



ANSI/CRRC S100 (2021)

Standard Test Methods for Determining Radiative Properties of Materials

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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. Roofing specimens are exposed to specific tests and to the exterior environment throughout a specified time period. The tests provide 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 the International System of Units (SI units), which is 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 coordinates 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 a *factory-applied roof product component* as its top coating.

Color Family Group - One or more production line factory-applied metal coatings or factory-coated metal roofing products that 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*.

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*).

Directionally Reflective Material - A roofing product material with solar reflectance that varies with solar incidence angle.

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 18 °C or 65 °F, there are as many degree-days as degrees Celsius or Fahrenheit temperature difference between the mean temperature for the day and 18 °C or 65 °F. 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 Coordinates - A set of three numbers characterizing the lightness (L), redness/greenness (a) and yellowness/blueness (b) of a color.

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. 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 in 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 reflectance*) 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 outdoor weathering at a test farm.

Radiative Properties, Initial - The *solar reflectance* and *thermal emittance* of a roofing product determined from a specimen that 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, Tested - The reported *solar reflectance* and *thermal emittance* of a roofing product as determined by an AITL.

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 - *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 Elements*.

Roofing Product, Tile - A tile made of clay or concrete that is intended as a roof covering. Roofing tiles are available in a variety of profiles, surface textures, and colors.

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

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

Specimen Mean - The arithmetic mean of the property values (e.g., *solar reflectance*) 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*. *Sellers* are 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 centimeter by 2.54-centimeter (1 inch by 1 inch) square or a 2.54-centimeter (1 inch) diameter circle, in which *solar reflectance* can be measured.

Steep-Sloped Roofing Product - Roof products designed to be installed with a slope 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 - Outer surface of a product specimen.

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 specimen preparation by the *Seller* or *Other Manufacturer*. Unusable refers to the inability to accurately measure the *aged radiative properties* of the product specimen. 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 specimen; 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 specimen beyond normal weather exposure.

Variegated - Having discrete markings of different colors.

S.1.6 References

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

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 International (ASTM)

100 Barr Harbor Drive

West Conshohocken, PA 19428-2959

www.astm.org

ASTM C1549-16, Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer.

ASTM C1371-15, Standard Test Method for Determination of Emittance of Materials Near Room Temperature using Portable Emissometers.

ASTM C1864-17, Standard Test Method for Determination of Solar Reflectance of Directionally Reflective Material Using Portable Solar Reflectometer.

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 D1730-09(2014), Standard Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting.

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

ASTM D7091-13, 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 D7897-18, Standard Practice for Laboratory Soiling and Weathering of Roofing Materials to Simulate Effects of Natural Exposure on Solar Reflectance and Thermal Emittance.

ASTM E805-12a(2017), Standard Practice for Identification of Instrumental Methods of Color or Color-Difference Measurement of Materials.

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 E1918-16, 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 G147-17, Standard Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests.

The International Organization for Standardization (ISO)

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

CH-1211 Geneva 20, Switzerland

www.iso.org

ISO/IEC Standard 17025-2017, General requirements for the competence of testing and calibration laboratories.

ISO/IEC Standard 17011-2017, Conformity assessment -- General requirements for accreditation bodies accrediting conformity assessment bodies.

National Oceanic and Atmospheric Administration (NOAA)

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.

An *Accredited Independent Testing Laboratory* (AITL) shall measure the dimensions of each test specimen. Specimen measurements shall be within 2.54 centimeters (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 in the initial test results if specimens meet the size requirements. If the specimens do not meet the size requirements, the AITL will notify the *Seller* or *OM* and obtain new specimens.

S.2.2 Solar Reflectance Tests

(A) *Solar reflectance* tests shall be conducted based upon one of the following test methods. See sections S.2.2(B–F) for more information.

