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Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Water-cooled Xenon Arc Apparatus

1. Scope

- 1.1 This test method specifies the operating procedures for a controlled irradiance, water cooled xenon arc apparatus used for the accelerated exposure of various automotive materials.
- 1.2 The sample preparation, test durations, and performance evaluation procedures are covered in material specifications of the different automotive manufacturers.

2. References

- 2.1 **Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply

- 2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1545—Instrumental Color Difference Measurement for Exterior Finishes, Textiles, and Colored Trim

- 2.1.2 ASTM PUBLICATION—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 859—Standard Test Method for Silica in Water

ASTM D 4517—Standard Test Method for Low-Level Total Silica in High-Purity Water by Flameless Atomic Absorption Spectroscopy

ASTM G 155—Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

3. Definitions

3.1 Black Panel Thermometer, n

- 3.1.1 A temperature measuring device, the sensing unit of which is coated with black enamel designed to absorb most of the radiant energy encountered in fade/weathering testing.

- 3.1.1.1 This device provides an estimation of the maximum temperature a specimen might attain during exposure to natural or artificial light.

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SAE WEB ADDRESS:

- 3.2 Center Wavelength, n**—The specified wavelength for bandpass filters; the wavelength midway between the half power points (e.g., 340 nm $\pm$ 2 nm).
- 3.3 Color Change, n**—As used in fade-weathering testing, a change in color of any kind (whether a change in hue, saturation, or lightness).
- 3.4 Half Power Bandpass, n**—The interval between wavelengths at which transmittance is 50% of peak. (It should not exceed 20 nm for a narrow bandpass filter.)
- 3.5 Irradiance, n. (E)**—The incident radiant flux per unit area of a surface. (W m^{-2})
- 3.6 Irradiance, Controlled, n**—The maintenance by closed loop feedback of a preselected irradiance throughout a designated exposure interval.
- 3.7 Irradiance, Spectral, n**—(E_λ) Irradiance per wavelength interval. ($\text{Wm}^{-2} \text{nm}^{-1}$).
- 3.8 Irradiance, Total, n**—(W m^{-2}) Irradiance integrated over all wavelengths of a light source on an exposed surface.
- 3.9 Irradiation, n**—See radiant exposure.
- 3.10 Long-Arc Xenon, n**—A xenon arc in which the length of the arc between electrodes is greater than the diameter of the envelope enclosing the arc.
- 3.11 Peak Wavelength, n**—The wavelength of peak transmission (e.g., 340 nm).
- 3.12 Radiant Exposure, n**—The time integral of irradiance (Jm^{-2}).
- 3.13 Radiant Exposure, Spectral, n**—The time integral of spectral Irradiance ($\text{Jm}^{-2} \text{nm}^{-1}$).
- 3.14 Reference Plastic, n**—A clear polystyrene plastic standard selected for exposure as a check on a test apparatus and operating conditions.
- 3.15 Sample, Laboratory, n**—A portion of material taken to represent the lot sample, or the original material, and used in the laboratory as a source of test specimens.
- 3.16 Specimen, n**—A specific portion of a material or a laboratory sample on which a test is performed or that is selected for that purpose.
- 3.17 Spectral Power Distribution, n**—The relative power emitted by a source as a function of wavelength.

4. Significance and Use

- 4.1** This test method is designed to accelerate extreme environmental conditions encountered outside a vehicle such as sunlight, heat, and moisture (in the form of humidity, condensation or rain) for the purpose of predicting the weatherability of automotive materials.

5. Apparatus

5.1 A more complete description of the apparatuses listed below may be found in ASTM G 155.

5.2 The apparatus employed utilizes a water-cooled xenon arc lamp as the source of radiation and should be one of the following:

5.2.1 TYPE AH—A controlled irradiance apparatus in which the radiant energy source is vertically located at the central axis of a specimen rack. The specimen rack shall rotate at $1 \text{ rpm} \pm 0.1 \text{ rpm}$ and shall be of the three-tiered, inclined type having a center segment of $648 \text{ mm} \pm 6 \text{ mm}$ ($25.5 \text{ in} \pm 0.25 \text{ in}$) outside diameter centered on the xenon arc lamp. The top and bottom segments shall be $511 \text{ mm} \pm 6 \text{ mm}$ ($20 \text{ in} \pm 0.25 \text{ in}$) outside diameter, positioned $28 \text{ degrees} \pm 2 \text{ degrees}$ from the vertical. Each segment shall accommodate 152 mm (6 in) specimen holders. The apparatus shall provide for control of dry bulb and black panel temperature, relative humidity, and irradiance at 340 nm^1 .

