



ANSI/CRRC S100 (2016)
Standard Test Methods for Determining
Radiative Properties of Materials

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TABLE OF CONTENTS

SECTION S.1 - GENERAL	1
S.1.1 SCOPE	1
S.1.2 SIGNIFICANCE AND USE	1
S.1.3 UNITS	1
S.1.4 ADVISORY NOTES	1
S.1.5 GLOSSARY OF TERMS	2
S.1.6 REFERENCES	6
SECTION S.2 - CONDUCT OF TESTS	7
S.2.1 PRODUCT SPECIMENS	7
S.2.2 SOLAR REFLECTANCE TESTS	7
S.2.3 THERMAL EMITTANCE TESTS	9
S.2.4 COLOR FAMILY ELEMENTS- INSTRUMENTALLY MEASURED COLOR TESTS	9
S.2.5 FLUID APPLIED ROOFING PRODUCTS-COATING THICKNESS TESTS	9
S.2.6 REQUIREMENTS FOR FIELD EXPOSURE OF ROOFING PRODUCTS	9
S.2.7 REQUIREMENTS FOR LABORATORY SOILING AND WEATHERING OF ROOFING MATERIALS	11
S.2.8 REPORT OF RESULTS	12
SECTION S.3 - TEST SPECIMEN SELECTION	13
S.3.1 GENERAL	13
S.3.2 STANDARD PRODUCTION LINE ROOFING PRODUCT SPECIMEN	13
S.3.3 FACTORY COLORED PRODUCTS	15
S.3.4 CUSTOM COLORS	17
S.3.5 VARIEGATED PRODUCTS	17
SECTION S.4 CRRC-1 TEST METHOD #1	20
APPENDIX A – TILE METHOD TEMPLATE (FIGURE S.2.2 (D.2))	21
APPENDIX B – SOLAR REFLECTANCE MEASUREMENT CALCULATIONS (NON MANDATORY) ..	22
BIBLIOGRAPHY	23

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

ANSI/CRRC S100

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 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 (CRRC), 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 10°C or 50°F, there are as many degree-days as degrees Celsius or Fahrenheit temperature difference between the mean temperature for the day and 10°C or 50°F. Annual cooling degree-days (CDDs) are the sum or 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 *Other Manufacturer* 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).

Laboratory Exposure of Roofing Products - A laboratory standard practice that replicates the effects of three years of natural exposure, including soiling and weathering, on the *solar reflectance* and *thermal emittance* of roofing products.

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.

Profiled Roofing Products - Roofing products that vary in rise over a given width as can be seen in a cross sectional view.

Radiative Properties - The *solar reflectance* and *thermal emittance* of a roofing product.

Radiative Properties, Aged - The *radiative properties* of a roofing product tested after completing field exposure, or tested after laboratory exposure if the product has begun, but not yet completed, field exposure.

Radiative Properties, Field Exposed - The *solar reflectance* and *thermal emittance* of a roofing product after three years of exposure to the weather at a test farm.

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, Laboratory Exposed - The *solar reflectance* and *thermal emittance* of a roofing product following application of the practice for laboratory soiling and weathering of roofing products.

Radiative Properties, Rated - The *solar reflectance* and *thermal emittance* of a roofing product, which is reported by an independent entity. **Radiative Properties, Tested** - The reported *solar reflectance* and *thermal emittance* of a roofing product as determined by an *Accredited Independent Testing 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 (i.e. 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 2.54 cm by 2.54 cm (1 inch by 1 inch) square or a 2.45 cm (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.

Variegated - Having discrete markings of different colors.

Wood Roofing Products – Roofing products manufactured from various trees, including but not limited to western red cedar, cypress, pine and redwood.

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

ANSI/ASHRAE Standard 169-2013– Climatic Data for Building Design Standards.

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 C1549-09, 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 D751-06 (2011), Standard Test Methods for Coated Fabrics.

ASTM D1005-95 (2013), Standard Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers.