1. ASTM E903 in conjunction with the beam-normal solar spectral irradiance reported in ASTM E891.
2. ASTM E1918
3. ASTM C1549, using instrument output 1.5E for Solar Spectrum Reflectometer version 6 or 1.5 Solar Spectrum Reflectometer version 5.
4. ASTM C1864, using instrument output 1.5E for Solar Spectrum Reflectometer version 6 or 1.5 Solar Spectrum Reflectometer version 5.
5. CRRC-1 Test Method #1, using instrument output 1.5E for Solar Spectrum Reflectometer version 6 or 1.5 Solar Spectrum Reflectometer version 5. CRRC-1 Test Method #1 is contained in Appendix X1 of ASTM C1549. There are three variants of CRRC-1 Test Method #1:
 - a. *Variegated roofing product*
 - b. *Tile roofing product*
 - c. *Wood roofing product*
6. Tile Template Method

- (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. No confirmation of non-variegated status is required when test method E1918 is used to conduct initial testing.
 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 (5) *solar reflectance* measurements varies by more than 0.05 from the arithmetic average of all five (5) measurements, then the product will be deemed to be a *variegated* product and shall be tested in accordance with Section S.2.2(B).
- (D) Tile Products. *Tile roofing products* shall be tested in accordance with (D)1 or (D)2 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.2.8.
1. Tile Test Method (Variant of CRRC-1 Test Method #1). Tests shall be conducted in accordance with CRRC-1 Test Method #1, and the following requirements:
 - a. Six (6) measurements shall be taken on randomly-chosen spots across the *test surface* and non-repeated test cells on each of the nine (9) selected tiles. A test cell is an element of a grid of contiguous 2.54 centimeter by 2.54 centimeter (1 inch by 1 inch) squares projected on the surface of each tile. The aperture of the measurement 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 specimen testing at an additional randomly selected and non-repeated location on each tile until either:
 - the *estimate of specimen mean standard error* is 0.02 or less is achieved, or
 - every test cell on every tile has been measured.

If either of these two conditions have been satisfied, the test is complete and both the specimen mean and the *specimen mean standard error* shall be reported. If only the second condition has been satisfied, report that all test cells have been measured.

2. Tile Template Method. The measurements shall be taken in the locations indicated by the tile template, in accordance with Appendix A. Position the template to include the maximum color variegation on each specimen. When specimens are tested for both initial and aged results, the measurement locations shall be the same for both tests.
 - a. The measurements shall be taken on each of the nine (9) selected tiles.
 - 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 need to be tested in accordance with Section S.2.2 (D)1 above (CRRC-1 Test Method #1).
- (E) Directionally Reflective Roofing Products. Directionally reflective roofing products shall be tested in accordance with ASTM C1864.
- (F) Wood Products. Wood products shall be tested using the CRRC-1 Test Method #1 variant for wood products. Wood product specimens shall be organized into arrays of three (3) panels to capture the widest range of natural color variation. Each array shall

contain one light-colored panel, one medium-colored panel, and one dark-colored panel. Measurements on the array shall be taken at randomly generated locations until a standard error of equal to or less than 0.02 is achieved with a minimum of 30 sample points.

- (G) Roofing Aggregate. Roofing aggregate shall be tested in accordance with ASTM E1918.
- (H) For all product categories not identified in items (B) through (G), any method in section S.2.2 (A) may be used, except for ASTM C1864, which applies only to directionally reflective materials.

***Advisory Note:** Lawrence Berkeley National Laboratory provides Excel tools for the use of CRRC-1 Test Method #1 (Variegated Products, Tile, and Wood) that calculate the standard error and records the locations of the measurements. Visit <https://heatisland.lbl.gov/resources/technical-resources> to download copies of these tools.*

S.2.3 Thermal Emittance Tests

Thermal emittance tests shall comply with the following:

- (A) Be conducted in accordance with ASTM C1371.
- (B) Have three (3) measurements taken on each specimen.
- (C) Any roofing product other than uninsulated metal or a factory-applied coating on an uninsulated metal substrate shall be tested using the Slide Method. In the Slide Method, the emissometer head shall be moved, without creating a gap between the specimen and the emissometer, every 15 seconds during the testing procedure.

***Advisory note:** The Slide Method can be found in Devices and Services (D&S) Technical Note 11-2 at <http://devicesandservices.com>. Moore, Charles. *Model AE1 Emittance Measurements using a Port Adapter, Model AE-ADP*. D&S Technical Note 11-2. Dallas, TX: Devices & Services Co., 2011.*

S.2.4 Color Family Elements – Instrumentally-Measured Color Tests

For *Color Family Elements*, only, *Color Family Element* product specimens shall be tested for L, a, and b coordinates on the Hunter color scale. Color measurement equipment specification: 0°/45° (illuminant/observer) geometry with 10° standard observer, D65 illuminant. (Informative Note: See ASTM E805, Section 9 for reference only.)