5.2.2 TYPE BH—A controlled irradiance apparatus in which the radiant energy source is vertically located at the central axis of one of the following two racks:

5.2.2.1 The specimen rack shall rotate at $1 \text{ rpm} \pm 0.1 \text{ rpm}$ and shall be of the three-tiered, inclined type having a center segment of $965 \text{ mm} \pm 6 \text{ mm}$ ($38 \text{ in} \pm 0.25 \text{ in}$) outside diameter centered on the xenon arc lamp. The top and bottom segments shall be $842 \text{ mm} \pm 6 \text{ mm}$ ($33.16 \text{ in} \pm 0.25 \text{ in}$) outside diameter, positioned $22 \text{ degrees} \pm 2 \text{ degrees}$ from the vertical. Each tier shall accommodate 152 mm (6 in) specimen holders. The apparatus shall provide for automatic control of temperature, relative humidity, and irradiance at 340 nm^1 . All specimen exposure openings may be used.

5.2.2.2 The specimen rack shall rotate at $1 \text{ rpm} \pm 0.1 \text{ rpm}$ and shall be of the two-tiered, inclined type, $965.2 \text{ mm} \pm 6 \text{ mm}$ ($38 \text{ in} \pm 0.25 \text{ in}$) outside diameter in the center. The top and bottom segments shall be $872.5 \text{ mm} \pm 6 \text{ mm}$ ($34.35 \text{ in} \pm 0.25 \text{ in}$) outside diameter positioned $11 \text{ degrees} \pm 2 \text{ degrees}$ from the vertical. The rack shall be positioned so that the exposure area is centered on the xenon lamp. Each tier shall accommodate 254 mm (10 in) long specimen holders. The apparatus shall provide for automatic control of temperature, relative humidity, and irradiance at 340 nm^1 . When using this two-tiered specimen rack, the test specimens shall not be placed in positions 1 and 8 (see Figure 1).

5.2.3 The xenon arc employed shall be of the "long-arc" water-cooled type. It shall employ cylindrical inner and outer optical filters to direct the flow of cooling water and to provide a selected spectral power distribution.

5.2.4 Distilled or deionized water shall be recirculated past the burner at a flow rate sufficient to remove excess heat. Passing water through a cartridge demineralizer installed in the recirculation line just ahead of the lamp minimizes contamination of the quartz envelope of the burner. A heat exchange unit shall be used to cool the recirculated lamp water.

6. Apparatus Setup

6.1 To insure repeatability of tests, maintain and calibrate the apparatus to manufacturer's specifications and as described in Appendix A and B. Appendix A contains additional maintenance instructions and replacement schedules, and Appendix B describes the use of a reference plastic to determine if the xenon arc apparatus is operating properly within the desired range.

6.1.1 The input voltage must be between 215 to 250 V.

1. The Ci35, Ci35A Xenon Arc Weather-Ometer® or equivalent with factory installed air heater meets the requirements of Type AH. The Ci65 and Ci65A Xenon Arc Weather-Ometer® or equivalent with factory installed air heater meets the requirements of Type BH.

- 6.1.2 Water for lamp cooling must be purified so that it is free of silica and has no more than 20 ppm total dissolved solids.
- 6.1.2.1 Water used for the specimen spray and humidification system shall leave no objectionable deposits or stains on the exposed specimens. It is strongly recommended that the water contain a maximum of 1-ppm solids and a maximum of 0.2-ppm silica. Silica levels should be determined using ASTM procedures D 859 or D 4517. A combination of deionization and reverse osmosis treatment can effectively produce water with the desired purity.
- 6.1.3 Install the specimen spray and the rack spray units.
- 6.1.4 Fit the xenon arc burner with a quartz inner filter and a "Type S" borosilicate outer filter.