ASTM D1669-07 (2013), Standard Practice for Preparation of Test Panels for Accelerated and Outdoor Weathering of Bituminous Coatings.

ASTM D2244-14, Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color and Coordinates.

ASTM D7091-05 (2013), Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals.

ASTM D7897-15, Standard Practice for Laboratory Soiling and Weathering of Roofing Materials to Simulate Effects of Natural Exposure on Solar Reflectance and Thermal Emittance.

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 E903-12, Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres.

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

ASTM E1980-11, Standard Practice for Calculating Solar Reflectance Index (SRI) of Horizontal and Low-Sloped Opaque Surfaces.

ASTM G7-13, Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials.

ASTM G147-09, Standard Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests.

ISO

The International Organization for Standardization

1, ch. de la Voie-Creuse, Case Postale 56

CH-1211 Geneva 20, Switzerland

www.iso.org

ISO/IEC Standard 17025-2005, General requirements for the competence of testing and calibration laboratories.

ISO/IEC Standard 17011-2004, Conformity assessment -- General requirements for accreditation bodies accrediting conformity assessment bodies.

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 *Other Manufacturer* (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.

Accredited Independent Testing Laboratories (AITL) shall measure the dimensions of each test specimen. Specimen measurements shall be within 2.54 cm (1 inch) of the minimum required specimen size, and specimens shall be measured to an accuracy of 0.64 centimeters (0.25 inches).

AITLs shall note if specimens meet size requirements on the Initial Test Results Report (F-2). If the specimen does not meet size requirements, the AITL will notify the licensee and obtain a new sample.

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).

1. ASTM E903 in conjunction with E891, analyzed using factors appropriate for an air mass value of 1.5
2. ASTM E1918
3. ASTM C1549, using an air mass value of 1.5
4. CRRC-1 Test Method #1, using an air mass value of 1.5
 - a. Tile Test Method
 - b. Tile Template Method
 - c. Wood Method

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:

- a. 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.

(D) Tile Products. Tile products shall be tested in accordance with Part D1 or D2 below. The AITL performing the measurements shall mark the arrangement of the tiles and record the locations of the measurements in the report developed in accordance with Section S.2.7. When specimens are tested for both initial and aged results, the measurement locations shall be the same for both tests.

1. CRRC-1 Test Method 1. Tests shall be conducted in accordance with CRRC-1 Test Method 1, and the following requirements:
 - a. Six measurements shall be taken randomly chosen and non-repeated test cells on each of nine tiles selected. A test cell is an element of a grid of contiguous one inch by one inch squares projected on the surface of each tile. The aperture of the measure device shall be centered within the cell.
 - b. Following the measurements of all specimens, compute the *estimate of specimen mean standard error* of the measurements.
 - c. If the *estimate of specimen mean standard error* is 0.02 or less the test is complete, and the measured property is permitted to be reported.
 - d. If the estimate of *specimen mean standard error* is greater than 0.02 the test is incomplete, and an additional test shall be performed at a seventh location on each tile.
 - e. Following the seventh test on each tile, compute the *estimate of specimen mean standard error*. If the *estimate of specimen mean standard error* is 0.02 or less the test is complete, and the measured property is permitted to be reported. If the *estimate of specimen mean standard error* is greater than 0.02 then repeat D.1.d specimen testing at an additional randomly selected and non-repeated location on each tile until either:
 - i. the *estimate of specimen mean standard error* is 0.02 or less is achieved, or
 - ii. every test cell on every tile has been measured.

If either condition (a) or (b) has been satisfied, the test is complete and both the specimen mean and the specimen mean standard error shall be reported. If condition (b) has been satisfied it shall be reported that all test cells have been measured.

