



CRRC-1 STANDARD

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Advisory note: all referenced documents such as CRRC Agreements, Applications, Forms, Procedures or other items may be found at <http://www.coolroofs.org>

CRRC-1 STANDARD

Section S.1 - General

S.1.1 Scope

This standard covers specimen preparation and test methods for determining the initial and aged Radiative Properties of Roofing Products.

S.1.2 Significance and Use

This Standard provides a practice and method for testing and reporting the radiative properties of roofing products before and after a specified test exposure. The tests expose roofing specimens to specific tests, and to the exterior environment, throughout a specified time period. The test(s) provides a relative measure of the roofing product response to the test conditions. The standard does not purport to be representative of all conditions that roofing products experience in the field. Variations of the test conditions or specimen construction also affect the specimen response.

S.1.3 Units

The values are stated in SI units, which are regarded as the norm for this standard. All other values shall be shown in parenthesis and are provided for informational purposes only.

S.1.4 Advisory Notes

The text of the standard contains references to advisory notes that are provided as explanatory material. These advisory notes shall not be considered part of the standard.

S.1.5 Glossary of Terms

Unless otherwise expressly stated, the following words and terms shall have the meanings as indicated in this document.

Accredited Independent Testing Laboratory (AITL) - A testing laboratory that is accredited for compliance with ANSI/ISO/IEC Standard 17025 to test Roofing Products and is completely independent from any roofing product manufacturer or roofing product seller. Accredited shall be defined as achieving third-party evaluation accreditation by an organization accredited to ISO 17011.

Accredited Manufacturer Testing Laboratory (AMTL) - A testing laboratory affiliated with a roofing product manufacturer or roofing product seller that is accredited to test the Radiative Properties of Roofing Products. Accredited shall be defined as achieving third-party evaluation by a nationally recognized organization, such as the Cool Roof Rating Council, of the compliance with testing requirements in this standard, competence of testing, and proper calibration of equipment.

Batch - A single quantity of product processed at one time as a mixture or combination of raw materials.

Coating Thickness – The dry film thickness of a coating when applied to a substrate, measured in accordance with section S.2.5 of this standard.

Color Family - A pre-defined range of absolute Hunter “L,” “a,” and “b” color values that establishes the color space for a pre-defined set (group) of colors.

Color Family Additional Element - A Color Family Element that is not the Color Family Representative Element.

Color Family Binder/Resin Technology - General class of Factory Applied Coatings used in metal Roofing Products which are defined by the family of related binder/resin chemicals used to formulate such coatings.

Color Family Element - A uniquely formulated Roofing Product that is a member of a Color Family Group and that is either a Factory-Applied Roof Product Component that serves as the top coating on a factory coated metal Roofing Product or a metal Roofing Product that has as its top coating a Factory-Applied Roof Product Component.

Color Family Group - One or more Production Line Factory-Applied metal coatings or Factory-Coated metal Roofing Products that are rated by Roofing Company and have the same binder/resin technology, and that have color properties and Radiative Properties that fall within the ranges established for the respective Color Family.

Color Family Representative Element - A Color Family Element that is used to initially establish a Color Family Group.

Compound Product Rating - A product rating for two or more models which share the same surface formulation and same radiative properties.

Cooling Degree Day (CDD) - For any one day, when the mean temperature is more than 10⁰C or 50⁰F, there are as many degree-days as degrees Celsius or Fahrenheit temperature difference between the mean temperature for the day and 10⁰C or 50⁰F. Annual cooling degree-days (CDDs) are the sum of the degree-days over a calendar year. (*Source: ASHRAE Standard 169*)

Custom Color - A unique Roofing Product color developed for the owner of a specific building or group of buildings on the same site that is produced in limited quantities and for a limited duration. A Custom Color is not individually promoted in general product information and marketing materials.

Emittance, Thermal - The ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody radiator at the same temperature.

Estimate of Specimen Mean Standard Error - The specimen (rather than population) standard deviation divided by the square root of the number of specimens.

Factory-Applied Roof Product Component - A material or component made by an OM which is applied to a substrate in a factory or coating facility (i.e. not in the field).

Heating Degree Day (HDD) - For any one day, when the mean temperature is less than 18⁰C or 65⁰F, there are as many degree-days as degrees Celsius or Fahrenheit temperature difference between the mean temperature for the day and 18⁰C or 65⁰F. Annual heating degree-days (HDDs) are the sum of the degree-days over the calendar year. (*Source: ASHRAE Standard 169*)

Heterogeneous - Consisting of dissimilar or diverse ingredients or constituents.