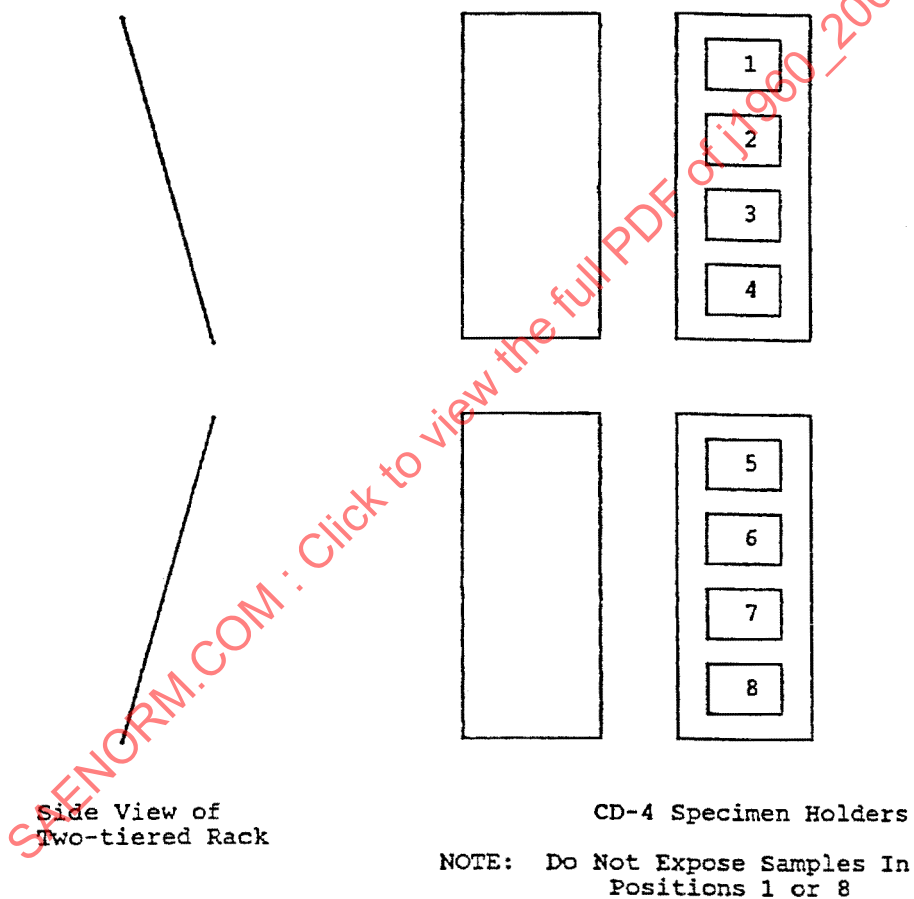


FIGURE 1—TWO-TIERED INCLINE SPECIMEN RACK

- 6.1.5 Set the operation switches/controls as follows in Table 1:

TABLE 1—OPERATION SWITCHES/CONTROLS

SWITCH	SETTING
Black panel/ambient air	Black panel
Wattage adjustment	Automatic
Irradiation/timed	Irradiation
Countdown meter	Set to required $\text{kJ m}^{-2} \text{nm}^{-1}$ at 340 nm
Lamp ignition	On
Lamp cooling water	On
Fixed air valve	Off
Humidifier	On
Water heater	On
Air heater	On
Specimen spray	On
Rack spray	On
Under the circuit breakers/mode switch cover, set the following:	
Air heater on cycle	Light-on cycle
Rack spray light cycle	Off
Test chamber/high temperature adjust.	75 °C

If the proper humidity cannot be achieved, set the air heater switch to dark-on cycle.

- 6.1.6 Set the thumb wheel controls as follows in Table 2:

TABLE 2—THUMB WHEEL CONTROLS

Controls	Dark Cycle	Light Cycle
Automatic/irradiance	—	$0.55 \text{ W m}^{-2} \text{nm}^{-1}$ at 340 nm
Black panel temperature	38 °C	70 °C
Wet bulb depression (See 6.1.6.1)	0.00 °C	12 °C
Conditioning water	40 °C	45 °C

- 6.1.6.1 These are suggested settings to obtain the specified humidity level. Because of ambient conditions in the room containing the apparatus, it may be necessary to adjust the wet bulb depression and/or the conditioning water temperature settings.

