Designation: G 179 – 04

Standard Specification for Metal Black Panel and White Panel Temperature Devices for Natural Weathering Tests[1]

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1. Scope

1.1 This specification provides specific information for the manufacturing and use of metal black and white panel temperature devices to measure temperatures that estimate highest maximum (black) and lowest maximum (white) temperatures of coated metal specimens during natural weathering tests.

1.1.1 The construction of a black or white panel has a significant effect on the indicated temperature. This standard describes a robust construction from the panels investigated, which has been shown to provide the highest, most consistent temperatures when compared side-by-side with other black panel constructions.

1.2 This specification includes details on design requirements and quantitative measurement techniques, which will lead to the proper selection of materials and use for black and white panel temperature sensors.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

NOTE 1—There is no equivalent ISO standard describing the selection and use of black panel sensors for natural weathering tests.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 523 Test Method for Specular Gloss

E 220 Test Method for Calibration of Thermocouples By Comparison Techniques

E 430 Test Methods for Measurement of High-Gloss Surfaces by Goniophotometry

E 772 Terminology Relating to Solar Energy Conversion

E 881 Practice for Exposure of Solar Collector Cover Materials to Natural Weathering Under Conditions Simulating Stagnation Mode

E 903 Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres

G 7 Practice for Atmospheric Environmental Exposure of Nonmetallic Materials

G 113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that use Laboratory Light Sources

2.2 *ISO Standard:*

ISO 4892-1 Plastics: Exposure to Laboratory Light Sources—General Guidance[3]

3. Terminology

3.1 The definitions given in Terminologies G 113 and E 772 are applicable to this practice.

4. Significance and Use

4.1 The measurement of the primary elements of weather; solar radiation, temperature, and moisture is necessary to quantify the weather conditions during exposure in natural weathering (outdoor) tests. This practice is applicable to weathering tests described in Practices G 7, G 24, or D 4141 (Method A) and other standards in which these standards are referenced.

4.2 The surface temperature of exposed materials depends primarily on the amount of radiation absorbed, the emissivity of the specimen, the thermal conduction within the specimen, and the heat transfer between the specimen and the air in contact with the specimen surface and specimen holder. Since it is often not practical to measure the surface temperature of individual test specimens, a specified black or white panel temperature sensor is used to measure a reference temperature. This reference temperature provides an indication of the temperature of a black or white specimen of similar construction to the panel sensor. It is important to locate the black or white panel sensor in proximity to the specimens, using the same support, so that it receives the same radiation and cooling conditions as the test specimen. For sites where multiple

[1] This specification is under the jurisdiction of ASTM Committee G03 on Durability of Nonmetallic Materials and is the direct responsibility of Subcommittee G03.02 on Joint Weathering Projects.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from the American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018.

exposure racks are used, a single black or white panel temperature measurement made at the site and at the same exposure orientation as the exposure racks is acceptable.

4.3 Black panels are used in weathering applications since they are an indicator of the maximum specimen temperature achieved during exposure due to the high solar absorptance of the black coating. White panels are used as an indicator of the lowest maximum specimen temperature.

4.4 Consideration must be given to the panel construction (for example, type of metal, type of sensor, sensor mounting, type of backing, coating system), as different configurations may give different results.

NOTE 2—At low irradiance, the temperature difference between backed and unbacked panels will be small compared to higher levels of irradiance. Backed panels also have a slower response time due to the insulating effects of the wood.

NOTE 3—In an effort to provide temperature comparisons between laboratory and natural weathering, some users have used the black panels described in Practice G 151 or ISO 4892-1 in natural weathering tests. Direct comparisons between black panel temperatures in laboratory and natural weathering should not be made unless correlation has been established. For instance, the temperature of specimens in a laboratory chamber with a black panel temperature of 60°C may be very different from the temperature of outdoor specimens when the outdoor black panel reads 60°C.

5. Reference Panel Types

5.1 Two types of reference panel sensors are commonly used in natural weathering tests: *(a)* Unbacked metal panels, or *(b)* Backed metal panels.

5.1.1 *Unbacked Panels*—These panels are mounted directly to the fixture by securing the top and bottom edges of the panel to the fixture. Ambient air can circulate on the front and back side of the panel to provide maximum cooling conditions for the panel.

5.1.2 *Backed Panels*—These panels are mounted onto a plywood substrate, which insulates the back of the panel. The panel and backing are then mounted on the exposure frame. Ambient air is only cooling the front side of the panel since the back side is insulated, resulting in higher surface temperatures.

NOTE 4—The selection of the proper type of panel backing is very important since the measured temperatures will be different. Typically, backed black panels are 5 to 10°C higher than unbacked black panels depending on the level of irradiance, wind speed, and other factors. If a more realistic exposure of the panel simulating test panel conditions is desired, the panel shall be mounted in the same manner (backed or unbacked) as the test panels.

