This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

INTERNATIONAL

Designation: C1859 − 17

Standard Practice for Determination of Thermal Resistance of Loose-Fill Building Insulation in Side Wall Applications[1]

This standard is issued under the fixed designation C1859; 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 This practice presents a laboratory guide to determine the thermal resistance of loose-fill building insulations installed in side walls behind netting at mean temperatures between –10 and 35°C (14 to 95°F).

1.2 This practice applies to a wide variety of loose-fill thermal insulation products including fibrous glass, rock/slag wool, or cellulosic fiber materials and any other insulation material that can be installed pneumatically. It does not apply to products that change their character after installation either by chemical reaction or the application of binders, adhesives or other materials that are not used in the sample preparation described in this practice, nor does it consider the effects of structures, containments, facings, or air films.

1.3 Since this practice is designed for reproducible product comparison, it measures the thermal resistance of an insulation material which has been preconditioned to a relatively dry state. Consideration of changes of thermal performance of a hygroscopic insulation by sorption of water is beyond the scope of this practice.

1.4 The sample preparation techniques outlined in this practice do not cover the characterization of loose-fill materials intended for open applications.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *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.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C168 Terminology Relating to Thermal Insulation

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

C518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

C1045 Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions

C1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus

C1363 Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus

3. Terminology

3.1 Unless otherwise stated, the terms and definitions found in Terminology C168 are applicable herein.

4. Significance and Use

4.1 The thermal resistance, *R*, of an insulation is used to describe its thermal performance.

4.2 The thermal resistance of an insulation is related to the density and thickness of the insulation. It is desirable to obtain test data on thermal resistances at thicknesses and densities related to the end uses of the product.

4.3 In normal use, the thickness of these products range from less than 100 mm (4 in.) to greater than 150 mm (6 in.). Installed densities depend upon the product type, the installed thickness, the installation equipment used, the installation techniques, and the geometry of the insulated space.

4.4 Loose-fill insulations provide coverage information using densities selected by manufacturers to represent the product

[1] This practice is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

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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.

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installed densities. Generally, it is necessary to know the product thermal performance at a representative density.

4.5 When applicable specifications or codes do not specify the nominal thermal resistance level to be used for comparison purposes, a recommended practice is to use the Rsi (metric) = 2.65 m F/Btu]) label density and thickness for that measurement.

4.6 If the density for test purposes is not available from the coverage chart, a test density shall be established by use of applicable specifications and codes or, if none apply, agreement between the requesting body and the testing organization.

4.7 Generally, thin sections of these materials are not uniform. Thus, the test thickness must be greater than or equal to the product's representative thickness if the results are to be consistent and typical of use.

NOTE 1—The representative thickness is specific for each product and is determined by running a series of tests in which the density is held constant but the thickness is increased. The representative thickness is defined here as that thickness above which there is no more than a 2 % change in the resistivity of the product. The representative thickness is a function of product blown density. In general, as the density decreases, the representative thickness increases. Fortunately, most products are designed to be blown over a small range of densities. This limited range yields a range of representative thicknesses between 75 to 150 mm (3 to 6 in.) for most products. To simplify the process for this practice, the representative thickness for the C1859 tests is considered 87.5 mm (3 ½ in). All thermal testing on this product is conducted at a thickness that is greater or equal to the representative thickness.

4.7.1 For this practice, the minimum test thickness shall be 87.5 mm (3 ½ in.). If the test is to represent an installation at a lesser thickness, the installed thickness shall be used.

4.8 For purposes of this practice, it is acceptable to estimate the thermal resistance at any thickness from the thermal resistivity obtained from tests on the product at the minimum test thickness (see 4.7.1) and at the density expected for the proposed thickness.

4.9 In principle, any of the standard methods for the determination of thermal resistance are suitable for loose-fill products. These include Test Methods C177, C518, C1114, and C1363. Of these test methods, the heat flow meter apparatus, Test Method C518, is preferred because of its lower cost and shorter testing time.

4.10 The thermal resistance of low-density insulations depend upon the direction of heat flow. Unless otherwise specified, tests shall be performed for the maximum heat flow condition, that is, a horizontal specimen with heat flow-up.

4.11 Specimens shall be prepared in a manner consistent with the intended installation procedure. Products for pneumatic installation behind netting shall be pneumatically applied (blown) using the manufacturer's installation instructions and netting specified.

5. Apparatus

5.1 Thermal test apparatus used for this practice shall meet these requirements.

5.1.1 *Conformance to Standards*—The apparatus shall conform to all requirements of the ASTM thermal test method used.

5.1.2 *Size and Error*—The apparatus shall be capable of testing specimens up to at least 150-mm (6-in.) thickness with an estimated error not greater than 1 % attributed to thickness/guard dimensions. (Parametric studies using a mathematical model of the proposed apparatus will give insight to this evaluation. For example, see Table 1 in the 1976 edition of Test Method C518.[3]

NOTE 2—Thermal test apparatus in use for this practice shall have overall plate dimensions of 457 to 1220 mm (18 to 48 in.) square with metering areas 152 to 457 mm (6 to 18 in.) square. Other sizes are acceptable if proper consideration of the size-thickness restrictions as outlined in the test method are observed in their design. (See Practice C1045 for additional discussion.)