The color specimen shall be conditioned to room temperature (24 ± 3 °C) for at least 30 minutes prior to measurement. The color specimen shall be placed on the instrument according to manufacturer instructions. L, a, and b coordinates shall be measured at three locations on the specimen surface and the average of each color coordinate shall be reported. Measurements shall be performed according to instrument manufacturer instructions. Results shall be reported in a way that identifies each number with its respective coordinate (L, a, b) and specimen.

S.2.5 Thickness Tests

- (A) Fluid Applied Coatings: *Thickness* tests shall be conducted in accordance with ASTM D1669, ASTM D1005 or ASTM D7091. A thickness measurement shall be taken at five (5) evenly spaced points on each of the nine (9) specimens. The average of the five (5) 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. The AITL shall notify the *Seller* or *OM* to supply a new product sample.
- (B) Single ply membranes: Thickness tests shall be conducted in accordance with ASTM D751. A thickness measurement shall be taken at five (5) evenly spaced points on each of the nine (9) specimens. The average of the five (5) measurements shall be used to determine the overall thickness of each specimen. The average thickness for a given specimen shall be within 20% of the manufacturer's stated thickness. A specimen which is not within this range shall not be used for ratings. The AITL shall notify the *Seller* or *OM* to supply a new product sample.

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 AITL, *OM* or *Seller*.
- (B) Test Farm Sites: Roofing product specimens shall be exposed in the following three (3) locations representing three (3) 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 10% of those values shown above.

Advisory note: *Examples of regions of the United States that comply with Section 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 (3) continuous years at the locations specified in Section S.2.6(B) in accordance with specimen preparations described 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. Products designated for only steep-sloped applications shall be exposed on plywood backing at a 45° tilt angle. Low-slope products shall be exposed on plywood backing at a 5° tilt angle. Products designated as both low- and steep-sloped are to be exposed at low-slope only (5° tilt angle).

(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.

To ensure the proper handling of specimens, AITLs and test farms shall adhere to the procedures in ASTM G147, **except** sections 14.3 through 14.4 involving the washing of specimens. The test surface of each specimen **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 the exposure location (i.e., *test farm site*).

S.2.7 Requirements for Laboratory Soiling and Weathering of Roofing Materials

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

(A) Specimen qualifications:

1. Each product specimen shall comply with the requirements of ASTM D7897.
2. The exposed area of each specimen shall be 10 centimeters by 10 centimeters (3.94 inches by 3.94 inches).

(B) Specimen quantity: Three (3) specimens of each roofing product randomly selected from the routine production for purposes of testing.

(C) 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 ASTM D7897.

- (D) Variegated Shingle Products: *Variegated* shingles undergoing laboratory soiling and weathering shall adhere to the requirements in Appendix B.
- (E) Reporting: The report for laboratory soiling and weathering of roofing materials shall include:
 1. Information as required by Section 10 of ASTM D7897.
 2. The *solar reflectance* and *thermal emittance* of each specimen measured in accordance with Sections S.2, before and after laboratory soiling and weathering. 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

Accredited Independent Testing Laboratories (AITL) 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 report shall contain the following information:

- (A) 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.
- (B) If a product has begun, but not yet completed, field exposure in accordance with Sections S.2.6 and S.2.3, 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.
- (C) The AITL shall note in its report whether the tested *aged radiative properties* are *field-exposed radiative properties* or *laboratory-exposed radiative properties*.
- (D) The report shall contain information as required by the appropriate test method and shall also include the following information:
 1. Name and address of the *OM* or *Seller*.
 2. Name and identification for the roofing product.
 3. Name and address of the AITL and name of the person overseeing testing and the technician who performed the testing.
 4. Test method(s) employed.
 5. Thickness of top coating or material tested, if applicable.
 6. Summary of data (i.e., test results).

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 part of a *Color Family Group*, a *Color Family Additional Element*, or a *variegated roofing product*.
- (B) Section S.3.3 for factory-applied coatings and factory-coated metal products.
- (C) Section S.3.4 for *variegated roofing products*.
- (D) Section S.2.7 for laboratory-soiled and weathered products.

S.3.2 Standard Production Line Roofing Product Specimen

(A) Specimen Selection:

Nine (9) specimens shall be randomly selected from routine production and sent to an AITL for testing. These specimens shall be grouped into three (3) sets:

1. Three (3) specimens from *Batch A*,
2. Three (3) specimens from a *Batch B*, and
3. Three (3) specimens for which each of the two (2) *batches* shall be represented.