Hunter “L,” ”a,” ”b” Color Values - A numeric measurement of a color’s lightness (L), redness/greenness (a) and yellowness/blueness (b).

Low-Sloped Roofing Product – Roofing products designed for installation with a slope of 2:12 or less.

Other Manufacturer (OM) - A manufacturer that supplies a Roofing Product, component or raw material to a Seller, either directly or indirectly. In the case of components or raw materials provided by the Other Manufacturer, they solely determine the Radiative Properties of the final Roofing Product. Manufacturers that supply Roofing Products to others for private label sales are also within the scope of this definition.

Population - A group of specimen values about which conclusions are to be drawn, such as a set of solar reflectance values determined from non-overlapping spots (small regions) that cover an entire test surface.

Population Mean - The arithmetic mean of the property values (e.g., solar reflectances) measured for all members of a population.

Population Standard Deviation - The square root of the arithmetic mean of the squares of the deviation from the population mean.

Radiative Properties - The Solar Reflectance and Thermal Emittance of a roofing product.

Radiative Properties, Aged - The Solar Reflectance and Thermal Emittance of a roofing product after three years of exposure to the weather at a test farm.

Radiative Properties, Rated - The Solar Reflectance and Thermal Emittance of a roofing product, which is reported by an independent entity.

Radiative Properties, Initial - The Solar Reflectance and Thermal Emittance of a roofing product determined from a specimen which is prepared or collected for the specific purpose of testing the Initial Radiative Properties.

Radiative Properties, Tested - The reported Solar Reflectance and Thermal Emittance of a roofing product as determined by an Accredited Laboratory.

Reflectance, Solar - The ratio of the reflected solar flux to the incident solar flux.

Reflectometer - A device that measures reflectance.

Relative Humidity (RH) - The ratio of the partial pressure or density of water vapor to the saturation pressure or density, respectively, at the same dry-bulb temperature, and barometric pressure of the ambient air. (*Source: ASHRAE Terminology of Heating, Ventilation, Air-Conditioning, & Refrigeration*)

Roofing Product, Fluid Field-Applied - A Roofing Product that is applied as a fluid in the field to a roofing substrate in order to improve the Solar Reflectance and/or Thermal Emittance, among other things.

Roofing Product, Production Line - A Roofing Product material that is not a Custom Color. Production Line Roofing Products are standard color offerings by the manufacturer and are promoted in general product information and in marketing materials.

Roofing Products, Standard - Production Line Roofing Products, excluding Color Family products.

Roofing Product, Variegated - A material with a varied surface color or which has discrete markings of different colors.

Specimen Mean - The arithmetic mean of the property values (e.g., solar reflectances) measured for all members of a specimen set.

Specimen Mean Standard Error - The population standard deviation divided by the square root of the number of specimens.

Specimen Set - A subset of the population, such as a set of non-overlapping spots (small regions) on a test surface.

Specimen Standard Deviation - The square root of the ratio of the sum of the squares of the deviation from the specimen mean to a number one less than the number of specimens.

Seller - A roofing product seller, limited to business entities that package, label and bring the Roofing Product to market.

Spot - A small region of a test surface, such as a 1 inch by 1 inch square or a 1 inch-diameter circle, whose solar reflectance can be measured.

Steep-Sloped Roofing Product - Roof products designed to be installed with a slope of greater than 2:12.

Test Farm Site - One of three locations where a product is placed for weathering exposure before the measurement of aged ratings.

Test Surface - A flat, opaque, and heterogeneous surface, such as that of a variegated, granule-covered asphalt shingle.

Test Surface Mean Solar Reflectance - The ratio of solar energy reflected from a test surface to the solar energy incident on a test surface, equal to the ratio of area-integrated solar reflectance to area.

Uncharacteristically Damaged- A specimen that is unusable after weathering exposure through no fault of sample preparation by the Seller or Other Manufacturer. Unusable refers to the inability to accurately measure the aged radiative properties of the product sample. Uncharacteristically damaged shall include, but not be limited to, the following: damage during transit of the product by improper handling; animal excrement that stained the sample; irreparable damage or destruction due to a natural disaster, such as a hurricane, tornado, flooding, or other disaster; or any other unforeseen event that might harm the sample beyond normal weather exposure.

S.1.6 References

ASHRAE

American Society of Heating, Refrigerating and Air-Conditioning Engineers

1791 Tullie Circle, NE

Atlanta, GA 30329-2305

www.ashrae.org

ASHRAE handbook – Fundamentals, 2005.

ANSI/ASHRAE Standard 169-2006 – Weather Data for Building Design Standards, 2006.

ASHRAE Terminology of Heating, Ventilation, Air Conditioning, & Refrigeration, 1991.