5.1.3 *Temperature*—As a minimum, the apparatus shall be capable of testing at a mean temperature of 23.9°C (75°F) with a temperature difference of 20 to 28°C (36 to 50°F). The equipment shall be calibrated at the same temperatures as the test conditions. Some existing test apparatus have been designed to provide measurements over a range of mean temperatures from –20 to 55°C (–4 to 131°F) and for a wider range of temperature differences.

5.1.4 *Humidity*—The absolute humidity within the test apparatus shall be maintained low enough to prevent condensation within the specimen or on the cold plate(s). A maximum 9°C (48°F) dew point is consistent with the recommended material conditioning levels.

5.1.5 *Orientation and Direction of Heat Flow*—The thermal test apparatus shall be capable of testing horizontal specimens with heat flow-up. This orientation represents the most adverse heat flow condition for testing between two solid boundaries.

5.1.6 *Thermal Test Specimen Frame*—The test frame shall be sized to match the test apparatus and shall be made of materials having low thermal conductivity (<0.12 W/m K) and minimum thickness. A thin, thermally insignificant, screen or membrane is stretched across the bottom to support the material. To simulate the actual installation process, a frame holder, test frames (top and bottom half), and a cover assembly are recommended. The frame holder, test frames and cover assembly shall have fixed rigid sides (see Figs. 1-5).

5.2 *Specimen Preparation Equipment:*

5.2.1 *Blowing Machine*—A blowing apparatus is required when pneumatically applied specimens are to be tested. Choose the combination of hopper, blower, and hose size and length that is representative of common use for the application of the material to be tested. The following machine specifications have been developed for use with mineral wool and cellulosic materials.

5.2.1.1 *Mineral Fiber Insulations:*

(1) Blowing Machine—A commercial blowing machine with a design capacity for delivering the subject material at a rate between 4 and 15 kg (9 to 33 lb)/min.

(2) Blowing Hose—The machine shall utilize 46 m (150 ft) of typical 75 to 100 mm (3 to 4 in.) diameter flexible, internally corrugated blowing hose. At least 30 m (100 ft) of the hose

[3] See Table 1, "Maximum Spacing Between Warm and Cold Plates of Heat Flowmeter Apparatus," of Test Method C518 – 76 published in 1985 Annual Book of ASTM Standards, Vol 04.06.