This results in a total of four (4) specimens from one *batch* and five (5) from the other.

For *tile roofing products*, both mono-color and *variegated*, shall be tested using nine (9) individual tiles. For tile blend assemblies that are made up of two (2) or more colors, each color must be tested as an individual product.

(B) Specimen Preparation (including size, batch, number of specimens, identification, substrate and thickness):

1. Each specimen shall be a minimum of 10.2 centimeters by 15.2 centimeters (4 inches by 6 inches) in size.
2. Each specimen shall be identified with the following:
 - a. manufacturer's name and address;
 - b. product name and/or model number; and
 - c. *batch* number and individual specimen number.

The label adhered to each specimen shall be durable, and the information on the label legible, for a minimum period of four (4) years, during which specimens will be exposed to the environment.

For *tile roofing products*, 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.

(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, 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 film thickness or coverage recommended by the manufacturer for use in the field. The dry film 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 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 tested radiative properties of the product specimens shall be reported according to the following provisions:

1. Initial tested *radiative properties* shall be reported as the average of the initial test results of the specimens from *Batches A* and *B*.

2. *Field-exposed tested radiative properties* shall be reported as the arithmetic average of the field-exposed test results of each of the nine (9) product specimens that undergo three-year 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 *aged radiative properties*. As a result of such an occurrence, the *aged radiative properties* that are reported shall be no higher than the arithmetic average of the averaged results from each *test farm site*.

Up to two (2) product specimens per *test farm site* shall be permitted to be discarded if *uncharacteristically damaged*. Should all three (3) specimens from one *test farm site* be *uncharacteristically damaged*, the *Seller* or *OM* shall have their products re-tested. For asphalt shingle products, see Section 3.4(C)3.

S.3.3 Factory-Colored Products

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.

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 (2) 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 (9) specimens shall be randomly selected from routine production and sent to an AITL for testing. These specimens shall be grouped into three (3) sets: a) three (3) specimens from one *batch*, b) three (3) specimens from a second *batch*, and c) another set of three (3) specimens for which each of the two *batches* must be represented. This results in a total of four (4) specimens from one *batch* and five (5) 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 for testing. The specimens shall be

grouped into two (2) sets: a) three (3) specimens from one *batch*, and b) three (3) specimens from a second *batch*.

(B) Specimen Preparation:

1. Each specimen shall be at least 155 square centimeters (24 square inches) in size.
2. Each specimen shall be identified with the following:
 - a. manufacturer's name and address;
 - b. product name and/or model number;
 - c. *batch* number and individual specimen number.

The label adhered to each specimen shall be durable, and the information on the label legible, for a minimum 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 *tested radiative properties* of the product specimens shall be reported according to the following provisions:

1. *Initial tested radiative properties* shall be reported as the average of the tests conducted on specimens from *Batches A and B*.
2. *Field-Exposed tested radiative properties* shall be reported as the arithmetic average of the *field-exposed* test results of each of the nine (9) 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 tested radiative properties* that are reported shall be no higher than the arithmetic average of the averaged results from each *test farm site*.

4. Up to two (2) product specimens per *test farm site* shall be permitted to be discarded if *uncharacteristically damaged*. Should all three (3) specimens from one *test farm site* be uncharacteristically damaged, the *Seller* or *OM* shall have their products re-tested.

Color Family Additional Elements are not subject to *aged radiative properties* testing. The *aged tested radiative properties* reported on the *Color Family Additional Element* and in the test results shall be identical to what is reported for the *Representative Element* of the *Color Family Group*. Either the initial *Color Family Group* default value or the actual aged value of the *Representative Element*, whichever is lower, shall be used.

S.3.4 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:

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

Advisory note: *specimens may be comprised of multiple pieces. Top surfaces may be particles, or other materials creating a variegated surface.*

2. For *variegated tile, non-shingle, or modified bitumen products* that are tested under CRRC-1 Test Method #1, specimens shall be randomly selected from routine production and sent to an AITL for testing. These specimens shall be grouped into three (3) sets:
 - a. Three (3) specimens from *Batch A*;
 - b. Three (3) specimens from *Batch B*;

- c. Three (3) specimens for which each of the two *batches* shall be represented.

Advisory Note: Tile is tested with either the tile variant of CRRC-1 Test Method #1 or the Tile Template Method, which specifies specimen size requirements.

