



Designation: D228/D228M – 15

Standard Test Methods for Sampling, Testing, and Analysis of Asphalt Roll Roofing, Cap Sheets, and Shingles Used in Roofing and Waterproofing¹

This standard is issued under the fixed designation D228/D228M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover procedures for sampling, examination, physical testing, and analyses of asphalt-containing materials used in roofing and waterproofing. These materials include but are not limited to roll roofing, cap sheets, and shingles. Any of these materials are allowed to be partially or fully coated, surfaced, or laminated, or a combination thereof.

1.2 The test methods and procedures in this standard appear in the following order:

Section	Content
6	Types of Roofing
7	Sampling
8	Mass and Area Determination
9	Selection of Representative Specimens
10	Moisture
11	Pliability
12	Mass Loss and Behavior on Heating
13	Tear Strength
14	Fastener Pull-Through Resistance
15	Preparation and Selection of Small Test Specimens for Analyses
16	Analysis of Glass Felt Products
17	Analysis of Roofing Products with Organic Felts
18	Ash of Desaturated Felt
19	Calculation
20	Adjusting Back Coating Fine Mineral Matter and Back Surfacing
21	Report
22	Precision and Bias

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:²

- D95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation
- D146 Test Methods for Sampling and Testing Bitumen-Saturated Felts and Woven Fabrics for Roofing and Waterproofing
- D225 Specification for Asphalt Shingles (Organic Felt) Surfaced With Mineral Granules (Withdrawn 2012)³
- D1079 Terminology Relating to Roofing and Waterproofing
- D1922 Test Method for Propagation Tear Resistance of Plastic Film and Thin Sheeting by Pendulum Method
- D2178 Specification for Asphalt Glass Felt Used in Roofing and Waterproofing
- D2626 Specification for Asphalt-Saturated and Coated Organic Felt Base Sheet Used in Roofing
- D3462 Specification for Asphalt Shingles Made from Glass Felt and Surfaced with Mineral Granules
- D3909 Specification for Asphalt Roll Roofing (Glass Felt) Surfaced With Mineral Granules
- D4601 Specification for Asphalt-Coated Glass Fiber Base Sheet Used in Roofing
- D4897 Specification for Asphalt-Coated Glass-Fiber Venting Base Sheet Used in Roofing
- D4932 Test Method for Fastener Rupture and Tear Resistance of Roofing and Waterproofing Sheets, Roll Roofing, and Shingles
- D6380 Specification for Asphalt Roll Roofing (Organic Felt)
- F1667 Specification for Driven Fasteners: Nails, Spikes, and Staples

¹ These test methods are under the jurisdiction of ASTM Committee D08 on Roofing and Waterproofing and are the direct responsibility of Subcommittee D08.02 on Steep Roofing Products and Assemblies.

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

³ The last approved version of this historical standard is referenced on www.astm.org.

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in these test methods, see Terminology D1079.

3.1.2 As referenced in 15.1, “Materials of Uniform Composition” designates products that are manufactured to be the same thickness, ply count, and mass per unit area in all areas of the material. This would include traditional mineral surfaced rolls, “3 Tab” shingles, and other shingles that have areas of material removed for appearance purposes (cut-outs) but the rest of the shingle is of uniform composition. See Fig. 1, Type 1 or Type 2.