6. Reference Panel Requirements

6.1 *Substrate*—Unless otherwise specified, the substrate shall be a flat cold rolled steel panel with nominal dimensions of 300 mm long, 100 mm wide, and 1.0 mm thickness.

NOTE 5—Less corrosive materials may need to be used if the black or white panel is used in a corrosive environment. If a corrosion resistant material is used as a substrate, an alternate construction method may be required. Alternate constructions may not compare to panel constructions described in this specification.

6.2 *Primer*—The panel shall be treated with an automotive technology zinc phosphate and coated with an automotive after-market grade two-component epoxy primer to ensure adequate corrosion resistance. Apply the two-component epoxy primer, according to the manufacturer's recommendations. Allow to air-dry for 24 h or baked at 30 min at 60°C (140°F). Sand primer with 320-400 grit sandpaper. Remove sanding residue with a final wash solvent and a clean cloth.

6.3 *Sensor*—The sensor shall consist of a Type T thermocouple (copper/constantan) meeting accuracy requirements of better than or equal to ± 1.0°C throughout the measuring range. The sensor shall be small enough to attach to the panel and have a known response throughout the expected temperature range. The thermocouple shall be attached to the panel by spot-welding it to the middle of the back side. The thermocouple junction must be in contact with the bare metal panel. Care shall be taken to provide support to the spot weld joint to avoid loosening of the connection. This can be achieved by adding a mounting point on the thermocouple lead, which can act as a stress relief for the junction.

6.4 Two coating colors are commonly used on temperature reference panels in natural weathering tests: *(a)* Black coating, or *(b)* White coating.

6.4.1 *Black Coating*—The top (exposed) surface of the panel shall be coated with a automotive technology high gloss black basecoat clearcoat system after the thermocouple sensor has been spot-welded to the panel. The coated panel shall absorb 90 % or greater at all wavelengths from 300 to 2500 nm per Test Method E 903.

6.4.2 *White Coating*—The top (exposed) surface of the panel shall be coated with a automotive technology high gloss white basecoat clearcoat system after the thermocouple sensor has been spot-welded to the panel. The reflectance of the white panel at all wavelengths between 300 nm and 1000 nm shall be 90 % or greater and 60 % or greater between 1000 nm and 2500 nm per Test Method E 903.

6.4.3 *Basecoat*—Wipe the prepared primer surface with a tack rag to remove dust and lint. Apply two to three coats of either an acrylic or a polyester basecoat, according to the manufactures recommendations. Allow 5 to 10 min flash off between coats and allow to dry for 30 min before applying clearcoat.

6.4.4 *Clearcoat*—Wipe prepared basecoat surface with a tack rag to remove dust and lint. Apply two coats of an automotive after-market two-component urethane clearcoat, according to the manufacturers recommendations. Allow 5 to 10 min flash off between coats. Allow to air-dry for 24 h or baked at 30 min at 60°C (140°F).

NOTE 6—ASTM subcommittee G03.02 has conducted natural weathering exposures on commercially available black coatings for a period of 6 years. For more information about this study and the coatings used see Appendix X1.

6.5 *Backing (Backed Panels)*—An exterior grade of 12 mm (nominal) thick plywood, with dimensions equal to the black panel, shall be used as the insulating backing for backed black panels. The panel shall be attached to the backing using corrosion resistant screws to ensure uniform contact between the panel and the wood substrate. The thermocouple lead shall be recessed in the wood the necessary distance to allow the panel to sit flat on the wood backing. The edges of the plywood shall be sealed with a wood sealer or paint to prevent moisture penetration. Follow the guidelines in Practice G 7 for replacement of plywood backing.

6.6 *Sensor Monitoring*—The temperature should be monitored at frequent intervals to provide accurate and complete data. A maximum allowable time interval for monitoring/recording panel temperatures is 6 min.

7. Calibration/Verification And Maintenance

7.1 The panels must be calibrated and verified for accuracy prior to placing it in service and on an annual basis.

7.2 Calibrate the panel, thermocouple, monitor system against ice and boiling water baths per Test Method E 220. Verify linearity against several mid range values.

7.3 Verification must be performed during the summer using natural sunlight under unobstructed sunlight conditions when wind speed is 8 km/h or less.

NOTE 7—ASTM subcommittee G03.02.01 is developing a procedure for conducting intercomparisons of black and white panels between sites.

7.3.1 The coated panels with their sensors attached shall be situated on either static test fixture normal to the sun (± 2°) or a tracking rack and allowed to stabilize for a minimum of 30 min prior to initiating measurement. If a static test fixture is used, measurements shall be performed within 1 hour of solar noon under unobstructed sunlight conditions to maximize solar radiant energy. If a tracking rack is used, measurements shall be performed within 3 h of solar noon under unobstructed sunlight conditions to maximize solar radiant energy. The sensor shall be connected to the appropriate readout device. Prior to performing the measurements, the data collection / readout device shall be calibrated per manufacturer's recommendations.