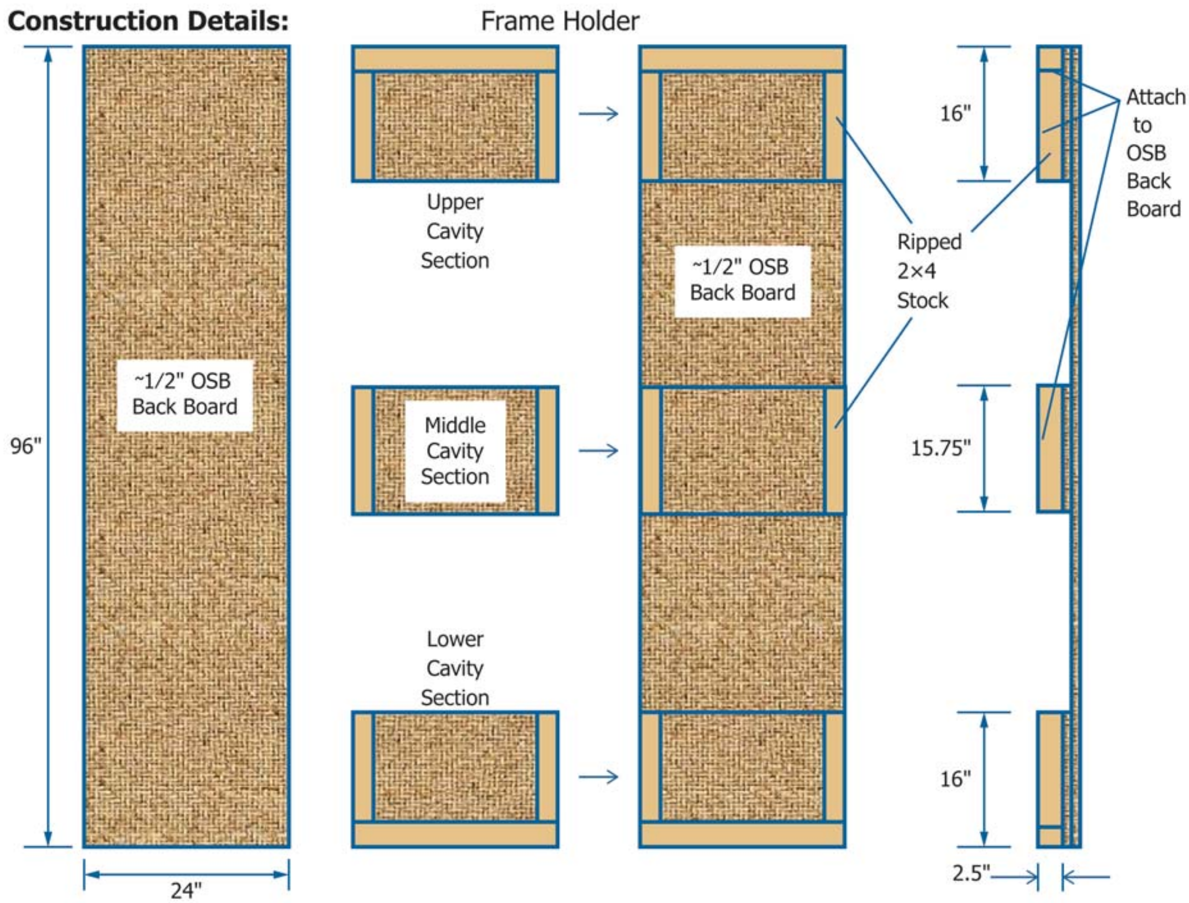


FIG. 1 Recommended Frame Holder (an Example)

shall be elevated between 3 and 6 m (10 and 20 ft) above the exit of the blowing machine to simulate a typical installation configuration. The hose shall have no more than eight 90° bends and all bends shall be greater than 1.2-m (4-ft) radius. Before each sample preparation session, examine the hose for material remaining from previous blows. Dislodge any remaining material by mechanically agitating the hose when the machine is running. Repeat as necessary to maintain a clean hose for each specimen.

(3) Insertion Device—The machine shall use a transition coupler to reduce the hose diameter down to 50 to 64 mm (2 to 2.5 in.), with a recommended minimum length of 6 m (20 ft).

NOTE 3—In case of dispute, for mineral fiber insulations a 75 mm (3 in.) hose shall be used to prepare the specimens.

5.2.1.2 *Cellulosic Insulations: Blowing Machine*—Use commercial blowing equipment designed for cellulosic material, that is, hopper, blower, and 30 m (100 ft) of typical 50 to 75 mm (2 to 3 in.) diameter hose.

NOTE 4—In case of dispute, for cellulosic insulations a 51 mm (2 in.) hose shall be used to prepare the specimens.

5.2.2 *Test Area Specimen Cutter*—A means for isolating the material within the metering area is required for the density determination. The isolated region shall have an area and shape identical to the metering area. Fig. 6 provides an example of a die cutter used for this purpose. The use of a compression plate to compress an area larger than the metering area, prior to metering area material removal is recommended. The compression plate shall extend at least 75 mm (3 in.) beyond the metering area boundary.

5.2.3 *Weighing Devices*—A device is required to weigh the test area material after the thermal test is complete. This device shall determine the test area weight to within 0.5 %. A second device is required during sample preparation and conditioning to determine the sample plus frame weight. This device shall determine the combined weight to within 0.5 %.

5.2.4 *Conditioning Room*—An enclosure held at near constant temperature and humidity is required to stabilize the materials or products prior to testing. The conditions are generally given in product specifications or in other appropriate documents. In the absence of specific directions, conditioning shall be carried out in an atmosphere of 23 ± 2°C (75 ± 4°F) and a relative humidity not greater than 45 % (see 5.1.4).

5.2.5 *Specimen Support Sheet*—A stiff cardboard or equivalent sheet to be used to support the specimen during preparation, conditioning, and transport.

5.2.6 *Specimen Preparation Room*—A semi-enclosed area where the test material is blown into the specimen frame is required. This enclosure protects the blowing operation from wind or strong air currents. The room size shall not influence