ASTM

ASTM International

100 Barr Harbor Drive

West Conshohocken, PA 19428-2959

www.astm.org

ASTM C1549-04, Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer.

ASTM C1371-04a, Standard Test Method for Determination of Emittance of Materials Near Room Temperature using Portable Emissometers.

ASTM D1669 -07 Standard Practice for Preparation of Test Panels for Accelerated and Outdoor Weathering of Bituminous Coatings.

ASTM D1730-03 (2003), Standard Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting.

ASTM D2244-07, Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color and Coordinates.

ASTM E772-05, Standard Terminology Relating to Solar Energy Conversion.

ASTM E891-87(1992), Tables for Terrestrial Direct Normal Solar Spectral Irradiance Tables for Air Mass 1.5. Note: Currently a withdrawn standard.

ASTM E903-96, Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres. Note: Currently a withdrawn standard.

ASTM E1918-06, Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field.

ASTM G7-05, Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials.

NOAA

National Oceanic and Atmospheric Administration

1401 Constitution Avenue, NW

Room 5128

Washington, DC 20230

www.noaa.gov

NOAA, Comparative Climatic Data – Average Relative Humidity.

Section S.2 - Conduct of Tests

S.2.1 Product Specimens

All candidate specimens used for the purposes of testing Initial Radiative Properties and Aged Radiative Properties shall be chosen by the Seller or OM. The Seller or OM shall be responsible for identifying each separate Roofing Product, material or component. Testing shall be in accordance with this section.

S.2.2 Solar Reflectance Tests

(A) Solar Reflectance tests shall be conducted based upon one of the following test methods, unless the roof product is listed in section S.2.2 (B) or S.2.2 (C). An air mass of 1.5 shall be used for E903, C1549 and CRRC-1 Test Method #1.

1. ASTM E903 in conjunction with E891-87 (1992).
2. ASTM E1918.
3. ASTM C1549.
4. CRRC-1 Test Method #1

Advisory note: The test procedure for CRRC-1 Test Method #1 is contained in Section S.4.

(B) Variegated Roofing Products. Test specimens of Variegated Roofing Products shall be tested for Solar Reflectance in accordance with ASTM E1918 or CRRC-1 Test Method #1.

(C) Presumed Non-Variegated Modified Bitumen Capsheets. Modified bitumen capsheets with non-continuous (particle) top coatings that are represented as non-variegated products shall be tested in accordance with the following requirements:

1. When test method E1918 is used to conduct initial testing no confirmation of non-variegated status is required.
2. When test method E903 or C1549 is used to conduct initial testing, the AITL shall first test the specimen as described below to confirm that the specimen is not a Variegated Roofing Product, as follows:

The AITL shall take a series of five (5) solar reflectance measurements approximately equidistant along a diagonal axis of the specimen. When any of the five Solar Reflectance measurements varies by more than 0.05 from the arithmetic average of all five measurements, then the product will be deemed to be a Variegated Product. The AITL shall reject these specimens and new specimens shall be submitted under the terms of Section S.2.2.B.

S.2.3 Thermal Emittance Tests

Thermal Emittance tests shall be conducted using equipment and procedures in accordance with ASTM C1371.

S.2.4 Color Family Elements- Instrumentally Measured Color Tests

For Color Family Elements, only, Color Family Element product specimens shall be tested for absolute Hunter "L", "a", and "b" values in accordance with ASTM D2244.

S.2.5 Fluid Applied Roofing Products-Coating Thickness Tests

(A) Fluid applied roofing products Coating Thickness tests shall be conducted based upon ASTM D1669.

(B) A thickness measurement shall be taken at five evenly spaced points on each of the nine product specimens. The average of the five measurements shall be used to determine the thickness of the coating on each specimen. The average thickness of the measured coating for a given specimen shall be within 20% of the manufacturer's recommended minimum thickness. A specimen which is not within this range shall not be used for ratings.

S.2.6 Requirements for Aged Testing

The following criteria shall be met to determine aged ratings:

(A) Test Farm Locations: Roofing product specimens shall be exposed in the following three locations representing three climate zones:

1. Hot/Humid climate with:

- Annual Heating Degree-Day (HDD) @ 18⁰ C of 111 (Annual HDD @ 65⁰ F of 200), and
- Annual Cooling Degree-Day (CDD) @ 10⁰ C of 5,263 (Annual CDD @ 50⁰ F of 9,474), and
- An average yearly relative humidity of 83% in the A.M. and 61% in the P.M.