NOTE 8—Practice E 881, Table 2 and Annex X2, provides guidance on mounting fixtures perpendicular to the incoming solar radiation at different geographical locations at different times of the year.

7.3.2 Due to the absence of a standard reference material and temperature probes for this application, an intercomparison of a series of five panels shall be performed to confirm that all panels are within a ± 2°C tolerance. This procedure is essential in identifying any panel-to-panel discrepancies. Measurements shall be performed and data shall be collected for 1 h within 1 h of solar noon for under unobstructed sunlight conditions to maximize solar radiant energy. A minimum of five panels shall be placed between 10 mm and 25 mm of each other. The maximum allowable temperature difference between any two sensors is 2°C. If the difference is greater than 2°C, the sensor with the farthest measurement farthest from the mean of all measurements must be replaced and/or reattached to the panel and the verification procedure repeated.

7.3.3 At least one of the minimum five panels shall be retained as a primary reference temperature device. This primary reference device shall be stored in a cool, dry location per Practice G 147 (room temperature of 20 to 30°C and the relative humidity ideally should be less than 60 %) and shielded from any light source.

7.3.4 Verification of the remaining in-use panels will be made annually against the primary reference temperature device. The temperature difference between the in-use and primary reference panels must be within a ± 2°C tolerance. If the difference is greater than 2°C, the in-use panel's sensor shall be replaced and/or reattached to the panel and the verification procedure repeated.

7.4 Hemispherical spectral reflectance measurements should be performed in accordance with Test Method E 903 to verify solar absorptance prior to placing panels in service. If a lot of panels is placed in service, then measurement is only required on a representative panel from the entire lot. For black panels, if the solar absorptance falls below the requirements of 90 % at all wavelengths between 300 nm and 2500 nm, the panels must be replaced or re-coated and the verification procedure repeated. For white panels, if the reflectance requirements fall below 90 % at all wavelengths between 300 nm and 1000 nm or 60 % for wavelengths between 1000 nm and 2500 nm, the panels must be replaced or re-coated and the verification procedure repeated.

NOTE 9—Solar absorptance/reflection measurements can be made on a regular basis to monitor the degradation of the coating. If solar absorptance requirements are not met, the panels should be re-coated or replaced. If a panel is re-coated or replaced, the verification procedure shall be repeated.

7.5 Maintenance of the panel shall include a visual inspection of the panel for any coating defects or loose connections and a light wash using deionized water only and a soft cloth to remove any dirt that may have accumulated. Maintenance shall be performed at least monthly, but whenever possible, weekly.

8. Test Report

8.1 If the exposure test report contains panel temperature data, the test report shall indicate the type of panel used during the exposure test.

8.2 At a minimum, the daily maximum and minimum panel temperatures shall be reported.

9. Keywords

9.1 exposure; temperature; weathering

APPENDIX

(Nonmandatory Information)

X1. EVALUATION OF BLACK PANEL CONSTRUCTION OPTIONS

X1.1 *Effect of Solar Absorptance on Indicated Temperature*—ASTM Subcommittee G03.02.01 compared temperatures indicated by two steel black panels prepared with black coatings with slightly different solar absorptance measured according to Practice E 903.[4] One of the black panels was coated with a paint that had a solar absorptance of 93.6 % and the other black panel was coated with a black paint with 88.8 % solar absorptance. Temperatures indicated by each black panel were measured in Miami and in Phoenix at three sky conditions: *(1)* clear, *(2)* hazy, broken clouds, and *(3)* overcast. Table X1.1 shows the difference in temperature between the black panels with the higher and lower absorptance coatings. Under unobstructed sunlight conditions, the temperature indicated by steel black panel with the paint that used the 93.6 % absorptance coating was at least 2°C higher than that of the black panel that used the 88.6 % absorptance coating. The indicated temperature difference was less for partly cloudy sky conditions and was neglible for overcast sky conditions. This clearly indicates the need to calibrate black panels under unobstructed sunlight conditions.

TABLE X1.1 Temperature Difference between Black Panels with Black Coatings with 93.6 % Absorptance and with 88.8 % Absorptance

Sky Condition	Location	Average Difference (°C)
sunny	Arizona	2.6
	Florida	1.1
hazy/broken clouds	Arizona	2.1
	Florida	0.7
overcast	Arizona	0.2
	Florida	-0.5

X1.2 *Effect of Long Term Exposure on Solar Absorptance / Reflectance*—ASTM Subcommittee G03.02.01 has also conducted natural weathering tests in accordance with Practice G 7 in a dry desert environment (Phoenix, Arizona) on the steel black panels with the two black paints with the different solar absorptance and on a black anodized aluminum black panel.[5] These exposures were conducted out to six years. Periodic absorptance measurements were performed to evaluate the performance of the coatings.