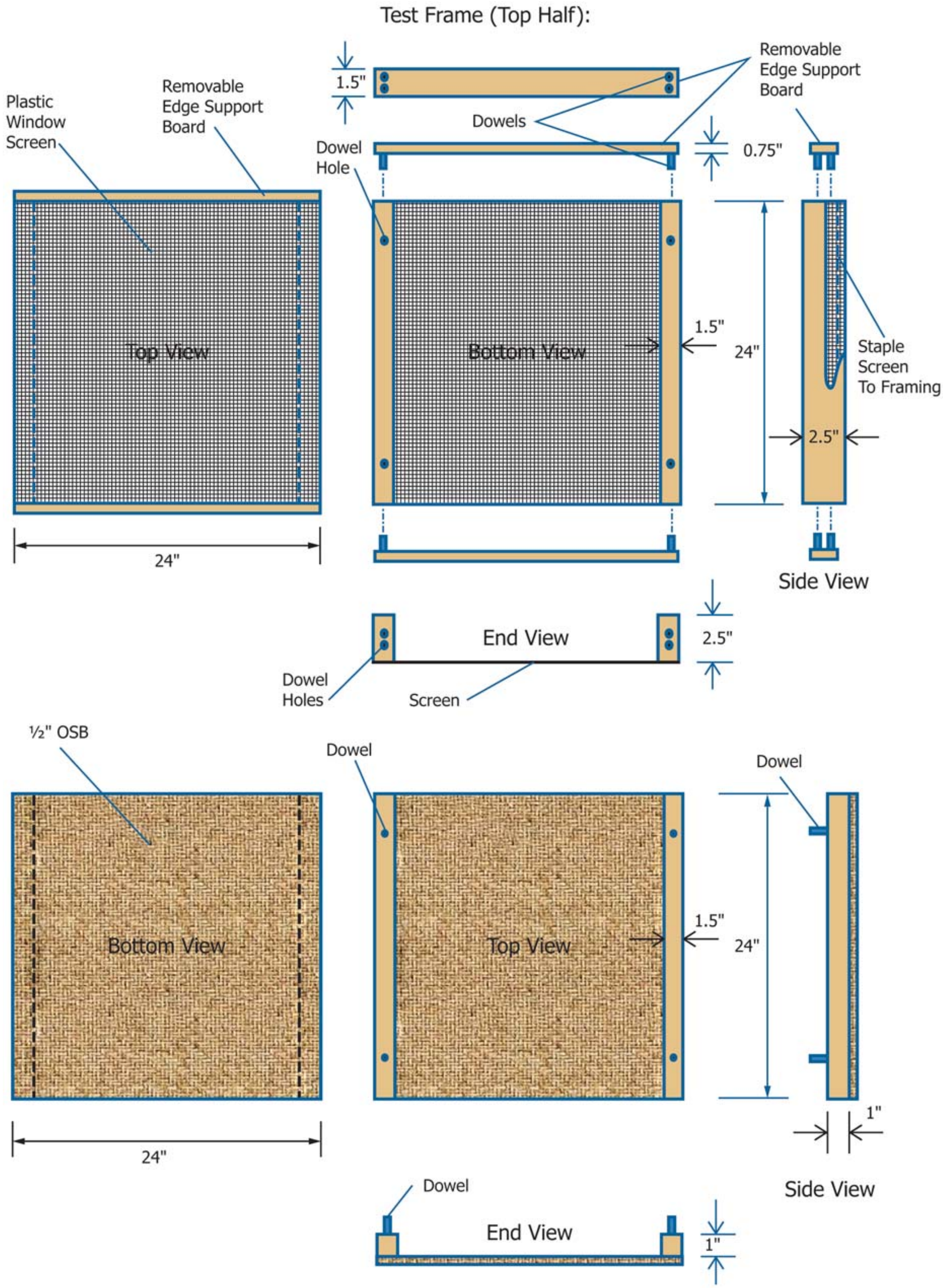


FIG. 2 Recommended Top and Bottom Test Frame (an Example)

the blowing stream from the hose. Minimum room dimensions of 3 by 3 by 2.5 m (10 by 10 by 8 ft) are generally adequate for this purpose. Experience has shown that, to obtain uniform specimens, it is necessary to blow an area greater than the

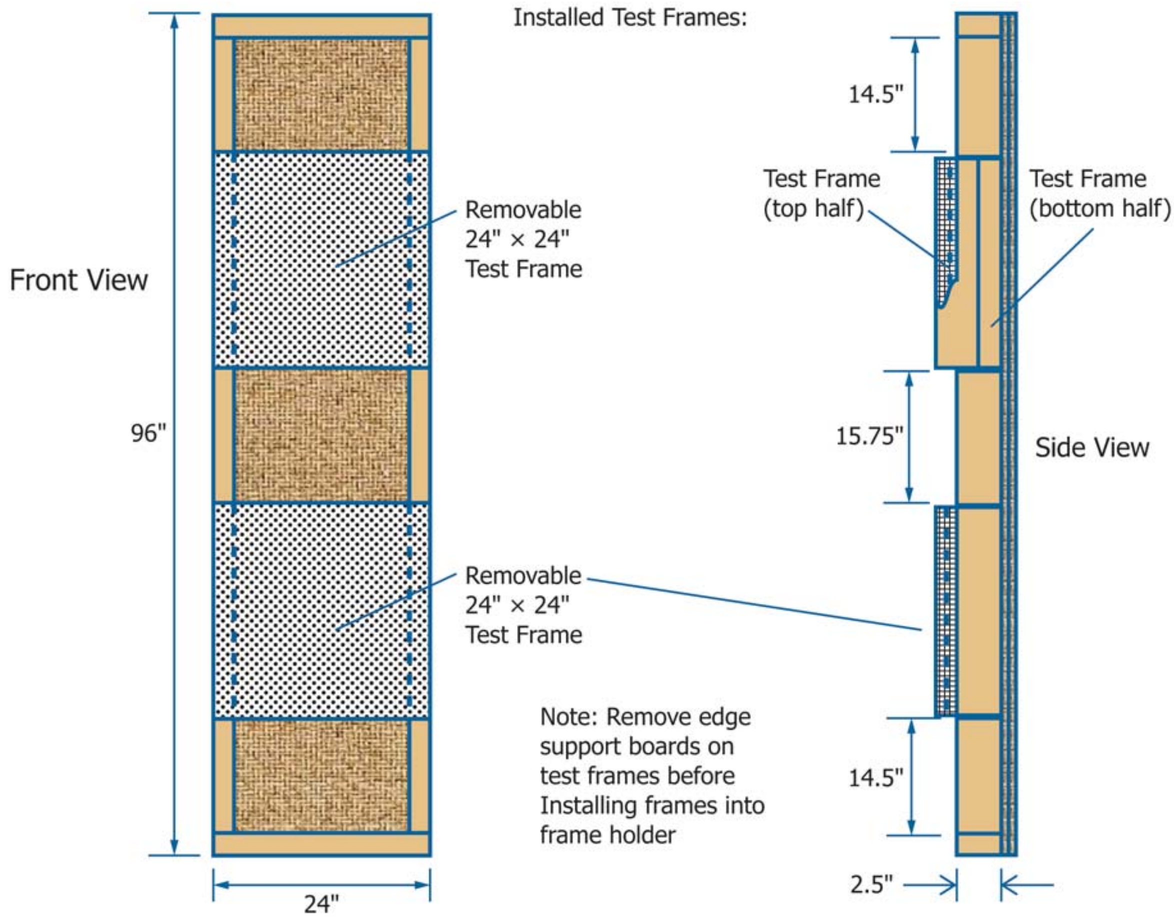


FIG. 3 Recommended Frame with installed Test Frames (an Example)