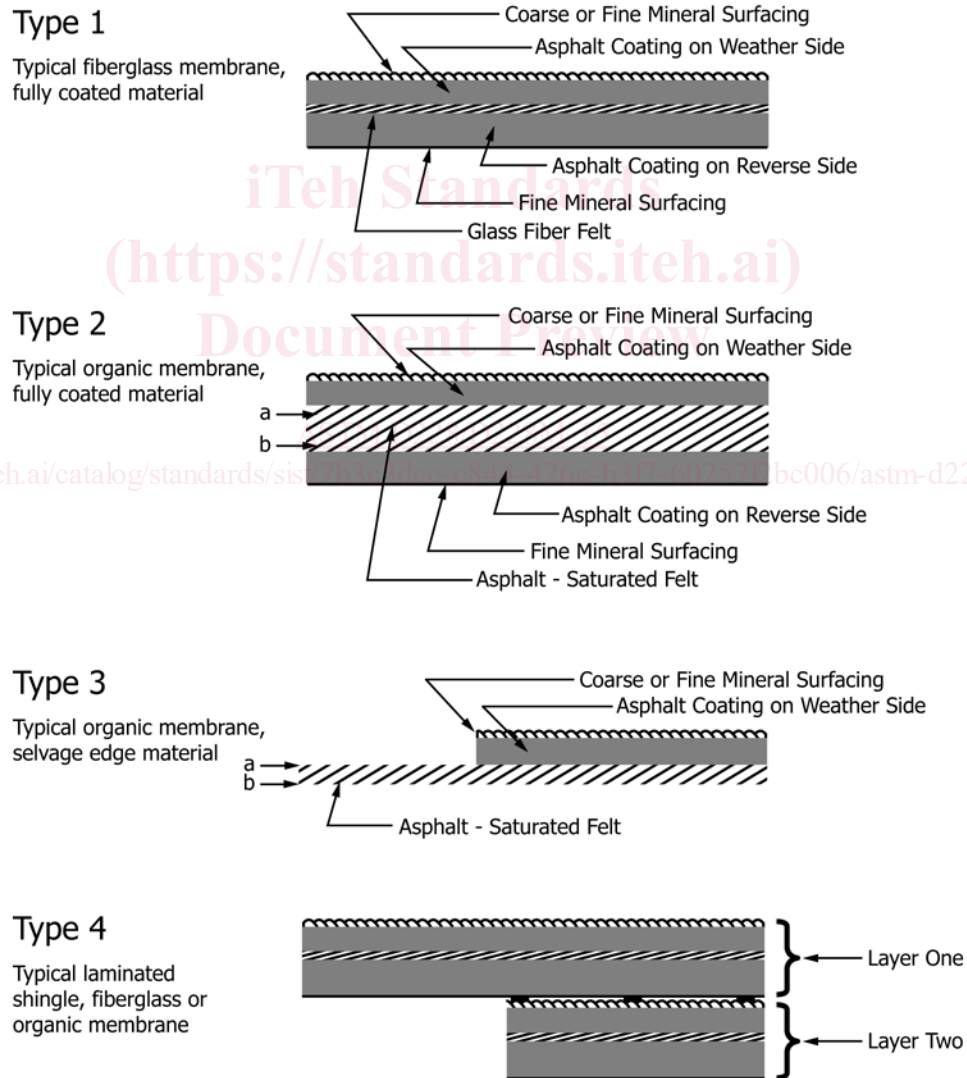
3.1.3 As referenced in 15.2, “Materials of Nonuniform Composition” designates products that are intentionally manufactured to have different thickness or mass per unit area within different areas of the product. Examples of materials of nonuniform composition are selvage edge rolls and overlaid or

embossed shingles (where not all of the product has the same thickness). See Fig. 1, Type 3.

3.1.4 As referenced in 15.4, “Materials of Multiple Layer Composition” designates products that are fabricated in multiple layers. See Fig. 1, Type 4.

3.1.5 As referenced in these test methods, “Machine Direction” (indicated as MD) is the direction running the long dimension of a roll product (before samples or specimens are cut) or the long dimension of a shingle, unless otherwise known and agreed to between supplier and purchaser. “Cross Direction” (indicated as CD) designates the direction perpendicular to the MD.

3.1.6 A production lot is defined as all material produced within one production shift of the same type, composition, and color (where applicable). A delivery lot is defined as a shipment or fraction thereof representing a product of the same type, composition, and color (where applicable).



NOTE 1—Not to scale.

NOTE 2—Type 3 has been illustrated without asphalt coating or fine mineral surfacing on the reverse side. It is not prohibited to fabricate this product with asphalt coating or fine material surfacing on the reverse side.

FIG. 1 Types of Asphalt-Coated Roll Roofing and Shingles

4. Significance and Use

4.1 These test methods include procedures for sampling, examination, physical testing, and analyses of asphalt roll roofing, cap sheets, and shingles used in roofing and waterproofing. Other components of these materials are allowed to include, but are not limited to, felts, mats, films, foils, mineral stabilizers, papers, and mineral surfacing.