2. **Template Method.** The measurements shall be taken in the locations indicated by the template, in accordance with Figure S.2.2 (D.2.) in Appendix A. Position the template to include the maximum color variegation on the specimens.
 - a. The measurements shall be taken on each of nine tiles selected.
 - b. Following the measurements of all specimens, compute the *estimate of specimen mean standard error* of the measurements.
 - c. If the *estimate of specimen mean standard error* is 0.02 or less the test is complete, and the measured property is permitted to be reported.
 - d. If the *estimate of specimen mean standard error* is greater than 0.02 the test is incomplete and the specimens will be tested in accordance with Section S.2.2 Part D.1 (CRRC-1 Test Method 1) above.

S.2.3 Thermal Emittance Tests

Thermal emittance tests shall be conducted in accordance with ASTM C1371. Three measurements will be taken on each sample. Any product not on an un-insulated metal substrate shall be tested using the Slide Method. In the Slide Method, the emissometer head should be moved, without creating a gap between the sample and the emissometer, every 15 seconds during the testing procedure.

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, Appendixes X1.1. Color Measurement Equipment Specification: 0–°/45° Geometry with 10° observer, D65 illuminant.

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, ASTM D1005 or D7091.
- (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 Field Exposure of Roofing Products

The following criteria shall be met to determine aged ratings:

- (A) **Test Farm Qualifications:** A weathering farm shall be accredited for compliance with ISO/IEC Standard 17025 to weather and test roofing products, and shall be independent from any roofing product manufacturer or roofing product seller.
- (B) **Test Farm Locations:** Roofing product specimens shall be exposed in the following three locations representing three climate zones:

1. Hot/Humid climate with:
 - a. Annual Heating Degree-Day (HDD) @ 18 °C of 72 (Annual HDD @ 65 °F of 130), and
 - b. Annual Cooling Degree-Day (CDD) @ 10 °C of 5,447 (Annual CDD @ 50 °F of 9,805), and
 - c. An average yearly relative humidity of 83% in the A.M. and 61% in the P.M.
2. Cold/ Temperate climate with:
 - a. Annual Heating Degree-Day (HDD) @ 18 °C of 3,280 (Annual HDD @ 65 °F of 5,904), and
 - b. Annual Cooling Degree-Day (CDD) @ 10 °C of 1,662 (Annual CDD @ 50 °F of 2,992), and
 - c. An average yearly relative humidity of 80% in the A.M. and 62% in the P.M.
3. Hot/Dry climate with:
 - a. Annual Heating Degree-Day (HDD) @ 18 °C of 523 (Annual HDD @ 65 °F of 941), and
 - b. Annual Cooling Degree-Day (CDD) @ 10 °C of 5,067 (Annual CDD @ 50 °F of 9,120), and
 - c. 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-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.

- (C) **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.

- (D) 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.
- (E) 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.
1. To ensure the proper handling of samples, AITLs and test farms shall adhere to the procedures in ASTM G147, **except** sections 14.3 through 14.4 involving the washing of samples. The test surface of each sample shall not be washed, cleaned, or wiped in any fashion. Loose dirt, embedded dirt, environmental stains, mold, mildew and any other material that rests on—or has become incorporated into—the surface of the material shall not be altered.
- (F) Testing of Exposed Specimens:** The specimens shall be tested in accordance with Section S.2.
- (G) 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 Requirements for Laboratory Soiling and Weathering of Roofing Materials

The following criteria shall be used to determine *laboratory-exposed radiative properties*:

1. Specimen qualifications:
 - a. Each product specimen shall comply with the requirements of ASTM D7897.
 - b. The exposed area of each specimen shall be 10 centimeters by 10 centimeters (4 inches by 4 inches).
2. Specimen quantity: Three specimens of each roofing product randomly selected from the routine production for purposes of testing.
3. Laboratory soiling and weathering: The laboratory soiling and weathering shall be conducted in accordance with ASTM D7897, using the soiling mixture for average U.S. conditions in accordance with Section 6.1 of the ASTM D7897.
4. Reporting: The report for laboratory soiling and weathering of roofing materials shall include:
 - (A)** Information as required by Section 10 of ASTM D7897.
 - (B)** The spraying time τ , and distance from spraying nozzle to specimen, established in accordance with Section 8 of ASTM D7897.
 - (C)** The *solar reflectance* and *thermal emittance* of each specimen measured in accordance with Section S.2, before and after laboratory soiling and weathering.