2. Cold/ Temperate climate with:

- Annual Heating Degree-Day (HDD) @ 18⁰ C of 3,445 (Annual HDD @ 65⁰ F of 6,201), and
- Annual Cooling Degree-Day (CDD) @ 10⁰ C of 1,531 (Annual CDD @ 50⁰ F of 2,755), and
- An average yearly relative humidity of 80% in the A.M. and 62% in the P.M.

3. Hot/Dry climate with:

- Annual Heating Degree-Day (HDD) @ 18⁰ C of 750 (Annual HDD @ 65⁰ F of 1,350), and
- Annual Cooling Degree-Day (CDD) @ 10⁰ C of 4,681 (Annual CDD @ 50⁰ F of 8,245), and
- An average yearly relative humidity of 50% in the A.M. and 23% in the P.M.

The heating degree-day and cooling degree-day shall be determined in accordance with ANSI/ASHRAE Standard 169-2006. The average yearly relative humidity shall be determined in accordance with NOAA comparative climate data. Test farm location climate values shall be within plus or minus ten-percent (10%) of those values shown above.

Advisory note: *Examples of regions of the United States that comply with S.2.6 are, but are not limited to, the following:*

Hot/Humid climate: Miami, Florida.

Cold/Dry climate: Chicago, Illinois; Cleveland, Ohio; Youngstown, Ohio; Pittsburgh, Pennsylvania.

Hot/Dry climate: Phoenix, AZ.

- (B) Specimen Exposure Period: Specimens of each product shall be exposed for a minimum of three continuous years in accordance with specimen preparations in Section S.3. Specimens shall remain untouched for that minimum period, except for removal and reinstallation within the test farm as result of weather conditions that have the potential for damaging the test specimens. Said removal and reinstallation shall be in accordance with the policy and procedures of the test farm responsible for the safe-keeping of the specimens.
- (C) Specimen Mounting: Exposure for both metallic and nonmetallic materials shall be in accordance with ASTM G7. Specimens shall be mounted for exposure on plywood in such a way that there is no run off from one panel to another. Steep-Sloped Roofing Products are to be exposed at minimum recommended slope; Low-Sloped Roofing Products at low-slope, and products designated as both low- and steep-sloped are to be exposed at low-slope only.
- (D) Exposure Removal: After three-year exposure, the specimens are permitted to be removed for purposes of testing and reporting aged solar reflectance and thermal emittance results.
- (E) Testing of Exposed Specimens: The specimens shall be tested in accordance with Section S.2.
- (F) Exposure Notification: The Test Farm shall be responsible for notifying the Seller or OM of exposure start and end dates and any other pertinent information about specimen damage or unusual appearance. The Test Farm is also responsible for accurately labeling exposed specimens to match with exposure location.

S.2.7 Report of Results

Accredited Independent Testing Laboratories shall submit a report of Tested Radiative Properties, both Initial and Aged, to the Seller or OM for use in compiling a product rating application. For custom colors only, Accredited Manufacturer Testing Laboratories shall submit a report of Tested Radiative Properties, initial only, to the Seller or OM for use in compiling a product rating application.. The report shall contain information as required by the appropriate test method, and shall include the following information:

- (A) Name and address of the manufacturer.
- (B) Name and identification of roofing product.
- (C) Name and address of the testing agency, and name of person in responsible charge of test.
- (D) Test method(s) employed.
- (E) Thickness of top coating or material tested, if applicable.
- (F) Summary of data.

Section S.3 - Test Specimen Selection

S.3.1 General

Roof product specimen selection shall be determined in accordance with one of the following:

- (A) Section S.3.2 for Standard Roofing Products, when the roof product is not a Color Family Group, a Color Family Additional Element, a Custom Color, or a Variegated Product.
- (B) Section S.3.3 for Factory Colored Products. *Advisory Note: This section applies to factory-applied coatings and factory-coated metal products.*
- (C) Section S.3.4 for Custom Colors.
- (D) Section S.3.5 for Variegated Products.

S.3.2 Standard Roofing Product Specimen

(A) Specimen Selection:

Nine specimens shall be randomly selected from routine production and sent to an Accredited Independent Testing Laboratory for testing. These specimens shall be grouped into three sets:

- a) Three specimens from one Batch,
- b) Three specimens from a second Batch, and
- c) Another set of three specimens for which each of the two Batches must be represented.

This results in a total of four specimens from one batch and five from the other.

In order for a single-ply product to qualify for a Compound Product Rating the thinnest thickness shall be tested.

(B) Specimen Preparation:

Each specimen shall be at least 155 square centimeters (24 square inches) in size and shall be identified with the manufacturer's name, address, product name and/or model number, batch number and individual specimen number within each batch. Labels shall be designed to be durable for a period of four (4) years, during which specimens will be exposed to the environment.