dimensions of the specimen frame. The recommended area to be covered is at least 2.5 times the minimum test frame dimension.

6. Sampling

6.1 Sampling plans given in the material specifications, regulations, or other appropriate documents shall be followed when applicable. In the absence of such directions, material from at least two randomly chosen packages shall be combined in equal portions (weight) and placed in the blowing machine so as to combine materials as uniformly as practicable. Alternatively, multiple tests are performed where each specimen is made from a single package.

6.2 The insulation material shall be preconditioned at laboratory conditions (see 5.2.4) prior to the specimen blowing, if necessary, to remove excess moisture added during the manufacturing process. Preconditioning of materials not only ensures controlled blowing conditions but reduces the time required to condition the prepared specimen prior to thermal testing.

7. Specimen Preparation

7.1 *Dry Application Behind Netting:*

7.1.1 The procedure described in this section is intended for products which are normally installed behind a netting or fabric and do not require the addition of water or any other liquid.

7.1.2 The specimen preparation room shall be clean and free of old insulation prior to the start of specimen preparation.

NOTE 5—Many factors influence the characteristics of the blown insulation. These include blowing rate, machine adjustments, the size and length of the hose, and type of netting used to blow behind in the test frame. Trained operators are required to duplicate field-installed conditioning.

NOTE 6—For ease of specimen preparation, the specimen shall be blown close to the desired test density. Operators have the option to establish a target weight of insulation required to fill the test frame as a control during the specimen preparation process. The reported test density, however, is obtained from the metering area density measurement conducted after the thermal test.

7.1.3 If the specimen is to be blown to a predetermined density, calculate the target weight of insulation required to fill the test frame to the target density. Weigh the empty test frame(s) to determine the tare weight for the density calculation. If the intent is to test the material at whatever density is blown, then this calculation is not required.

7.1.4 Assemble the blowing machine, hose, and hose length combination as appropriate for the material being prepared (see recommendations in 5.2.1.1).

7.1.5 Set the blowing machine adjustments and select the feed rates in accordance with the insulation manufacturer's recommendations. If the insulation manufacturer does not provide this information, consult the machine manufacturer for recommended settings. Record the machine settings used.