1. The laboratory-exposed *solar reflectance* value and laboratory-exposed *thermal emittance* value of the product shall be determined by calculating the arithmetic means of the corresponding values of the three specimens measured after laboratory soiling and weathering.

S.2.8 Report of Results

AITLs 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.

The AITL shall report as tested *aged radiative properties* the *field-exposed radiative properties* of any product that has completed field exposure in accordance with Section S.2.6.

If a product has begun, but not yet completed, field exposure in accordance with Section S.2.6, the AITL shall report as tested *aged radiative properties* the *laboratory-exposed radiative properties* obtained in accordance with Section S.2.7, or report that *aged radiative properties* have not been tested.

The AITL shall note in its report whether the tested *aged radiative properties* are *field-exposed radiative properties* or are *laboratory-exposed radiative properties*.

For *custom colors* only, AMTL 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 roofing 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 roofing products*.
- (E) Sections S.2.7 for laboratory soiled and weathered products.

S.3.2 Standard Production Line Roofing Product Specimen

(A) Specimen Selection:

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

1. Three specimens from one Batch,
2. Three specimens from a second Batch, and
3. 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 (including size, batch, number of samples, identification, substrate and thickness):

1. Each sample shall be a minimum of 10.2 centimeters by 15.2 centimeters (4 inches by 6 inches) in size.
2. Each sample shall be identified with the manufacturer's name, address, product name and/or model number, batch number and individual sample number within each batch such that labels are designed to be durable for a period of four (4) years, during which samples 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. 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 determined by the average of the initial test results of the specimens from Batches A and B.
2. *Field-exposed rated radiative properties* reported shall be determined by the arithmetic average of the field-exposed 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 OM shall re-test their products.

(E) Product Type Specific Compound Ratings

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 are permitted to be applied to flat or profiled roofing products.
2. Shingle Products: If a manufacturer or OM has multiple shingle products with the same exposed color blend granule formulation, the *solar reflectance* and *thermal emittance* ratings for the tested product shall be permitted to be applied to these other products. The manufacturer or OM submitting the shingle product for certification must declare as part of their application any differences, which shall include varying granule distributions, the non-exposed shingle system components, or design features.

3. **Modified Bitumen Products:** If a manufacturer or OM has modified bitumen products whose granules have the same color blend formulation, size, *solar reflectance*, and *thermal emittance*, and/or whose *factory-applied* coatings have the same coverage rate and formulation, the *solar reflectance* and *thermal emittance* ratings for the tested product shall be permitted to be applied to these other products. The manufacturer or OM submitting the modified bitumen product for certification must declare as part of their application any differences in the non-exposed system components or design features.
4. **Polymer Shaped Products:** All polymer slate, polymer shake, and polymer tile shaped products shall be initially measured by the AITL to determine the lowest reflectance and the shape with the lowest reflectance to be used for reporting values. For *field-exposed* testing, the lowest reflectance *profiled* product will be sent to weather at the *test farm sites*. The manufacturer or OM submitting the polymer shaped product for certification shall declare as part of their application any differences, such as shape or design features.
5. **Tile Products:** Tile products, both mono-color and *variegated*, shall be rated using nine individual tiles. Tiles shall be flat, unless only profiled products are available. Flat and S-shape tiles shall be permitted to be cut down by the tile manufacturer to a smaller size of not less than 15.24 centimeters by 15.24 centimeters (6 inches by 6 inches), allowing any unreadable areas to be removed, as long as a representative specimen remains intact in order to be tested. All other curved tiles must be sent as full, uncut tiles. For tile blend assemblies that are made up of two or more colors, each color must be tested and rated as an individual product. Each color will appear in the CRRC database as a unique product. Tile blend ratings will be determined by calculating a weighted average of the colors in each particular blend.
6. **Wood:** In order for cedar roofing products to qualify for a *compound product rating*, all geometries (i.e. types of cuts) must be initially tested. All geometries must be measured by the AITL to determine the lowest reflectance and the shape with the lowest reflectance will be used for reporting the *initial* and *aged* values. The product geometry with the lowest reflectance will be sent to weather at the test farm. The *Seller* will submit nine specimens for each geometry.
7. **Single ply:** In order for a single-ply product to qualify for a *compound product rating* for *solar reflectance* and *thermal emittance* the product with the thinnest overall thickness must be tested. If a *Seller* or OM has multiple single ply products with the same surface formulation but varying backing thicknesses, the *solar reflectance* and *thermal emittance* ratings for the thinnest of these products may be applied to these other 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 OM 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 S.2.6. 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, AMTL, test farm, Seller, or OM.*