4.2 These test methods include tests that are not required by every product standard that references Test Methods D228/D228M. The individual product standards are the authority for which tests are required for compliance. It is not prohibited to run tests in addition to those required in the product standards, but these test methods make no claim to their suitability or significance.

4.3 Five random samples are required from lots equal to or less than 1000 packages. The number of samples required for lots greater than 1000 packages is dependent on the variation in the unit mass within the lot and is determined by the two-step sampling plan in 7.4.

4.4 The results of a visual examination, physical testing, and compositional analysis are required for each sample. The analytical data are further used to compute the probable minimum and the probable range for the average mass of each of the components.

5. Materials

5.1 *Filter Paper*—The extractions for analysis of glass felt products (Section 16) and analysis of roofing products with organic felt (Section 17) require the use of filter paper with a particle retention of 2.7 μm (see Note 1). This filter paper is dried for 60 min \pm 10 % in an 80°C [176°F] oven and stored until needed in a desiccator.

NOTE 1—Whitman No. 50 filter paper [185 mm] has been found satisfactory for this use.

6. Types of Roofing

6.1 Asphalt-coated roll roofing and shingles are divided into the following types for the purposes of these test methods (see Fig. 1).

6.1.1 *Type 1*—A single thickness of glass felt, coated with asphalt and mineral surfacing such as in Specifications D2178, D3462, D3909, D4601, and D4897. The backing material (designated “Fine Mineral Surfacing” in Fig. 1) shall be permitted to be any suitable material that prevents these products from sticking together while packaged.

6.1.2 *Type 2*—A single thickness of asphalt-saturated felt coated with asphalt and mineral surfacing such as in Specifications D225, D2626, and D6380, Class M. The backing material (designated “Fine Mineral Surfacing” in Fig. 1) shall be permitted to be any suitable material that prevents these products from sticking together while packaged.

6.1.3 *Type 3*—Similar to Type 2, but asphalt coated and surfaced with mineral granules for part of one side of the saturated felt such as in Specification D6380, Class WS. This type also includes products similar to Type 1 or Type 2 that have overlay or embossed areas. This does not include products that are fabricated in multiple layers.

6.1.4 *Type 4*—This material is comprised of multiple layers bonded with a suitable adhesive, typically a bituminous material. Evaluation of the nature of the adhesive or quality of the bond, or both, is outside the scope of this test method. Fig. 1 illustrates a typical configuration for Type 4. This “Type” description is provided to aid the user in understanding how to match a given product composition and assembly to its corresponding Type. It is not intended to limit or exclude products with similar, but not identical constructions. Examples of known variations, which shall not be prohibited include (but are not limited to):

6.1.4.1 Materials using other adhesives,

6.1.4.2 Materials fabricated with more than two layers,

6.1.4.3 Materials that use different relative proportions for the layers, and

6.1.4.4 Materials with other core compositions

7. Sampling

7.1 The rolls or packages selected in accordance with this section constitute the representative sample used in Sections 8 and 9.

7.2 Select five rolls or packages from the lot at random. Do not select any material that shows visual indications of damage from shipping or handling. Determine the average net mass in g/m^2 [lb/100 ft^2] and the standard deviation in accordance with 8.1 – 8.8.

7.3 If the lot is 1000 or fewer rolls or packages, proceed to Section 8. If the lot is 1001 or greater in number, follow the second part of the sampling plan in 7.4.

7.4 Calculate the required number of samples based on the standard deviation (s) of the preliminary sampling by:

$$n = \frac{t^2 s^2}{d^2} \quad (1)$$

where:

n = total number of samples required ($n - 5$ more rolls or packages must be selected at random as samples),

t = test statistic for number of samples in the preliminary test series for 4° and a 95 % confidence that the calculated average mass will not exceed d ($t = 2.776$), and