- 6.1.7 Choose the program cycle which provides 120 min of light and 60 min of dark in the following cycle: 40 min of light followed by 20 min of light and front specimen spray, followed by 60 min of light, followed by 60 min of dark with both back and front spray and repeating. The test cycle is shown in Table 3.

NOTE— Users of instruments that employ a program logic controller (PLC) should consult their manual for the appropriate program cycle. Others should use a #180 cam.

TABLE 3—TEST CYCLE

Cycle Segment	Light	Dark	Spray	Inner Filter	Outer Filter
1	N/A	60 min	Front and back	Quartz	S-Boro
2	40 min	N/A	None	Quartz	S-Boro
3	20 min	N/A	Front	Quartz	S-Boro
4	60 min	N/A	None	Quartz	S-Boro

- 6.1.8 Operate the apparatus to maintain the following tolerances listed in Table 4. If the actual operating conditions do not agree with the machine settings after the equipment has stabilized, discontinue the test and correct the cause of the disagreement before continuing.

NOTE 1—To maintain dry bulb tolerance, blower speed adjustment may be required.

NOTE 2—For instruments equipped with automatic blower control, for this test manufacturer recommends that the control be switched to the manual mode.

TABLE 4—TOLERANCES

Controls	Dark Cycle	Light Cycle
Automatic irradiance	—	$\pm 0.01 \text{ W m}^{-2}$
Black panel	$\pm 2 \text{ }^{\circ}\text{C}$	$\pm 2 \text{ }^{\circ}\text{C}$
Dry bulb	$38 \text{ }^{\circ}\text{C} \pm 2 \text{ }^{\circ}\text{C}$	$47 \text{ }^{\circ}\text{C} \pm 2 \text{ }^{\circ}\text{C}$
Relative humidity	$95\% \pm 5\%$	$50\% \pm 5\%$
Conditioning water	$\pm 4 \text{ }^{\circ}\text{C}$	$\pm 4 \text{ }^{\circ}\text{C}$
Radiant exposure	See applicable specification.	See applicable specification.

- 6.1.8.1 The tolerances do not apply during the spray portion of the cycle.

- 6.1.9 Adjust the temperature of the lamp cooling water to provide sufficient cooling but prevent condensation from forming on the lamp assembly. Suggest $50 \text{ }^{\circ}\text{C}$ for cooling water and $70 \text{ }^{\circ}\text{C}$ for high temperature cut out.

7. Test Procedure

- 7.1 Prepare a specimen to be exposed to fit the specimen holder being used.

- 7.1.1 Specimen sizes must conform to the size of the approved specimen holder. Specimens that exceed these sizes may not give proper exposure results. The correct means of mounting odd sized specimens can be obtained from the automotive company for which the material is being tested.

- 7.1.2 Approved frames for the three-tier rack are the SL-3T and the CD-3T only.

- 7.1.3 Approved frames for the two-tier rack are the SL, CD, SL-X, and the CD-4 only.

- 7.2 Insert the specimen in the specimen holder and attach the spring-loaded holding device.

NOTE—If the apparatus has an inclined panel rack (supplied with attached clips), the samples must fit the provided spaces.

- 7.3 Fill all unused slots with an inert non-reflective material to maintain desired airflow. Anodized aluminum panels are an example.

NOTE— High reflectance material may effect the operation of the equipment. Refer to the manufacturer's instructions for proper operation of the equipment.

- 7.4 After setting up the instrument to run for the required radiant exposure (kJm^{-2}) at 340 nm, start the test at the beginning of a dark cycle. See applicable material specification.

- 7.5 Report the change in color or any other property as outlined in SAE J1545.

7.6 Exposure report.

- 7.6.1 A copy of the exposure report (Figure 2) must be included with each exposed specimen being submitted for approval.