(A) Specimen Selection:

1. Standard Color or Color Group: Nine specimens shall be randomly selected from routine production and sent to an AITL 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.
2. Color Family Additional Element: For each *color family additional element* to be added to an existing *color family group* six (6) specimens shall be randomly selected and sent to an AITL. The specimens shall be grouped into two sets: a) three specimens from one Batch, b) three specimens from a second Batch.

(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. *Field-Exposed rated radiative properties* reported shall be determined by the arithmetic average of the *field-exposed* test results of each of the nine product specimens that undergo field exposure.
3. In the event that a specimen is uncharacteristically damaged during field exposure, the specimen shall be removed from the calculation of the *field-exposed radiative properties*. As a result of such an occurrence, the *field-exposed rated radiative properties* reported shall be no higher than the arithmetic average of the averaged results from each *test farm site*.
4. 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 OM shall re-test their products. *Color family additional elements* are not subject to *aged radiative properties* testing. The *aged rated radiative properties* reported on the *color family additional element* and test results report shall be identical to that which is reported for the *representative element* of the *color family group*. Either the initial *color family group* default value or the actual *aged rated* value of the *representative element*, whichever is lower, shall be used.

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 determined by 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 roofing products shall either be tested using ASTM E1918 or CRRC-1 Test Method #1. When products are tested in accordance with CRRC-1 Test Method #1 the following provisions must be followed:

(A) Specimen Selection:

Specimens of *variegated roofing products* with non-continuous (e.g., granules, particles) top surfaces 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 comprised of at least two shingles from Batch A (for shingle products);
2. One (1) specimen comprised of at least two shingles from Batch B (for shingle products);
3. One (1) specimen for which each of the two Batches shall be represented, including at least one shingle from Batch A and one shingle from Batch B (for shingle products).

Advisory note: *specimens may be comprised of multiple pieces. Top surfaces may be particles, or other materials creating 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,
 - a. Shingle products shall have a minimum dimension of 25 centimeters by 91 centimeters (10 inches by 36 inches) of exposure surface. Shingle specimens shall include at least 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. The labels must be designed to be durable for a period of four (4) years, during which time specimens will be exposed to the environment.
 - b. Non-shingle or modified bitumen products, the area of each sample shall be a minimum 258 square centimeters (40 square inches) and no less than 10 centimeters (4 inches) in length or width (102 square centimeters or 15.8 square inches in length or width).

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 determined by 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. *Field-exposed* rated *radiative properties* reported on the *field-exposed* product rating application shall be determined by 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 field 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 field exposure, the specimen shall be removed from the calculation of the *field-exposed radiative properties*. As a result of such an occurrence, the *field-exposed 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 OM shall re-test their products.