1. Profiled Metal Roofing Products: Profiled metal roofing products shall be rated using flat specimens of the same color and material. Ratings for these specimens may be applied to standing seam, agricultural panel, and modular/metal shingle profile types. Exceptions: All other profile types of any solar reflectance shall be rated using profiled test specimens and the solar reflectance shall be measured using ASTM E1918.

(C) Substrate:

The Seller or Other Manufacturer shall be responsible for ensuring that product specimens are prepared on the appropriate substrate(s) according to the following provisions:

1. Non-Variegated Roofing Products: With the exception of Fluid Field-Applied coatings and Factory-Applied Roof Product Components, Non-Variegated Roofing Product specimens need not be applied to a substrate.

Advisory note: Non-Variegated Products may include, for example, single ply membrane, factory-coated metal, non-variegated asphalt shingles and capsheets.

2. Fluid Field-Applied Roofing Products: Shall be applied to the substrate(s) intended for end use or to a standard aluminum panel or to a substrate approved by the certifying agency. The standard substrate shall conform to 3003 H14 uncoated aluminum alloy in accordance with ASTM D1730. Alternative substrates shall be as

recommended by the manufacturer for field installation. Fluid Field-Applied Roofing Product specimens shall be applied at the minimum dry mil thickness or coverage recommended by the manufacturer for use in the field. The dry mil thickness shall be within 20% of the manufacturer's recommended minimum thickness and shall be verified upon initial testing by an AITL in accordance with ASTM D1669 and the procedures set forth in Section S.2.5 of this document.

3. **Factory-Applied Roof Product Components:** Factory-Applied Roof Product Component specimens shall be applied to the substrate(s) intended for end use or to a standard aluminum panel. The standard aluminum panel shall conform to 3003 H14 uncoated aluminum alloy in accordance with ASTM D1730.

(D) Radiative Properties Reporting:

The rated radiative properties of the product specimens shall be reported according to the following provisions:

1. *Initial* Rated Radiative Properties reported shall be no greater than the average of the initial test results of the specimens from Batches A and B.
2. *Aged* Rated Radiative Properties reported shall be no greater than the arithmetic average of the aged test results of each of the nine product specimens that undergo aging exposure.
3. In the event that a specimen is uncharacteristically damaged during weathering exposure, the specimen shall be removed from the calculation of the Aged Radiative Properties. As a result of such an occurrence, the Aged Rated Radiative Properties reported shall be no higher than the arithmetic average of the averaged results from each Test Farm Site.

Up to two product specimens per test farm site shall be permitted to be discarded if uncharacteristically damaged. Should all three specimens from one test farm site be uncharacteristically damaged, the Seller or Other Manufacturer shall re-test their products

S.3.3 Factory Colored Products

Advisory note: This section refers to both factory-applied coatings and factory-coated metal panels.

A Seller or Other Manufacturer shall establish a standard color or a Color Family Group. A Color Family group shall consist of the same Color Family Binder/Resin Technology. In establishing a standard color or Color Family Group, the standard color or a representative of the group shall be tested for radiative properties by an AITL and aged according to section S2.6. Concurrent rating of additional colors in the Color Family Group is permitted.

Color for an individual product or color family group shall be established using Hunter "L," "a," and "b" measurements, which are conducted on product specimens from two distinct Batches A and B. The reported values shall establish the color of the product.

Advisory note: Colorimetry measurements may be made by an AITL, AITL, Seller, or Other Manufacturer.

(A) Specimen Selection:

Nine specimens shall be randomly selected from routine production and sent to an Accredited Independent Testing Laboratory for testing. These specimens shall be grouped into three sets: a) three specimens from one Batch, b) three specimens from a second Batch, and c) another set of three specimens for which each of the two Batches must be represented. This results in a total of four specimens from one batch and five from the other.

(B) Specimen Preparation:

Each specimen shall be at least 155 square centimeters (24 square inches) in size and shall be identified with the manufacturer's name, address, product name and/or model number, batch number and individual specimen number within each batch such that labels are designed to be durable for a period of four (4) years, during which specimens will be exposed to the environment.

(C) Substrate:

The Seller or OM shall be responsible for ensuring that product specimens are prepared on the appropriate substrate(s) according to the following provisions:

1. Factory-Coated Metal Products: Factory-coated metal product specimens need not be applied to a substrate.
2. Factory-Applied Coatings: Factory-Applied Roof Product Component specimens shall be applied to a substrate(s) intended for commercial use or to a standard aluminum panel. The standard substrate shall conform to 3003 H14 uncoated aluminum alloy in accordance with ASTM D1730.