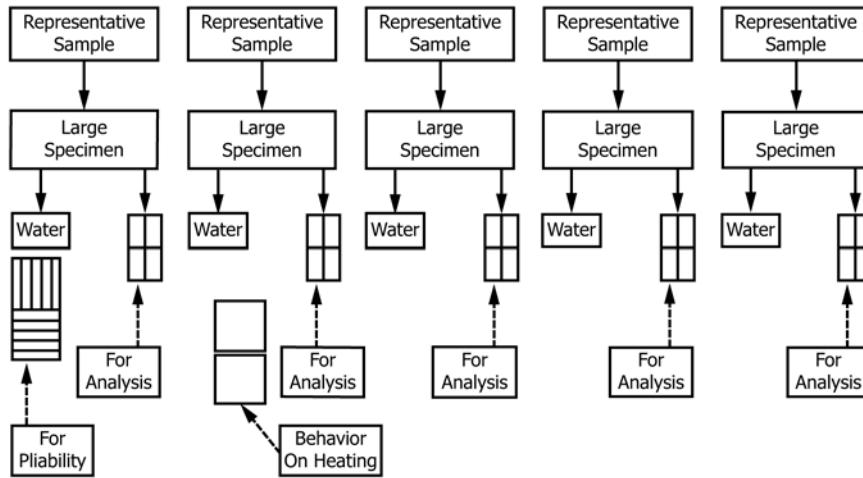
d = 100 g/m^2 [2 lb/100 ft^2] (the mean mass obtained from the analysis should be within $\pm 100 \text{ g/m}^2$ of the true value, with 95 % confidence).

7.5 See Fig. 2.

8. As Received Mass and Area Determinations, All Types of Roofing

8.1 *Gross Mass*—Determine and record the mass of each representative sample to the nearest 0.1 kg [0.2 lb].

8.2 *Net Mass*—Disassemble each package or unroll each roll of the representative sample; shake off any loose surfacing and determine and record the net mass of all the shingles or the entire roll to the nearest 0.1 kg [0.2 lb]. Where a product standard requires it, the loose surfacing is to be collected and the mass determined.



In Section 7, initial “Representative Samples” are selected (typically five per lot). These are full bundles or rolls. These are the samples used in Section 8. In Section 9, one large “Specimen” is taken from each representative sample (full shingles from 8.5 or a portion of each roll selected in Section 7). These are confirmed to be within 1.5 % of the mass per area (from 8.6) for the corresponding representative sample. In Section 10 (where product standards require measurement of water content per Test Method D95), 50-g small test specimens are taken from each “Large Specimen” for determination of water. In Section 11, five MD and five CD small test specimens are cut from one of the “Large Specimens” for evaluation of pliability. In Section 12, two small test specimens are cut from one of the “Large Specimens” for evaluation of behavior on heating. In Section 15, small test specimens (three for glass felt, four for organic felt) are cut from each of the “Large Specimens” for analysis by Section 16 (for glass felt) or by Section 17 (for organic felt).

FIG. 2 Sample Selection Summary and Flow Diagram
(See Individual Sections for Sample Selection Details)

8.3 *Packaging and Fixture Mass*—Determine and record the mass to the nearest 0.1 kg [0.2 lb] of the packaging and all associated fixtures shipped with each roll or package of the representative sample, such as nails and adhesive.

8.4 *Dimensions of Roll Products*—Measure and record the length and width of each roll of roofing and the selvage width to the nearest 3 mm [$\frac{1}{8}$ in.].

8.5 *Shingle Count and Dimensions*—From each of the representative sample packages generated in Section 7, count and record the number of shingles in each package. Select one shingle randomly from each package. Measure the width, length, and cutout dimensions for each of these selected shingles to the nearest 1 mm [$\frac{1}{32}$ in.]. Calculate and record the average for each of these measurements.

8.6 Calculate the area of the roofing and the net mass per unit area of the roofing. Report the net mass per unit area in g/m^2 [$\text{lb}/100 \text{ ft}^2$] for each representative sample (without packaging, cut outs or loose surfacing).

8.7 Calculate and record the average net mass per unit area for the combined representative samples (without packaging, cut outs, or loose surfacing) in g/m^2 [$\text{lb}/100 \text{ ft}^2$].

8.8 Calculate and record the estimate of the standard deviation by:

$$s = \sqrt{\frac{\sum X^2}{n-1} - \frac{(\sum X)^2}{n(n-1)}} \quad (2)$$

where:

s = an unbiased estimate of the standard deviation,
 $\sum X^2$ = the sum of the squares of the individual mass determinations,

$(\sum X)^2$ = the square of the sum of the individual mass determinations, and
 n = the number of rolls or packages in the representative sample.