XENON ARC REFERENCE MATERIAL CONTROL CHART

LABORATORY	INSTRUMENT TYPE & SERIAL NUMBER	MONTH / YEAR	TEST METHOD	IRRADIANCE CONTROL LEVEL
REFERENCE MATERIAL LOT #	FREQUENCY OF READINGS	CIELAB DELTA (Δb) REQUIREMENTS	For Data Points Outside of the Control Points/Equipment Malfunctions/Dev from Test Method, see Comments Below.	
COMMENT				

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31									
Reference Material #1																																								
Reference Material #2																																								
Black Panel Temperature																																								
Dry Bulb Temperature																																								
Sample Data	Sample ID										Radiant Exposure (kJm^{-2})										Start Date										End Date									

FIGURE 2—Xenon Arc Reference Material Control Chart

8. Notes

- 8.1 Marginal Indicia**—The change bar (I) located in the left margin is for the convenience of the user in locating areas where revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

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APPENDIX A

MAINTENANCE INSTRUCTIONS AND REPLACEMENT SCHEDULES

A.1 Maintenance

A.1.1 Test Chamber—The frequency of cleaning will vary with water quality. However, the chamber should be cleaned at least once a month with a stainless steel cleaning agent and flushed with deionized water. Do NOT use cleaning agents containing chlorine.

A.1.2 Conditioning Chamber—The frequency of cleaning will vary with the water and air quality in the laboratory. However, the chamber should be drained once a month and flushed with deionized water to remove sediment.

A.1.3 Lamp Assembly—Frequency of cleaning will vary with water quality. However, at least once each week wipe the outer surface of the outer filter with alcohol and a soft cloth. If deposits cannot be removed, replace the filter.

A.1.4 Quartz Light Rod—Clean weekly the end of the light rod with alcohol and a soft cloth.

A.1.5 Black Panel Sensor—Polishing monthly, using a good quality automotive polish, should be adequate. The need for more frequent polishing may indicate a problem. For resolution, contact the manufacturer.

A.1.6 Spray Nozzles—Check daily for any signs of clogging. If continual clogging occurs, additional filters may be necessary in the distilled water lines supplying the instrument.

A.2 Replacement Schedule

A.2.1 Lamp assembly and related parts.

A.2.1.1 Replace the inner filter when the specified irradiance level can no longer be achieved or after a maximum of 1000 h of operation.

A.2.1.2 Replace the outer filter when the specified irradiance level can no longer be achieved or after a maximum of 1000 h of operation.

A.2.1.3 Replace the burner tube when the specified irradiance level can no longer be achieved or when the black panel temperature can no longer be controlled.

A.2.1.4 Replacement of the interference filter located in the light monitoring system after 9000 h of operation in the light cycle or 18 months of use, whichever comes first. Earlier replacement may become necessary if after replacement of lamp and filters, the wattage level does not return to normal. Refer to the operators manual.

A.2.2 Replace the black panel sensor when local surface luster can no longer be maintained or when bare metal can be seen.

A.2.3 Inspect the wet bulb wick weekly and replace when discoloration or mineral deposits are observed.

A.3 Calibration Checks

A.3.1 Check daily the switches and thumb wheel controls for proper settings.

A.3.2 Calibrate the apparatus every two weeks following the procedures detailed in the operating manual provided by the manufacturer. It is suggested that the calibration be performed on the same day of the week.

A.3.3 When proof of calibration is required, contact specific Automotive manufacturers for the appropriate reporting forms.

A.3.4 Calibration records are maintained using the recording form as provided in Figure A1. Set point may differ depending on the model of apparatus used. Refer to the operating manual provided with the equipment for the exact requirements.

A.3.5 The use of the "Temperature Calibration PC Board," provided by the manufacturer, is a requirement for the every two week calibration of the apparatus. This replaces the biweekly use of the hot and cold-water method which may be outlined in the instrument's operating manual. Complete adherence to the manufacturer's instructions for calibration using this "PC board" is mandatory.

RECORD OF EQUIPMENT CALIBRATION

COMPANY/AREA: _____ EQUIPMENT TYPE: _____
 MODEL NUMBER: _____ SERIAL NUMBER: _____
 XENON LAMP OPERATING HOURS: _____ CALIBRATION LAMP OPERATING HOURS: _____
 OUTER FILTER OPERATING HOURS: _____ INNER FILTER OPERATING HOURS: _____
 LAST CALIBRATION DATE: _____ CURRENT DATE: _____

CALIBRATION POINTS	SET POINT	DATE							
		first read	final read	first read	final read	first read	final read	first read	final read
Wattage Regulator	Min: Max:								
Light Measuring Circuit									
Irradiance Zero	0.00								
Irradiance Thumbwheel Span	0.10vdc								
Integrator Zero									
Integrator Reference									
Integrator Span									
Irradiance Thumbwheel	Min: Max:								
Calibration Lamp	Irradiance Wattage								
Black Panel Temperature	Min: 0.0 Max:100.0								
Dry Bulb Temperature	Min: 0.0 Max:100.0								
Wet Bulb Temperature	Min: 0.0 Max:100.0								
Depression	Min: 0.0 Max:100.0								
Conditioning Water	Min: 0.0 Max:100.0								