(D) Radiative Properties Reporting:

The rated radiative properties of the product specimens shall be reported according to the following provisions:

1. Initial Rated Radiative Properties reported shall be determined by the average of the tests conducted on specimens from Batches A and B.
2. Aged Rated Radiative Properties reported shall be no greater than the arithmetic average of the aged test results of each of the nine product specimens that undergo aging exposure.
3. In the event that a specimen is uncharacteristically damaged during weathering exposure, the specimen shall be removed from the calculation of the Aged Radiative Properties. As a result of such an occurrence, the Aged Rated Radiative Properties reported shall be no higher than the arithmetic average of the averaged results from each Test Farm Site.

Up to two product specimens per test farm site shall be permitted to be discarded if uncharacteristically damaged. Should all three specimens from one test farm site be uncharacteristically damaged, the Seller or Other Manufacturer shall re-test their products.

S.3.4 Custom Colors

Initial testing of radiative properties is required for Custom Colors; no aged testing is required.

Advisory Note: Initial radiative property testing may be conducted by either an AITL or an AMTL.

(A) Specimen Selection:

Each individual Roofing Product identified as a Custom Color shall be sampled based on an average of at least two specimens from one Batch.

(B) Specimen Preparation:

These products shall be identified as “Custom Colors” with the other necessary information for identification. Specimens for initial testing shall be prepared in accordance with Section S.3.2.

(C) Radiative Properties Reporting:

The rated radiative properties of Custom Colors shall be reported according to the following provisions:

1. *Initial* Rated Radiative Properties reported shall be no greater than the average of the initial test results of the specimens provided.
2. No aged testing is required for Custom Colors.

S.3.5 Variegated Products

Variegated products shall either be tested using ASTM E1918 or CRRC-1 Test Method #1. Products which are tested in accordance with CRRC-1 Test Method #1 shall adhere to the following provisions:

(A) Specimen Selection:

Specimens of Variegated Products with non-continuous (particle) top coatings that are tested under CRRC-1 Test Method #1 shall be randomly selected from routine production and sent to an AITL for testing. These specimens shall be grouped into three sets:

1. One (1) specimen from Batch A comprised of at least two shingles for shingle products;
2. One (1) specimen from Batch B comprised of at least two shingles for shingle products;
3. One (1) specimen for which each of the two Batches shall be represented, including at least one shingle from each of the two Batches for shingle products.

Advisory note: specimens may be comprised of multiple pieces. Top coatings may be particles, or other methods of obtaining a variegated surface.

(B) Specimen Preparation:

Three specimens shall be prepared in accordance with this section. *Advisory note: the manufacturer may opt to work with an AITL to prepare specimens in accordance with the following provisions.*

1. The Seller or OM is responsible for assuring that specimens are sufficiently large and properly constructed so as to yield Radiative Property test results that are representative of the expected average Radiative Properties of a complete roof surface of such product that has been installed in accordance with published manufacturer instructions. Shingle specimens shall be constructed with as many shingles as necessary to achieve this. In no event, however, shall the specimens fail to meet the provisions set forth in Section S.3.5(B)(2) as follows:
2. Specimens to be tested under CRRC-1 Test Method #1 shall have a minimum dimension of 25 cm by 91 cm (10 inches by 36 inches) of exposure surface.

3. Shingle specimens shall include at least two courses (two full courses of exposure surface in height). Specimens, including individual pieces that comprise the specimen, shall be labeled with the necessary information for identification by batch and specimen, such that labels are designed to be durable for a period of four (4) years, during which specimens will be exposed to the environment.

The Seller or OM shall be responsible for ensuring that specimens of Variegated Roofing Products that require ASTM E1918 testing are prepared on the appropriate substrate(s) in accordance with the recommendations of the manufacturer.

(C) Radiative Properties Reporting:

1. *Initial* Rated Radiative Properties reported on the Product Rating Application shall be no greater than the arithmetic average of the average Radiative Property values for each of the two specimens, one specimen from batch A and one specimen from batch B, determined in accordance with CRRC-1 Test Method #1. In the event that the two specimens yield Radiative Property values that differ by more than 0.05 both specimens shall be deemed to be non-compliant with the requirements stated in the second paragraph of this Section S.3. The Seller or OM shall then be required to prepare three additional specimens of sufficiently larger dimensions to ensure that the difference of the Radiative Property values between each of the two new measured specimens is equal to or less than 0.05.
2. *Aged* Rated Radiative Properties reported on the Aged Product Rating Application shall be no greater than the arithmetic average of the average radiative values for each of the three specimens as determined in accordance with CRRC-1 Test Method #1 for the three product specimens that undergo aging exposure. One specimen shall be exposed at each of the three Test Farm locations.
3. In the event that a specimen is uncharacteristically damaged during weathering exposure, the specimen shall be removed from the calculation of the Aged Radiative Properties. As a result of such an occurrence, the Aged Rated Radiative Properties reported shall be no higher than the arithmetic average of the averaged results from each Test Farm Site.