8.9 Calculate the 95 % confidence interval for the average mass by:

$$\frac{\sum X}{n} \pm \frac{ts}{\sqrt{n}} \quad (3)$$

where:

$\sum X$ = sum of the individual mass determinations, and
 t = appropriate t statistic for 95 % confidence and $n - 1$ df ($t = 2.776$ for $n = 5$; consult standard reference table for other values of n).

9. Selection of Representative Specimens, All Roofing Types

9.1 Several product standards reference sampling as designated in Test Methods D228/D228M for tests that are not specifically covered by Test Methods D228/D228M. Unless otherwise specified in these test methods, the large specimens and small test specimens shall all be selected from the representative sample (roll or package selected in Section 7) that has the individual net mass per unit area closest to the average net mass per unit area for the combined representative samples as determined in Section 8. If more than one roll or package needs to be selected to provide sufficient specimens for all the tests dictated within the product standard, any additional specimens shall be selected from the representative sample that has the net mass per unit area that is next closest

to the average net mass per unit area of the combined representative samples.

NOTE 2—It is the intent of these test methods that whenever not specifically directed to select specimens in some other manner, specimens shall be selected from the representative sample that is the closest in mass per unit area to the average mass per unit area of the combined representative samples.

9.2 For roll products, select a specimen of roofing, the full sheet width and at least 1 m [3 ft] in length from each roll, starting a minimum of three wraps into the roll. For shingle products, the shingles from 8.5 shall be used.

9.3 Determine the mass of each specimen and calculate the mass in g/m^2 [$\text{lb}/100 \text{ ft}^2$].

9.4 For Types 1, 2, or 3, discard all specimens that differ by more than 1.5 % from the net mass determined in 8.6, select replacements, and determine the mass as in 9.3.

9.5 Continue this process until five representative specimens are obtained, no more than one from each package or roll, that reflect that roll or package's average net mass as determined in 8.6.

9.6 If fewer than five specimens are available, use all the available specimens and adjust the final calculations to reflect the lower number of samples tested.

9.7 See Fig. 2.

10. Moisture

10.1 Determine the water in each sample in accordance with Test Method D95; use 50 g [0.11 lb] of product for each determination, cut up to fit in the flask. Report the water content as a percent of the dry (water-free) product mass.

10.2 See Fig. 2.

11. Pliability

11.1 From one of the large specimens selected in Section 9, cut ten small test specimens $25.4 \pm 3 \text{ mm}$ [$1 \pm \frac{1}{8} \text{ in.}$] in width by $200 \pm 50 \text{ mm}$ [$8 \pm 2 \text{ in.}$] in length, five MD and five CD. For Type 3 materials, these small test specimens are to be taken from the area that is asphalt-coated and surfaced with mineral granules. For Type 4 (laminated) materials, unless the product standard to be applied directs otherwise, the small test specimens are to be cut from a single layer. It is not prohibited to use single layer specimens from a multiple layer section of the shingle that has been separated into individual layers with suitable care. Any material damaged or significantly bent or creased during the separation process is to be discarded. Unless the product standard being evaluated directs testing at another temperature, condition the small specimens and the block at $23 \pm 2^\circ\text{C}$ [$73 \pm 4^\circ\text{F}$] for $2 \pm 0.1 \text{ h}$ and perform the test at $23 \pm 2^\circ\text{C}$ [$73 \pm 4^\circ\text{F}$]. Perform the test with the weather side up, at a uniform speed through 90° in approximately 2 s over the rounded edge of a block. If a water bath is needed to hold the designated temperature, the samples are to be placed in a plastic bag before placing them in the water bath so that they can be tested dry. Evaluation of the sample for cracking is much clearer when the sample does not have a wet surface.

11.1.1 The corner radius over which the small specimens are to be tested is typically specified in the individual product

standards. If not otherwise specified, the block will be 75 mm minimum [3 in. minimum] square by 50 mm minimum [2 in. minimum] thick with rounded corners of $13 \pm 1 \text{ mm}$ [$\frac{1}{2} \pm 0.04 \text{ in.}$] radius for Type 2 roofing and $19 \pm 1 \text{ mm}$ [$\frac{3}{4} \pm 0.04 \text{ in.}$] radius for Types 1 and 3 roofing. When bending, hold the specimens by hand tightly against the upper face of the block and bend the projecting end of the specimen over the rounded corner without exerting any stress other than that required to keep the specimen in contact with the block and avoid kinking.