FIGURE A1—EQUIPMENT CALIBRATION RECORD

APPENDIX B

PROCEDURE FOR DETERMINING COLORFASTNESS TO LIGHT

B.1 Scope

B.1.1 Appendix B describes the procedure for using a clear polystyrene lightfastness standard as a reference plastic for the purpose of determining whether the xenon arc apparatus is operating properly.

B.1.2 The color difference values in CIELAB units are obtained by instrumentally measuring the reference plastic before and after a specified amount of radiant exposure.

B.1.3 The clear polystyrene lightfastness standard may be exposed for equivalent kilojoule periods from two to seven days. The reference plastic may be obtained from Test Fabrics, Inc., 415 Delaware Avenue, West Pittston, PA 18643, Phone 570-603-0432.

B.2 Procedure

B.2.1 The instruments used to determine color difference for this procedure requires a capability for providing CIELAB illuminant D-65, 10 degree observer, specular included readings. No substitutions are permitted. Either a transmission or a reflection mode may be used.

B.2.2 Calibrate the instrument to be used for the color measurements to the manufacturers instructions.

B.2.3 Reflection Mode

B.2.3.1 Place a piece of unexposed reference plastic backed with the white tile used for calibration against the sample port of the instrument.

NOTE— IN ORDER TO PRESERVE THE SURFACE OF THE WHITE CALIBRATION TILE, IT IS RECOMMENDED THAT A SECOND CALIBRATION TILE BE PURCHASED FOR THESE MEASUREMENTS.

B.2.3.2 Take an initial reading. Save this reading and store it as your standard reading.

B.2.4 Transmission Mode

B.2.4.1 Place a piece of unexposed reference plastic in the proper location as instructed by the manufacturer.

B.2.4.2 Place the white tile used for calibration against the outer sample port of the instrument.

NOTE—IN ORDER TO PRESERVE THE SURFACE OF THE WHITE CALIBRATION TILE, IT IS RECOMMENDED THAT A SECOND CALIBRATION TILE BE PURCHASED FOR THESE MEASUREMENTS.

B.2.4.3 Take an initial reading. Save this reading and store it as your standard reading.

B.2.5 Place a piece of reference plastic in a specimen holder and attach the spring-loaded holding device.

B.2.6 Secure it on the specimen rack adjacent to the black panel thermometer Figure B1 and Figure B2.

B.2.7 Always start the exposure apparatus at the beginning of the dark cycle and expose the reference plastic for an equivalent radiant dosage period of two to seven days.

B.2.8 After the radiant exposure, remove the reference plastic from the apparatus.

B.2.9 Examine the surfaces for water spotting. If spotting is found, carefully remove it using a piece of water-saturated white cheese cloth. Thoroughly dry the reference plastic using another piece of white cheese cloth.

B.2.9.1 Care must be taken not to scratch the surface of the reference plastic as the measurement could be affected.

B.2.10 Repeat the color measurement steps specified in B.2.3 or B.2.4 on the exposed area of the reference plastic and determine the delta L^* , a^* , b^* , and E^* .

B.2.11 Compare the delta b^* reading to the graph chart for the cycle used.

B.2.11.1 The supplier is to provide graph charts with each purchase of the polystyrene chip.

B.2.12 If the delta b^* value does not fall within the predetermined value as established by the supplier, immediately run another polystyrene per Section B.2 for the shortest time interval. If the polystyrene reference standard continues to be out of specification, discontinue testing until the problem is corrected.

B.2.13 The polystyrene standard is to be run after every calibration (every two weeks) for the specified amount of kilojoules or hours. As each group of test specimens completes its specified radiant exposure, record and report as required by the customer the delta b^* values and the mean and standard deviation of the reference plastic used during the test period.

B.2.14 The intent of the polystyrene is to monitor the performance of the test. It is for Statistical Process Control (SPC) purposes. A point outside of the range does not necessarily invalidate the test.