Up to two product specimens per test farm site shall be permitted to be discarded if uncharacteristically damaged. Should all three specimens from one test farm site be uncharacteristically damaged, the Seller or Other Manufacturer shall re-test their products.

Section S.4 CRRC-1 Test Method #1

Standard Practice for Measuring Solar Reflectance of a Flat, Opaque, and Heterogeneous Surface Using a Portable Solar Reflectometer

S.4.1 Scope

Section S.4 covers a technique for estimating the mean solar reflectance of a flat, opaque, and heterogeneous test surface at standard conditions, such as a variegated, granule-covered asphalt roofing shingle. The mean solar reflectance of the test surface is determined by averaging the solar reflectances of randomly located spots (small regions) measured with a commercial portable solar reflectometer in accordance with ASTM C1549.

This standard practice shall be used in conjunction with ASTM C1549.

This standard practice 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 practice to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

S.4.2 Reference Documents

ASTM STANDARDS

C1549, Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer.

TERMINOLOGY

Estimate of Sample Mean Standard Error. The sample (rather than population) standard deviation divided by the square root of the number of samples.

Heterogeneous. Consisting of dissimilar or diverse ingredients or constituents.

Population. The group of sample values about which conclusions are to be drawn, such as a set of solar reflectance values determined from non-overlapping spots (small regions) that cover an entire test surface.

Population Mean. The arithmetic mean of the property values (e.g., solar reflectances) measured for all members of a population.

Population Standard Deviation. The square root of the arithmetic mean of the squares of the deviation from the population mean.

Reflectometer. A device that measures reflectance.

Sample Mean. The arithmetic mean of the property values (e.g., solar reflectances) measured for all members of a sample set.

Sample Mean Standard Error. The population standard deviation divided by the square root of the number of samples.

Sample Set. A subset of the population, such as a set of non-overlapping spots (small regions) on a test surface.

Sample Standard Deviation. The square root of the ratio of the sum of the squares of the deviation from the sample mean to a number one less than the number of samples.

Spot. A small region of a test surface, such as a 1 inch by 1 inch square or a 1 inch-diameter circle, whose solar reflectance can be measured.

Test Surface. A flat, opaque, and heterogeneous surface, such as that of a variegated, granule-covered asphalt shingle.

Test Surface Mean Solar Reflectance. The ratio of solar energy reflected from a test surface to the solar energy incident on a test surface, equal to the ratio of area-integrated solar reflectance to area.

Variegated. Having discrete markings of different colors.

Summary of Standard Practice

For a flat, opaque, and heterogeneous test surface, solar reflectances are measured in accordance with ASTM C1549 at a series of randomly located, non-overlapping spots (small areas) until the specimen mean standard error is small enough to use the specimen mean as an estimate of the mean solar reflectance of the test surface.

S.4.3 Significance and Use

This standard practice provides a method for determining the mean solar reflectance of a flat, opaque, and heterogeneous surface, from multiple, random and non-duplicative spot measurements of solar reflectance.

Advisory note: The algorithm for selecting measurement locations, computing the specimen mean, and computing the specimen mean standard error may be implemented with assistance of software.¹

S.4.4 Procedure

(A) Set-up

1. Obtain a representative test specimen, as determined by CRRC-1 Standard.
2. Let w and h represent the width and height of the test surface in units of centimeters.

Place a pair of marked rulers at a right angle on two sides of the test surface to establish a grid of $w \times h$ square cells, each 2.5 cm by 2.5 cm (1 inch by 1 inch) and centered on integer coordinates. If the area of the test surface does not exceed 194 square centimeters (30 square inches), apply Procedure A. If the area is 194 square centimeters (30 square inches) in area or greater, apply Procedure B.

(B) Procedure A (for test surfaces not exceeding 30 square inches in area)

1. Measure the solar reflectance at the center of each cell with a solar spectrum reflectometer in accordance with ASTM C1549, centered over each cell.
2. Report the mean value of cell solar reflectance as the mean solar reflectance of the test surface.