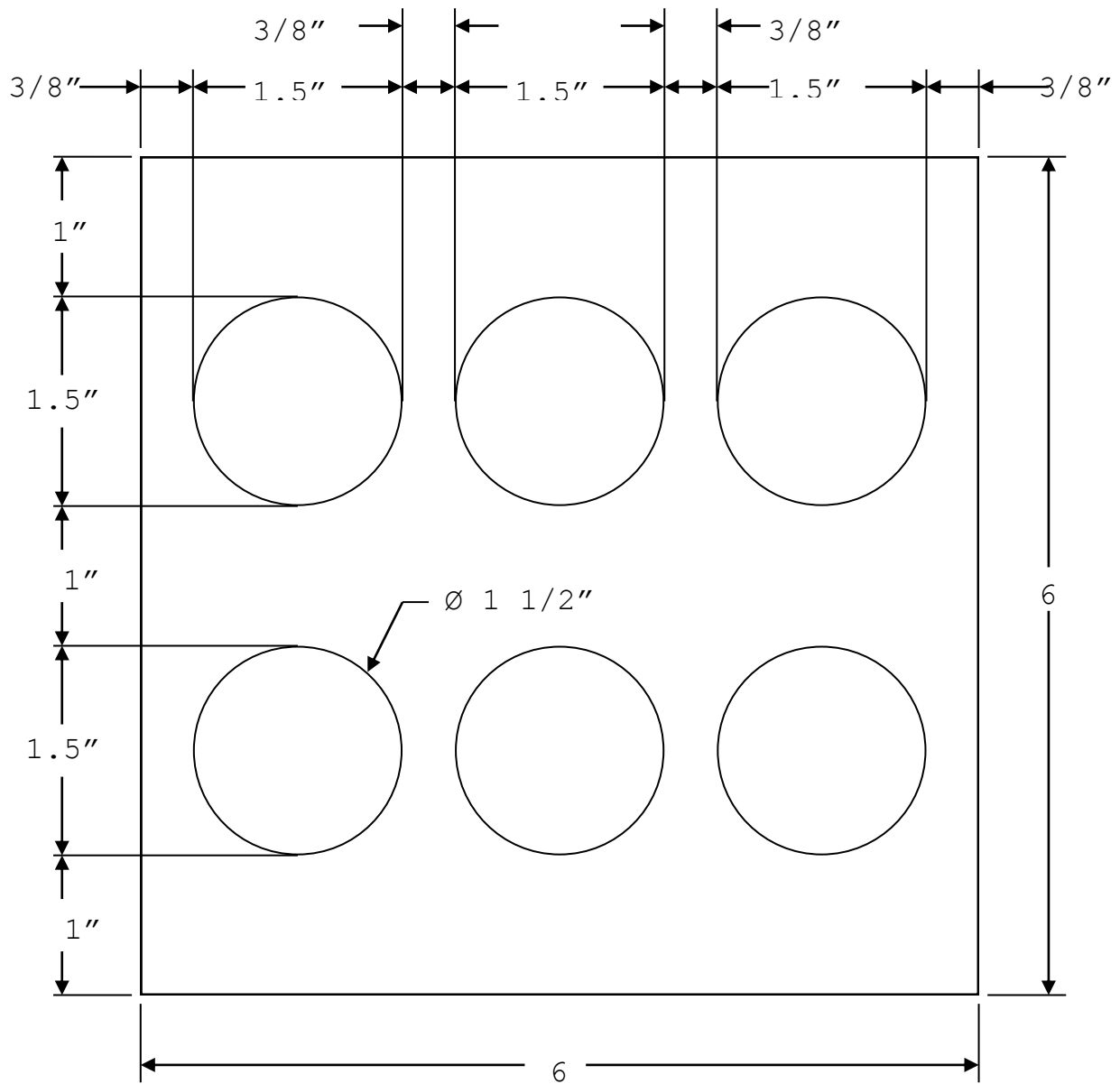
Section S.4 CRRC-1 Test Method #1

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

Follow Appendix X1 of ASTM C1549.

Appendix A – Tile Method Template (Figure S.2.2 (D.2))

Note: All dimensions are in inches. This template is not accurately drawn to scale. All diameters must be 1.5 inches.



Appendix B – Solar Reflectance Measurement Calculations (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

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

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.