge the useful life of a product.

### **Specimen Cleaning**

It is strongly recommended that all instrumental measurements on weathered surfaces be made on a washed section of the specimen. All of these measurements are highly sensitive to surface attachments such as dirt and mildew. These particles form a barrier layer over the test surface, and prevent the instrument from measuring the true surface. If the surface is dirty, the instrument will measure the dirt, not the surface.

### **Gloss Measurements**

Measurements of gloss are an essential part of many evaluation programs. They are particularly important for paints and plastics. Gloss is one of the first properties that is affected during weathering exposure. It is also one of the first aspects of appearance that appeals to the observer.

Instrumental gloss is the most widely used form of electro-optical surface appearance measurement. Instrumental gloss measures the overall shine of a surface. A gloss measurement consists of shining a beam of light onto a surface at a fixed angle and then sensing the percentage of that light that reflects at exactly the opposite angle (instead of scattering). A perfectly smooth surface would reflect everything at the angle of incidence and would therefore have a gloss value of 100.

Any surface roughness or other imperfection will cause a percentage of the light beam to scatter. This will reduce the amount of light that is recaptured and therefore reduce the gloss value.

The *gloss angle* refers to the angle (relative to the vertical) at which the light beam strikes the surface. The most common gloss angles are:

20 Degrees: This angle is used for very glossy surfaces when the 60° gloss value is over 70

60 Degrees: This angle is used for most intermediate gloss specimens.

85 Degrees: This grazing angle reading is used for low gloss surfaces when the 60° gloss value is less than 20.

*For a complete discussion of gloss measurement, consult ASTM D523 or ISO 2813.*

### **Distinctness of Image (DOI) Measurements**

When we look at an automotive paint finish, we see reflected images. The more clearly defined those images are, the better we feel about the finish. Distinctness of Image is easily affected by surface deterioration such as ripples, orange peel, micro-scratches, hazing, etc.

DOI is a specialized, more precise form of gloss measurement, using a 30 degree reflection angle. DOI uses a narrow, very highly focused, light beam. Regular gloss utilizes a much wider light beam. The DOI sensor measures the sharpness of the edge of the light beam and uses a 100-point scale, where perfect distinctness of image is 100.

*For a complete discussion of DOI measurement, consult ASTM E430.*

### **Color Measurements**

Instrumental color is the most complicated of all the electro-optical measurements. Color measurements are made by shining a light on the specimen and collecting the light that is reflected from the specimen. The wavelength spectrum of the reflected light is used to calculate numbers that are then used as a shorthand to describe the color of the measured object.

#### ***L a b* Color Space**

Most instrumental color readings use some form of the *L a b* color calculation to define color. In this system, three numbers are used to describe a color. Each of the three numbers refers to one of the three color coordinates:

*Lightness Factor.* The measured object's lightness or darkness is quantified by the "L" number on a scale of 0 to 100, where 0 = black, 50 = gray, and 100 = white.

*Red/Green Factor.* The object's redness or greenness is quantified by the "a" number. When the "a" value is a positive number, the measured object is a red color. The higher the number, the more red the object is.

When “a” is a negative number, the measured object is a green color. The larger the negative number, the greener the color. A value of zero for “a” would be exactly intermediate between red and green.

*Blue/Yellow Factor.* The object’s yellowness or blueness is quantified by the “b” number. When “b” is a positive number, the object is yellow. The larger the number, the yellower the object.

When the “b” value is a negative number, a blue colored object is indicated. The larger the number, the more intense the color. A value of zero for “b” would be intermediate between yellow or blue.

Any color can be described by its L a b coordinates. For example, a mauve color could have an L value greater than 50, a positive a value (red), and a negative b value (blue).

### **Color Measurement Issues**

Unlike gloss and DOI, there are a number of fundamental variations in the measurement conditions that can be used when making color measurements. In addition, there are a several different types of color measurement instruments in common use. Each will give slightly different measurements. For comparable measurements, each of the following measurement parameters must be consistent.

*Geometry (Reflectance or Sphere).* Color measurements are made by shining a light on the specimen and analyzing the spectrum of reflected light to generate the L a b numbers. The light sensor is, depending on instrument type, either a reflectance unit or a sphere. Reflectance units are usually described by the angle of incidence/reflection at the point of measurement, for example: 45/0 or 0/45.

*Observer Angle.* This is a straight choice between older and newer technology. Older color instruments used only a 2 degree observer. Newer devices use the 10 degree observer. Many newer instruments allow a choice to enable comparison with older devices.

*Illuminant.* Any one of several different light sources may be used to illuminate the specimen during measurement. Different sources may give different results.

*Specular Component.* The specular component is the glossy reflection that the illuminant produces. On sphere instruments the specular component may be either included or excluded from the reflected light. The specular component cannot be excluded when using reflectance devices (e.g., 0/45 geometry).

*Calculations of Color Change.* Color change is calculated as the difference in the L a b values before and after exposure. The term “delta” ( $\Delta$ ) is used to denote the difference. Therefore  $\Delta$  = current measurement - original measurement. The larger the  $\Delta$  number, the larger the color change. Thus  $\Delta L$  is the change in the Lightness Factor.  $\Delta a$  and  $\Delta b$  are treated in the same manner:

- +  $\Delta L$  means there has been a lightening of the color
- $\Delta L$  means there has been a darkening of the color
- +  $\Delta a$  means more red (or less green)
- $\Delta a$  means more green (or less red)
- +  $\Delta b$  means more yellow (or less blue)
- $\Delta b$  means more blue (or less yellow)

A total color change value of *delta E* ( $\Delta E$ ) is calculated as composite of all three factors and is widely used as pass-fail criteria for exposed materials.

*Color Scales.* The color of the measured object is normally reported in one of several recognized color scales: *CIE L a b*, *Hunter L a b*, or *CIE XYZ*. The CIE and Hunter Lab scales are widely used and based on similar calculations. The XYZ scale is not much used anymore.

Certain specialized color indexes are also used to determine specific changes. *Yellowness Index* (YI) and *Whiteness index* (WI) are used to evaluate color on near white opaque materials, such as TiO<sub>2</sub> pigments. These scales were originally visual, but have been converted into instrumental, calculated values to compare with the old visual data.

For a discussion of instrumental color measurement, consult ASTM D2244. Excellent publications are available on the theory and practice of color measurement from all of the major color-measurement equipment manufacturers.

### **Conclusion**

Because useful service life is often based on aesthetic or other visual considerations, it is frequently important to quantify any changes in the appearance of a weathered test specimen. There are a number of techniques available. Visual evaluations, if performed by an expert, allow good qualitative and quantitative ratings. When applicable, instrumental measurements are especially useful because of their objectivity. Both visual and instrumental evaluations are a crucial part of a comprehensive testing program.