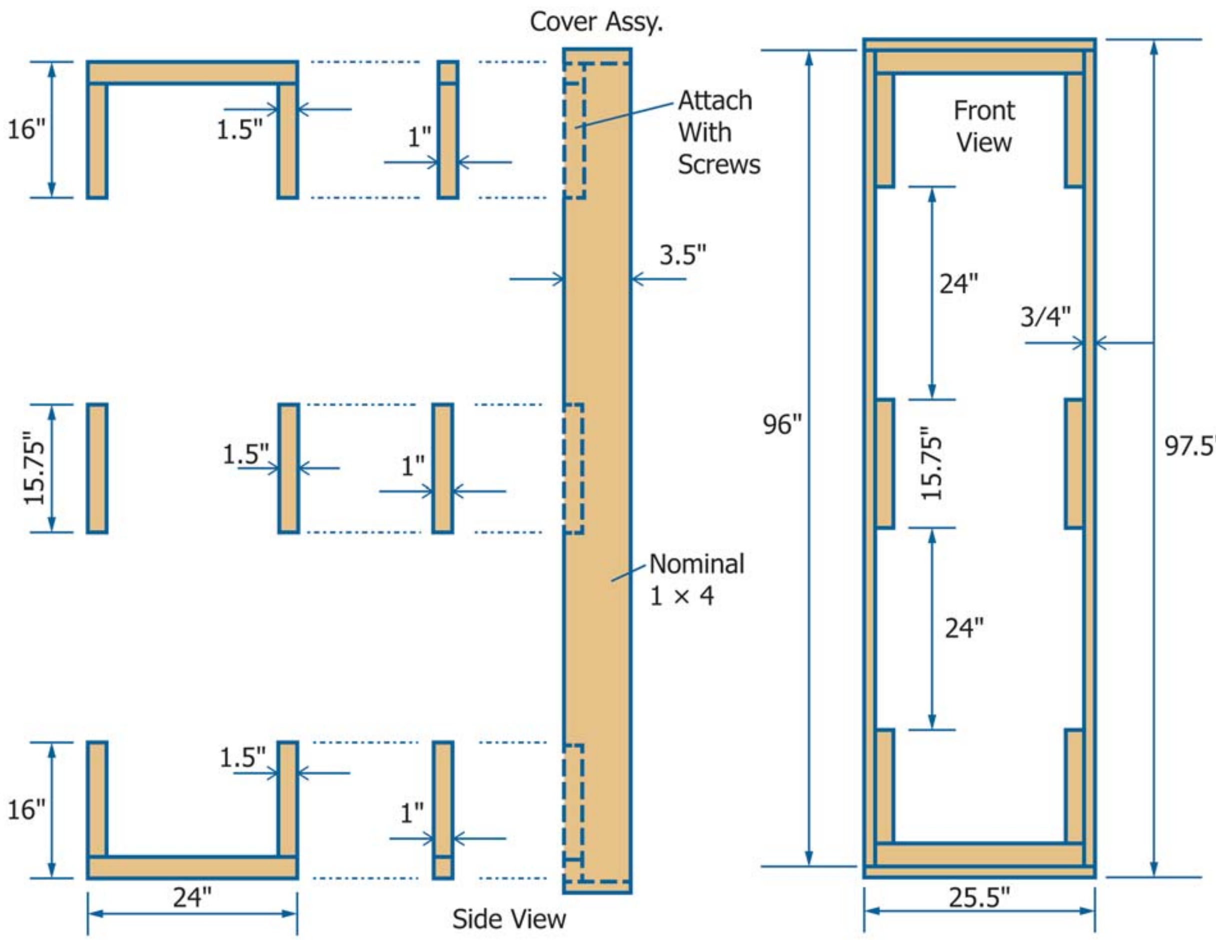


FIG. 4 Recommended Frame Cover Assembly (an Example)

7.1.6 Place at least two packages (see 6.1) of the insulation material into the blowing machine hopper. If the hopper is too small to hold two packages of material, fill the hopper to capacity with equal portions of material from two packages.

7.1.7 Place the test frames in the frame holder and install the cover assembly over the frames and frame holder.

7.1.8 Place the complete test assembly vertically in the specimen preparation area.

7.1.9 Turn on the blowing machine with the hose outlet directed away from the test assembly. Do not blow the thermal test specimen until a steady flow of insulation material has been achieved.

7.1.10 Once steady flow is achieved, (approximately 30 to 45 s), turn off the machine and insert the hose into the center of the test assembly. The insertion point shall be outside of the test frame area(s).

7.1.11 The entire test assembly shall be installed with insulation material using the insulation manufacturer's recommended installation technique.

7.1.11.1 If the insulation manufacturer does not have a recommended technique, use the following as a guide.

7.1.11.2 Insert the blowing hose and direct it towards the bottom of the test assembly. The end of the blowing hose should start approximately 300 to 450 mm from the bottom of the test assembly.

7.1.11.3 Start the blowing machine and begin filling the test assembly from the bottom. The operator shall move rotate the hose in order to move it side to side within the test assembly to ensure even distribution.

7.1.11.4 As the test assembly begins to fill, the operator shall slowly and evenly remove the blowing hose while still rotating the hose side to side. The operator shall continue withdrawing the hose from the test assembly until the bottom half is full.

7.1.11.5 Once the bottom half of the test assembly is full, the operator shall in one motion direct the blowing hose towards the top of the test assembly and feed the hose into the test assembly until the end of the blowing hose is approximately 300 to 450 mm from the top of the test assembly.

7.1.11.6 The operator shall fill the top of the test assembly in the same manner as the bottom of the test assembly directing the hose side to side and withdrawing the hose from the test assembly as it fills.

7.1.11.7 Once the top half of the test assembly is full, the operator shall fill any additional voids in the center of the test assembly that may be left.

7.1.11.8 The operator shall pull the blowing hose out of the test assembly until the end of the blowing hose is 10 to 25 mm inside the test assembly netting and stop the blowing machine. The coast of the blowing machine will complete the fill of the