(B) Specimen Preparation:

Advisory note: *the manufacturer may opt to work with an AITL to prepare specimens in accordance with the following provisions.*

1. Specimens to be tested under CRRC-1 Test Method #1:
 - a. *Variegated* shingle products shall have a minimum dimension of 25.4 centimeters by 91.4 centimeters (10 inches by 36 inches) of exposure surface. Shingle specimens shall include at least two (2) 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, with the information legible, during which time specimens will be exposed to the environment.
 - b. For *variegated tile roofing products*, specimens may be full uncut tiles or cut by the tile manufacturer to a smaller size not less than 15.24 centimeters by 15.24 centimeters (6 inches by 6 inches). Unreadable areas may be removed as long as a representative specimen remains intact for testing. Specimens 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, with the information legible, during which time specimens will be exposed to the environment.
 - c. For variegated products that are neither shingles nor modified bitumen, the area of each specimen shall be at least 10.2 by 25.4 centimeters (4 inches by 10 inches). Specimens 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, with the information legible, during which time specimens will be exposed to the environment.
2. The *Seller* or *OM* shall be responsible for ensuring that specimens of *variegated roofing products* that are tested in accordance with ASTM E1918 are prepared on the appropriate substrate(s) in accordance with the recommendations of the manufacturer, and meet the minimum size requirements for testing under ASTM E1918.

(C) Radiative Properties Reporting:

1. *Initial tested radiative properties* shall be reported as the arithmetic average of the average radiative property values determined in accordance with CRRC-1 Test Method #1.

For *variegated* shingle products, in the event that two (2) specimens yield radiative property values that differ by more than 0.05 from each other, both specimens shall be deemed to be non-compliant with the requirements stated in this section (Section S.3). The *Seller* or *OM* shall then be required to prepare three (3) additional specimens of sufficiently larger dimensions to ensure that the difference in the radiative property values between each of the two (2) new measured specimens is equal to or less than 0.05.

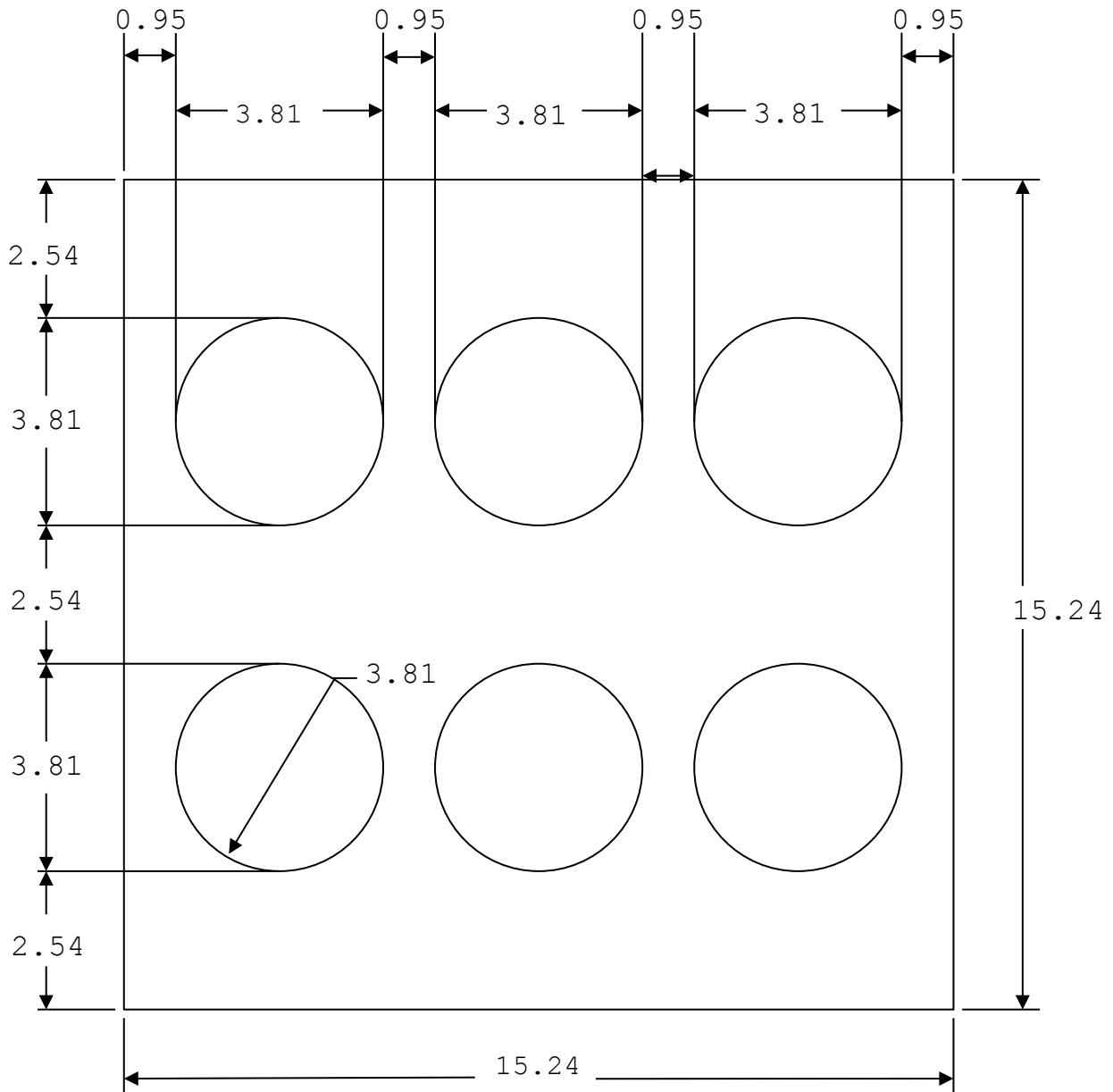
2. *Field-exposed tested radiative properties* shall be reported as the arithmetic average of the average radiative values for each of the three (3) test farm sites, as determined in accordance with CRRC-1 Test Method #1.
3. In the event that a specimen is uncharacteristically damaged during field exposure, the specimen shall be removed from the calculation of the *field-exposed radiative properties*. As a result of such an occurrence, the *field-exposed testing radiative properties* that are reported shall be no higher than the arithmetic average of the averaged results from each *test farm site*.