11.1.2 For coated products, failure of a specimen in this test is defined as cracking of the coating asphalt that exposes the reinforcement of the specimen (organic or fiberglass). The cracking shall be visible to the naked eye when the specimen is viewed in the bent condition on the mandrel block. Separation of granules or other superficial fissures that do not extend through the coating asphalt surface to the reinforcement do not constitute cracking. Fracture through the specimen is also considered a failure. Report the number of specimens passing.

NOTE 3—Some products require testing with granules surfacing up and granule surfacing down. Those products shall have that additional requirement clearly stated in their product standard. The additional samples are to be selected in a manner consistent with the instructions above. This test method is intended for use only with coated products. See Test Methods D146 for pliability testing on non-coated products.

11.2 See Fig. 2.

12. Mass Loss and Behavior on Heating

12.1 Cut two test specimens, each approximately 100 by 100 mm [4 by 4 in.] from a large specimen selected in accordance with Section 9. Condition the smaller specimens for 24 h in a desiccator, determine the mass to the nearest 0.1 g, and then by means of a thin wire fastened through holes punctured near one edge, suspend them vertically in the center of an air oven maintained at $80 \pm 3^\circ\text{C}$ [$176 \pm 5^\circ\text{F}$] with the cross machine direction vertical. The internal dimensions of the oven shall be not less than 305 by 305 by 305 mm [12 by 12 by 12 in.]. The oven shall be electrically heated with forced draft. Insert a thermometer in the center of the oven to such a depth that its bulb is in line with the center of the specimens. Maintain the specimens at the prescribed temperature for $2 \text{ h} \pm 5 \text{ min}$, then cool in a desiccator and determine the mass of each specimen. Calculate the average loss of volatile matter as a percentage of the final specimen mass. Record any change in appearance of the specimen such as blistering, absorption of the asphalt coatings, or sliding of coating or granular surfacing. Record the extent of the latter to the nearest 2 mm [$\frac{1}{16} \text{ in.}$].

12.2 See Fig. 2.

13. Tear Strength

13.1 *Tear Strength*—Use Test Method D1922 as modified here.

13.1.1 Specimens shall be rectangular, 76 by 63 mm [3 by 2.5 in.] $\pm 3 \%$.

13.1.2 Condition specimens at $23 \pm 2^\circ\text{C}$ [$73 \pm 4^\circ\text{F}$] for at least 2 h prior to testing and conduct tests at $23 \pm 2^\circ\text{C}$ [$73 \pm 4^\circ\text{F}$].

13.1.3 Each specimen will be composed of a single layer. Cut specimens from shingles in areas free of sealing resin and

release tape. The 76-mm edges of the specimens shall be parallel to the long dimension (machine direction) of the shingles so that the tears will run in the short dimension (cross machine direction) of the shingle. Enough specimens shall be prepared so that ten results can be recorded after excluding any that must be rejected as prescribed in 13.1.4.

13.1.4 Use an Elmendorf Tear Strength Tester with 3200 or 6400 g [31 or 63 N] full scale capacity. Make all tests with granule surface of specimens facing away from the knife blade. Do not reject the results from specimens that tear through a side edge as opposed to the top edge. Reject results of specimens that tear in such a way that the portion of the specimen that is in the stationary jaw rubs against the pendulum.

13.1.5 Report the average tear resistance of ten specimens to the nearest 0.1 N [10 g].

13.1.6 The following criteria shall be used to judge the acceptability of the results at the 95 % confidence level:

13.1.6.1 *Repeatability*—Duplicate results by the same operator should be considered suspect if they differ by more than 17 %.

13.1.6.2 *Reproducibility*—The results submitted by each of two laboratories should be considered suspect if they differ by more than 28 %.

14. Fastener Pull-Through Resistance

14.1 *Scope*—This test method measures the force required to pull a fastener head through a specimen of material under defined conditions in a specified test apparatus. See the individual product standards for the significance and use of this test.