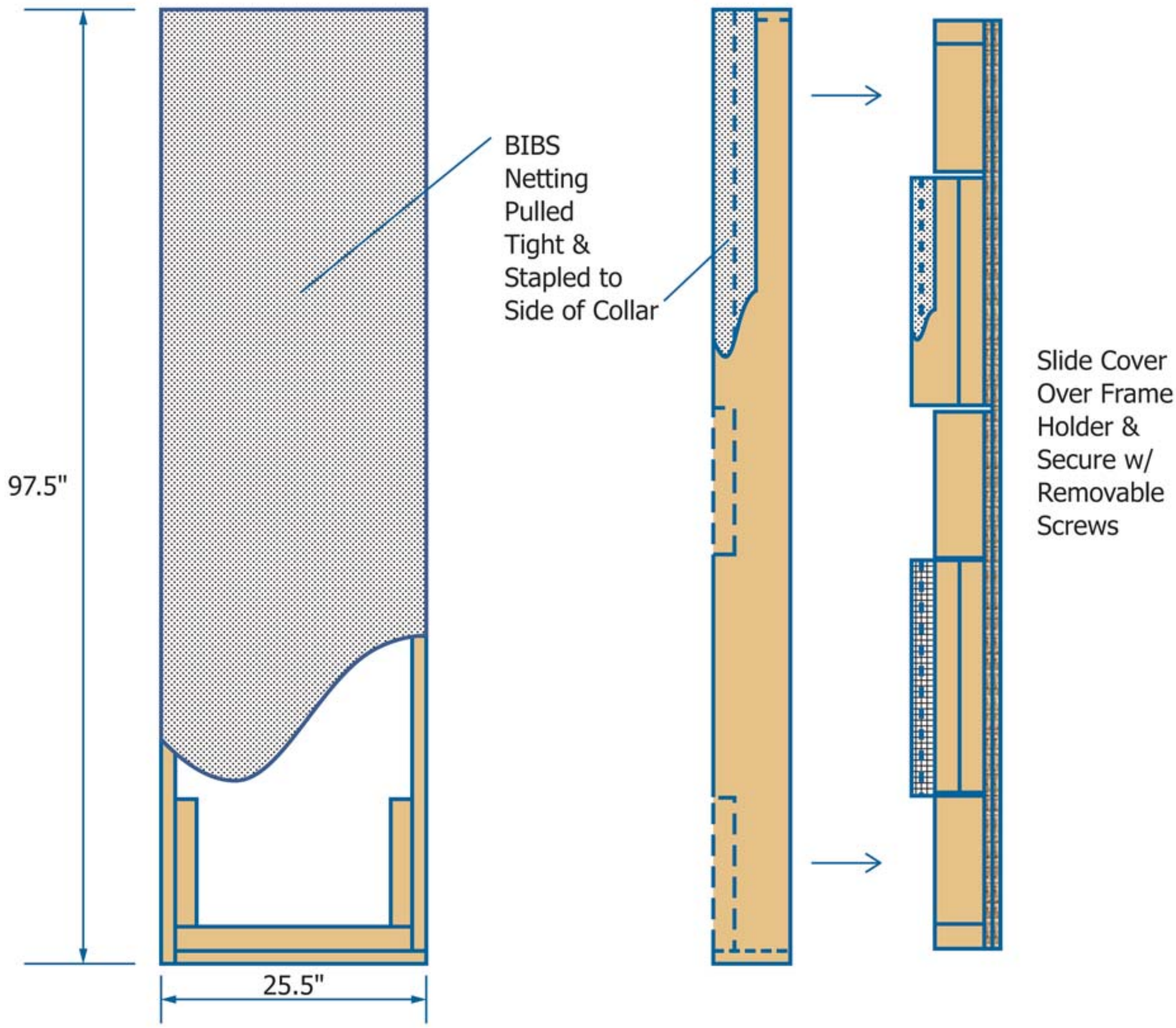


FIG. 5 Recommended Completed Frame Assembly (an Example)

test assembly. Once the blowing machine has stopped and no additional material is coming out of the blowing hose, the blowing hose may be removed completely and placed to the side.

7.1.12 Orient the test assembly horizontally and remove the cover assembly.

7.1.13 For test assemblies with test frame(s), the test frames shall be removed from the test assembly.

7.1.13.1 Carefully remove the insulation material that is outside of the test frame(s) area. Do not disturb the material that is inside the test frame.

7.1.13.2 Remove the test frame(s) from the frame holder and place on a flat level table.

7.1.13.3 Install the edge support boards on the open ends of the frame(s).

7.1.13.4 Move the test frame(s) to the specimen conditioning room.

7.1.14 For test assemblies using the whole assembly as the test frame, move the test assembly to the specimen conditioning room.

7.1.15 Condition the specimen and frame for sufficient time to reach constant weight (less than 1.0 % weight change in 24 h.)

8. Test Procedure

8.1 *Individual Specimen Test Frame:*

8.1.1 Carefully move the thermal test specimen frame to a level area at table height and place the specimen screen-side down on a support sheet.