Up to two (2) product specimens per *test farm site* shall be permitted to be discarded if uncharacteristically damaged. Should all three (3) specimens from one *test farm site* be uncharacteristically damaged, the *Seller* or *OM* shall have the product re-tested.

For *variegated* shingle specimens, if the test specimen from one test farm site is uncharacteristically damaged, the *Seller* or *OM* shall have the product re-tested.

Appendix A – Tile Method Template

All values shown are in centimeters. All diameters must be 3.81 centimeters (1.5 inches). This template is not accurately drawn to scale.



Appendix B - Procedure for Variegated Shingles Undergoing Laboratory Soiling and Weathering

The following criteria shall be used to determine the laboratory-exposed radiative properties of variegated shingles. The procedure is limited to products with a designed exposure height of not less than 10.16 centimeters (4 inches) and not greater than 30.48 centimeters (12 inches).

- (A) Specimen selection: A minimum of nine (9) specimens shall be randomly selected from a minimum of three (3) full shingle boards. Specimens shall be selected from the portion of the shingle designed for exposure and weathering, which shall be separated from the full shingle board. Discard the “unexposed shingle area” portion. Shown in Figures 1 and 2 below.
- (B) Specimen size: Starting from left to right, cut nine (9) specimens 10.16 centimeters (4 inches) wide by full height of the exposed area as shown in Figure 3 below. If needed, adjust the location where the 10.16-centimeter-wide specimens are obtained in order to have a continuous, flat piece of material without gaps or raised edges (i.e., typical of three tab and laminated shingles). Once the shingles boards have been cut into nine (9) specimens that are 10.16 centimeters wide, discard the remaining material.
- (C) Testing locations: For each cut piece that is 10.16 centimeters (4 inches) wide by no more than 30.48 centimeters (12 inches) high, apply a random procedure to determine the location (e.g., top, middle or bottom) where each 10.16-centimeter by 10.16-centimeter specimen will be obtained (see Figures 4 – 6 below).
- (D) Identification: The manufacturer shall assign a unique number for each of the 10.16 centimeter by 10.16-centimeter (4 inch by 4 inch) pieces obtained from the three (3) shingle boards and mark the numbers on the back of each specimen.
- (E) Pre-test preparation: Before proceeding, measure the average initial solar reflectance of each un-aged specimen. Ensure that the average initial solar reflectance is ± 0.02 of the value determined by Section S.2.2(B) if *variegated* or S.2.2(C) if *non-variegated*. If the value is not ± 0.02 , then other test specimens that were previously cut shall be used as replacements for testing. Recalculate the initial solar reflectance of the new set of nine (9) specimens. If necessary, repeat this substitution process until the average initial reflectance of the nine (9) specimens is ± 0.02 of the initial reflectance values as measured using Section S.2.2.