14.2 *Fasteners*—Various fasteners suitable for application of asphalt roofing materials shall not be prohibited in this test. The following instructions and procedures are based on a standard galvanized roofing nail with 10 mm [$\frac{3}{8}$ in.] diameter head (as specified in Specification F1667, Table 29). See Note 4. The specific fastener(s) required or allowed is specified in the product standard where this test method is applied. When this test method is not used for determining compliance to a product standard, the fastener employed must be reported with the results and the orientation of any prominent geometric features of the fastener with respect to the roofing product orientation shall also be reported (for any fastener other than the standard nail referenced above).

NOTE 4—When other fasteners, for example staples, are used with this test method and apparatus, the effects of varying orientation of the staple crown with the orientation of the specimen (parallel to machine direction or at some angle to the machine direction), or the effects of the staple crown not being flat and flush relative to the specimen surface, will generally cause greater variability in the results than when using a roofing nail.

14.3 *Specimens*—For single layer materials, prepare ten specimens 98 ± 3 mm [$3\frac{7}{8} \pm \frac{1}{8}$ in.] square for each test condition. If specimens include areas containing sealant (factory-applied adhesive) or release tape, or both, because it is inherently located in the nailing area when the material is applied in accordance with the application instructions, then it shall be noted in the report since it could affect the result. When

testing materials with cutout areas, any specimen where the cutout is visible through the opening in the plate (see 14.6) will have the effect of increasing the variability of the results.

14.4 For materials that include multiple layers, prepare ten specimens 98 ± 3 mm [$3\frac{7}{8} \pm \frac{1}{8}$ in.] square using the following procedure: These specimens shall be cut from the manufacturer's specified fastening position on the material. First, determine the fastener placement position from the manufacturer's application instructions. Once this position is determined, cut a 98 ± 3 mm [$3\frac{7}{8} \pm \frac{1}{8}$ in.] wide strip of material centered on this fastening position. Typically, this strip will be cut from the long dimension, or length, of the shingle or roll product. Use this strip to cut consecutive specimens 98 ± 3 mm [$3\frac{7}{8} \pm \frac{1}{8}$ in.] in length. These strips are cut from multiple large specimens such that no less than three specimens in a row nor more than four specimens in a row are cut from one large specimen when generating the ten specimens required for testing. If specimens include areas containing sealant (factory-applied adhesive) or release tape, or both, because it is inherently located in the nailing area, then it shall be noted in the report since it could affect the result.

NOTE 5—Specimens shall be permitted to include areas containing factory-applied adhesive (sealant) or release tape, or both, if this is expected to be in the nailing area when the shingles are applied in accordance with the manufacturers'/sellers' instructions. If this is the case, it shall be noted in the report since it could affect the result. For normal testing, the central area of the specimen where the nail penetrates shall be typical of the single thickness exposed area of the shingle under test. For multi-layered shingles, the test shall be performed in the area specified for fastening in the manufacturers'/sellers' instructions.

14.5 *Conditioning*—Condition specimens at the temperatures prescribed in the appropriate product standard for at least two hours prior to testing, and conduct the test at the prescribed temperatures. Other test conditions shall be permitted to give indications of fastener pull-through resistance at different temperatures, provided that the specimens are conditioned for at least 2 h and test at the desired temperature, and that the temperature used is noted in the report.

14.6 *Nail Placement*—Push a 38 mm [$1\frac{1}{2}$ in.] long galvanized roofing nail with a 10 mm [$\frac{3}{8}$ in.] diameter head through the center of the specimen within ± 5 mm [$\pm \frac{1}{4}$ in.] of the intersection of the diagonals of the square specimen (entering from the granule side and exiting at the backsiding side as in normal application) such that the head of the nail rests against the granule surface and the shank protrudes from the back surface. The use of a fixture to locate the center of the specimen or to draw diagonals with chalk to facilitate central positioning of the nail is not prohibited.

14.7 Fixture and Sample Assembly:

14.7.1 Prepare the specified number of specimens, each with a new nail in position, and condition them to the test temperature as directed by the product standard under investigation as a set prior to testing. When this test method is not used for determining compliance to a product standard, the test temperature must be reported.

14.7.2 Clamp the base part of the apparatus shown in Fig. 3 into the lower jaws of a constant rate of extension test machine capable of applying a force of at least 450 N [100 lbf] at an extension rate of 100 mm [4 in.]/min.