(C) Procedure B (for test surfaces exceeding 30 square inches in area)

1. Measure the solar reflectances at the centers of a minimum of 30 different and randomly selected cells with a solar spectrum reflectometer centered over each cell in accordance with ASTM C1549.
2. Compute the mean, standard deviation, and estimate of standard error of the solar reflectance of the specimen set. These quantities are defined in Eqs. (3), (4) and (6) of the Appendix, respectively.
3. If the estimate of specimen mean standard error exceeds 0.005, increase the number of specimens by measuring solar reflectances of additional, different, and randomly selected cells.
4. Repeats steps 2 and 3 until the estimate of specimen mean standard error of the specimen set does not exceed 0.005.
5. Report the specimen mean plus or minus twice the estimate of specimen mean standard error as the mean solar reflectance to within 95% confidence.

S.4.5 Report

Include in the report, in addition to the requirements stated in ASTM C1549, the following:

(A) Data Requirements

1. The width, height, and area of the test surface.

¹ Available from the Cool Roof Rating Council (www.coolroofs.org)

2. The solar reflectance measurement procedure followed (A or B).
3. The central coordinates and solar reflectance of each cell measured.
4. For Procedure A (applied to test surfaces not exceeding 30 square inches in area), the mean solar reflectance of the test surface, equal to the mean value of cell solar reflectance.
5. For Procedure B (applied to test surfaces exceeding 30 square inches in area), the mean solar reflectance of the test surface to within 95% confidence, expressed as the specimen mean plus or minus twice the estimate of specimen mean standard error.

(B) Test Specimen

1. Manufacturer of the product
2. Manufacturer-designated product name and color.

(C) Date

Date specimen was tested.

S.4.6 Precision and Bias

Procedure B was evaluated in a round robin test for six products (solar reflectance 0.04 - 0.20) by five laboratories (Table 1). For five of the six products, the spread in reported values (maximum – minimum) did not exceed 0.01. For the sixth product, the spread was 0.03.

Table 1 Precision and Bias

Specimen Number	Specimen	A	B	C	D	E	Mean
#2	Black 3 Tab	0.038	0.036	0.04	0.034	0.04	0.04
#3	Lt. Gray 3 Tab	0.201	0.19	0.20	0.174	0.19	0.19
#4	Contrast 3 Tab	0.070	0.068	0.07	0.064	0.073	0.07
#5	Brown Laminate	0.067	0.06	0.06	0.058	0.062	0.06
#6	Green Slate	0.060	0.055	0.06	0.049	0.059	0.06
#1	Brown Shake	0.060	0.061	0.06	0.053	0.069	0.06

S.4.7 Appendix (Non Mandatory)

All reflectances in the following discussion are solar reflectances.

The mean reflectance

$$R \equiv A^{-1} \int_A r dA \quad (1)$$

of a test surface of area A is equal to the mean reflectance of the entire population of $N = A/a$ surface “spots,”

$$\mu \equiv \frac{1}{N} \sum_{i=1}^N r_i \quad (2)$$

Each spot i is a subregion of reflectance r_i and area a that is small enough to be measured with a reflectometer, and does not overlap any of its neighbors. If N is large, it is convenient to estimate the population mean spot reflectance μ , and hence the test surface mean reflectance R , of a large surface by randomly sampling a population subset. Consider a specimen set of n different, non-overlapping, and randomly located spots that have mean reflectance

$$\bar{r} \equiv \frac{1}{n} \sum_{i=1}^n r_i \quad (3)$$

with standard deviation

$$s \equiv \sqrt{\frac{1}{n-1} \sum_{i=1}^n (r_i - \bar{r}_n)^2} \quad (4)$$

By the Central Limit theorem, the specimen mean \bar{r} has a standard error

$$\sigma_{\bar{r}} = \sigma / \sqrt{n} \quad (5)$$

where σ is the standard deviation of the spot reflectances of the entire population (Crow et al., 1960). The population mean spot reflectance μ (which is also the mean solar reflectance of the test surface, R) is equal to $\bar{r} \pm 2\sigma_{\bar{r}}$ (95% confidence). If the specimen size n is sufficiently large (say, $n \geq 30$), the population standard deviation σ is well approximated by the specimen standard deviation s , and the estimate of the specimen mean standard error is

$$\sigma_{\bar{r}} \approx s / \sqrt{n} \quad (6)$$

The instrument used to measure spot reflectance in accordance with C1549 has a circular aperture. Hence, the test surface formed by a matrix of contiguous, non-overlapping circular measurement spots will cover a fraction $\pi/4 \approx 79\%$ of the rectangular region bounding the matrix of circles. The remaining 21% of the rectangular region will not be sampled. This should be acceptable if the optical properties of the area between each measurement circle and its bounding square are expected to be the same as those of the surface within each measurement circle.

Bibliography

Crow, E.L., F.A. Davis, and M.W. Maxfield. 1960. *Statistics Manual: With Examples Taken From Ordnance Development*. New York: Dover Publications.