X1.2.1 The hemispherical spectral reflectance from 300 to 2500 nm was measured in accordance with Practice E 903 on each panel at 6, 12, 24, 36, 48, 60, and 72 months. The percent solar reflectance was determined by integrating the spectral data against Air Mass 1.5 global and direct normal solar spectrum and is shown in Table X1.2.

TABLE X1.2 Percent Solar Absorptance of Three Different Black Coatings after Exposure

Months Exposed	DuPont Super Dulux Black Gloss Auto., direct/global	Rustoleum BBQ Black, direct/global	Black Anodized 6063 Aluminum, direct/global
6	94.5/94.5	89.5/90.5	89.3/90.0
18	93.1/93.2	88.5/89.1	89.0/89.3
24	93.1/93.1	88.1/88.7	88.9/89.5
36	93.9/93.8	87.7/88.2	89.3/89.8
48	94.4/94.3	88.1/88.6	90.5/91.1
60	94.4/94.3	88.0/88.5	90.6/91.1
72	94.4/94.4	87.8/88.4	90.8/91.4

X1.2.2 This data indicates that there are commercially available coatings that do meet the performance requirements of this practice and have proven to be durable over an extended exposure period. If these coatings are no longer available, similar tests shall be conducted on new coatings to evaluate their performance.

NOTE X1.1—Two out of the three coatings evaluated in this study are non-automotive and do not meet the absorptance requirements of this specification.

X1.3 *Evaluation of Black Panel Construction Options*—ASTM Subcommittee G3.02 has also evaluated a number of different construction options for black panels.[6] The objective of this evaluation was to identify a black panel construction that provided a robust bonding of the thermocouple to the panel, gave the highest indicated temperature, and provided very consistent temperature readings between replicate panels. This work is the basis for the black panel construction specified in this standard. Three different construction variables were evaluated: *(1)* substrate (aluminum and steel), *(2)* thermocouple location (front side and back side), and *(3)* thermocouple mounting technique (conductive epoxy adhesive, solder, spot weld). All constructions used an automotive black base coat with an automotive clear coat as described in this standard and were prepared by Advanced Coating Technologies. Spot welding or soldering the thermocouples to aluminum failed to produce a reliable bond, so these constructions were dropped from further consideration. Soldering on the front side of the steel panels was particularly difficult because the base coat / clear coat. Seven different constructions were evaluated. Table X1.3 shows these constructions, the number of the construction prepared and the number that was actually used to measure temperature. If the quantity of replicate panels used for measurement was less than the quantity prepared, it is an indication that the thermocouple bond failed during handling or shipping, and that the construction is not very robust. Solder

[4] Robbins, J. R. III, letter to members of ASTM Subcommittee G3.02, Progress Report—Black Panel Round Robin Study, January 27, 1988.

[5] Eoff, K. R., "Hemispherical Spectral Reflectance Test Report," DSET Report Number 3708602, March 6, 1997.

[6] Results from the evaluation of black panel constructions were reported to Subcommittee G3.02 by W. Ketola at the June 2001 meeting.

TABLE X1.3 Black Panel Constructions Evaluated by ASTM Subcommittee G3.02

Thermocouple Location	Thermocouple Mounting Technique	Substrate and Number of Panels Tested	
		Aluminum, # prepared / # tested	Steel, # prepared / # tested
Front side	Epoxy	1 / 1	1 / 1
	Solder	could not prepare	could not prepare
	Spot weld	could not prepare	4 / 2
Back side	Epoxy	1 / 1	1 / 0
	Solder	could not prepare	3 / 3
	Spot weld	could not prepare	3 / 3

and spot weld provided more robust bonds for the thermocouple to the panel. Solder or spot welding on the back side of the panel was the most robust construction.

X1.3.1 All black panel constructions were exposed on a single rack for four days. Temperature data was collected at one-minute intervals using data loggers. Two different data loggers were used. Statistical analysis indicated that there was no significant difference between the data loggers at the 95 % confidence level. The following conclusions were drawn based on analysis of the temperature data using EXCEL™ and MINITAB™.

X1.3.1.1 The construction giving the best repeatability for indicated temperature between replicate panels was steel, spot welding, thermocouple attached to the back side of the panel.

X1.3.1.2 Temperatures indicated by the steel panels were consistently significantly higher than for the aluminum panels (at the 95 % confidence level).

X1.3.1.3 For steel panels, higher temperatures were indicated when the thermocouple was attached to the back side than when the thermocouple was attached to the front side. For aluminum panels, there was no significant difference in temperature indicated by the front or back side mounting of the thermocouple.