- (F) Solar reflectance soiling, testing and reporting: Randomly select nine (9) of the numbered 10.16 centimeter by 10.16-centimeter (4 inch by 4 inch) specimens assigned for soiling and weathering. Conduct laboratory soiling and weathering on each the nine (9) test specimens in accordance with ASTM D7897. Upon completion of the laboratory soiling and weathering procedure, record the nine (9) solar reflectance measurements for each of the nine (9) specimens in the locations shown in Figure 7 below. Calculate each specimen's aged solar reflectance as the average of the nine (9) measurements for each specimen. Calculate the overall average aged solar reflectance based on all nine (9) specimens. Report the aged solar reflectance of each specimen with the test results. If initial solar reflectance values were determined using the optional process described above then report those values.
- (G) Thermal emittance testing and reporting: Measure the aged thermal emittance of each of the nine (9) aged specimens in accordance with Section S.2.3(C). Calculate the overall average thermal emittance for all nine (9) specimens. Report the thermal emittance of each specimen with the test results.

Figure 1. Full Shingle Board as Received from Manufacturer



Figure 2. Unexposed and Exposed Areas of Separated Shingle Board



Figure 3. Diagram of Full Shingle as Cut into 10-Centimeter Pieces

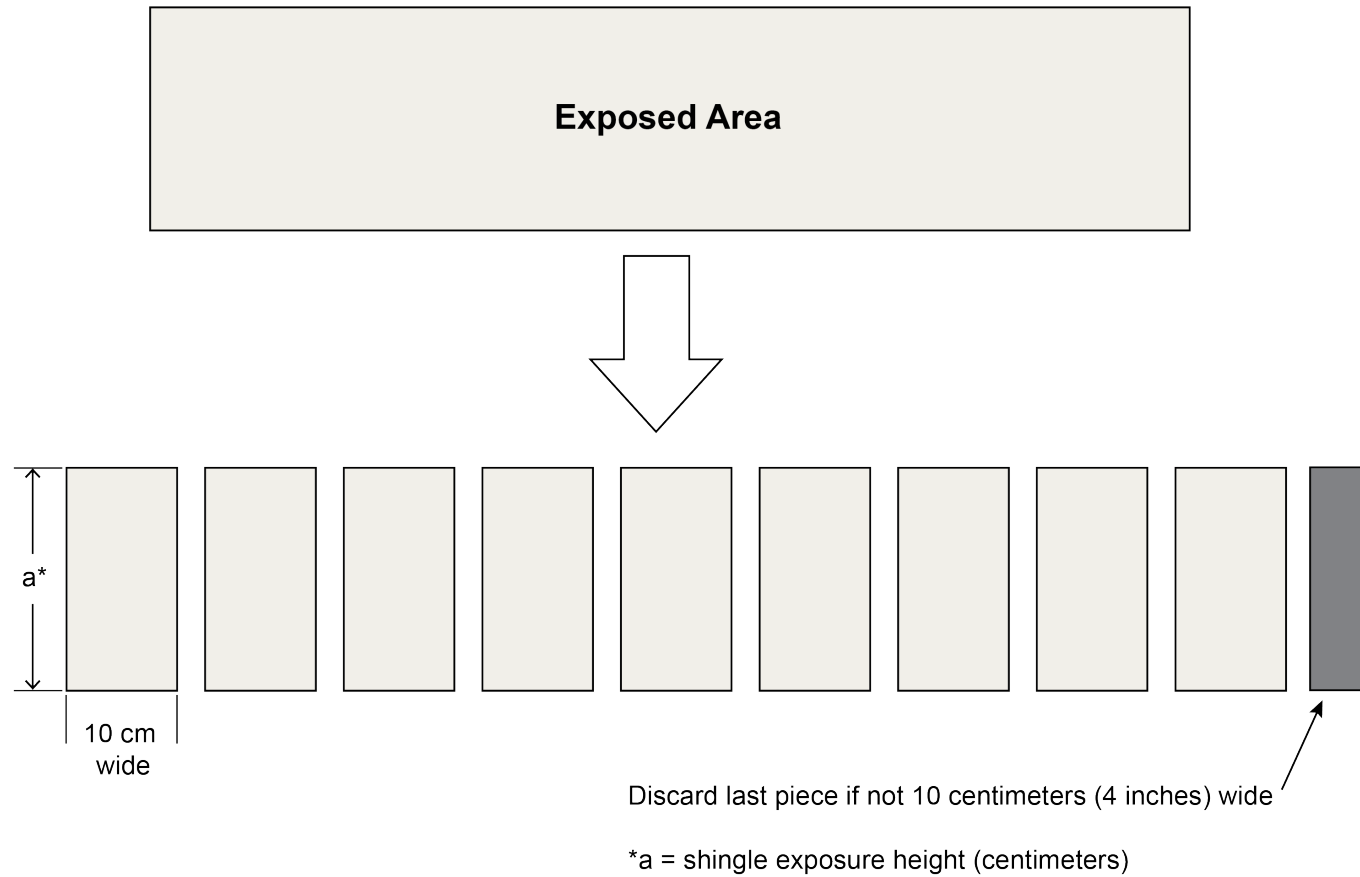


Figure 4. Test Specimen Obtained from Bottom Portion of Exposed Area

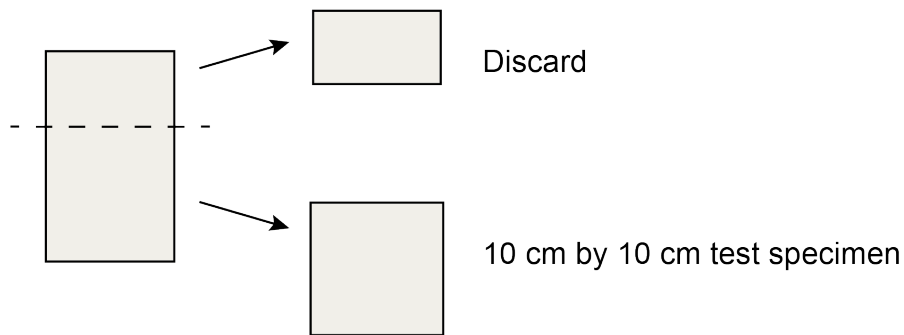


Figure 5. Test Specimen Obtained from Middle Portion of Exposed Area

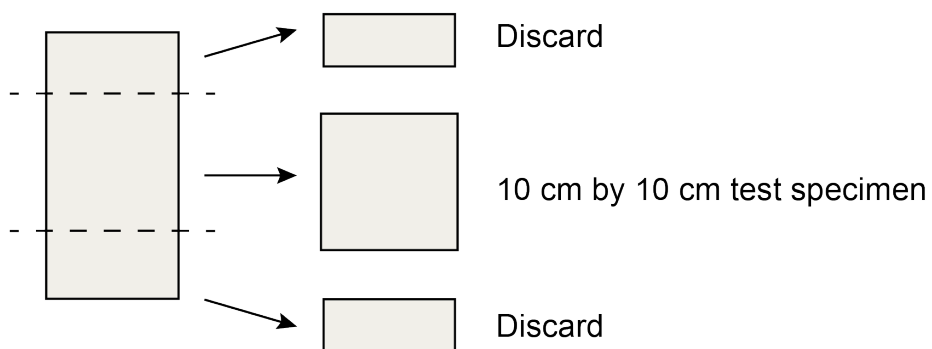


Figure 6. Test Specimen Obtained from Top Portion of Exposed Area

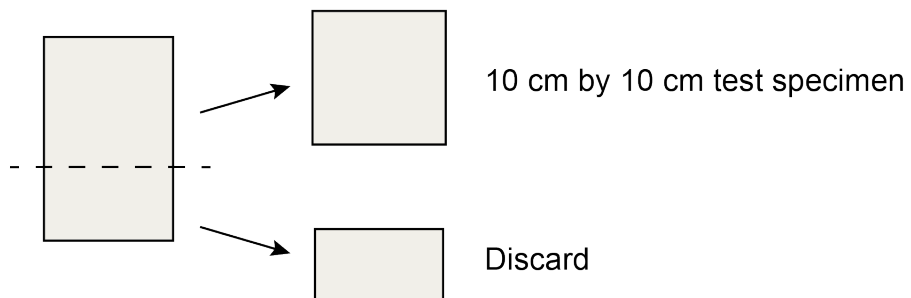


Figure 7. Variegated Shingle Measurement Template