8.1.2 Remove the edge support boards from the test frame.

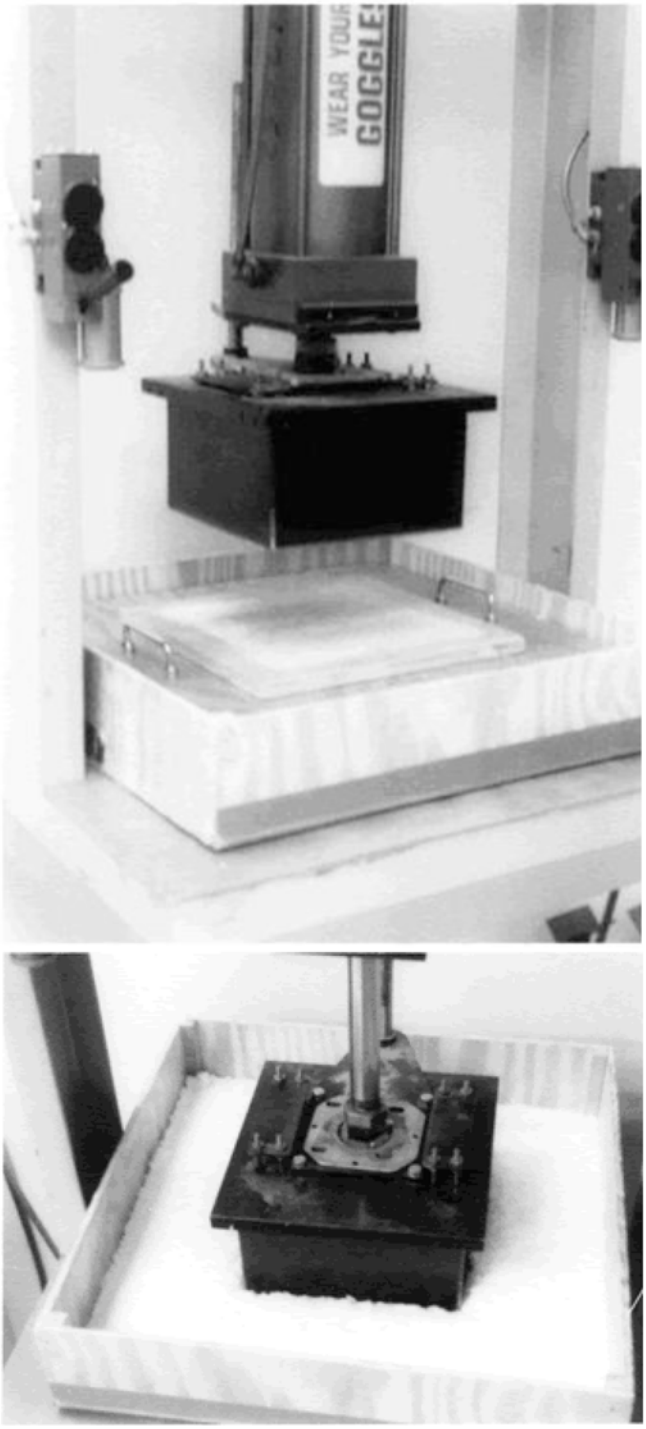
8.1.3 Remove the backing board and partial thickness side boards.

8.1.4 Transfer the conditioned specimen and support sheet in its horizontal position to the thermal test apparatus, being careful not to disturb the specimen.

8.2 *Full Assembly Test Frame:*

8.2.1 Carefully move the test frame assembly to a level area at table height.

8.2.2 Install support legs on the end(s) of the test frame assembly.



NOTE 1—Top: Use of a pressure plate to compress a loose-fill specimen prior to cutting the metering area.

NOTE 2—Bottom: Use of a hydraulic die cutter to cut the metering area. Note the compressed specimen after using the pressure plate.

FIG. 6 Test Area Cutter

8.2.3 Remove the backing board in the test area of the frame exposing the screen on the bottom of the frame.

8.2.4 Transfer the conditioned test frame assembly in its horizontal position to the thermal test apparatus and insert the assembly into the thermal test apparatus until the exposed test area is centered in the test apparatus. One of the support legs may need to be removed.

8.3 Testing shall be done at the nominal installed thickness per the dimensions of the test frame assembly. (See 4.7.1.)

8.4 Close the test apparatus until the test thickness (see 8.3) is achieved.

8.5 Conduct the test in accordance with all requirements of the appropriate thermal test procedure. Unless otherwise specified, the test shall be conducted at a mean temperature of 23.9°C (75°F) and a fixed temperature difference in the range from 20 to 28°C (36 to 50°F).

NOTE 7—High-moisture contents result in unacceptably longtime requirements for the insulation specimen to reach thermal equilibrium in the testing apparatus. For the test conditions shown in 8.5, cellulosic materials require moisture contents below 10 % of dry (equilibrium at 100°C (212°F)) weight to reduce the testing time to a reasonable level.

8.6 If the full test frame assembly is being used and multiple test areas are to be tested, remove the backing board for the next test area and re-center the next test area in the test apparatus. Repeat 8.3 – 8.5 for remaining areas.

8.7 After the thermal test(s) are complete, remove the specimen and frame from the apparatus and place on a plane level surface. Place the test area specimen cutter (5.2.2) or other suitable means to isolate the metering area material within the specimen frame at the center of the test area of the specimen. Cut, remove, and weigh, to the nearest 0.5 %, the insulation within the metering area for the density determination.

9. Calculation

9.1 *Density*—Calculate the test density(s) from the metering area, the weight of the insulation in the cutter (from 8.7) and the test thickness (from 8.3) according to the following formula:

$$\text{Test Density} = \frac{\text{Metering Area Weight}}{\text{Thickness Area}} \tag{1}$$

9.2 *Thermal Resistivity:*

9.2.1 Calculate the thermal resistance at the test thickness following the procedures given in the test method.

9.2.2 Calculate the thermal resistivity and thermal conductivity of the test density using Eq 2 and Eq 3.

$$\text{Thermal Resistivity} = \frac{\text{Thermal Resistance}}{\text{Test Thickness}} \tag{2}$$

$$\text{Thermal Conductivity} = \frac{\text{Test Thickness}}{\text{Thermal Resistance}} \tag{3}$$

10. Report

10.1 Report the following information:

10.1.1 References to applicable specifications and test methods,

10.1.2 The name, address, and other identification of the test laboratory and the date of the report,

10.1.3 The name and other identification of the material or product tested and the date of the test,

10.1.4 The source of the material or product, the date obtained, and the method of sampling, 10.1.5 The method and details of the specimen preparation including blowing machine, machine settings used, and any preconditioning,

10.1.6 The method and conditions of specimen conditioning,

10.1.7 The ASTM thermal test method used for the test results reported,

10.1.8 The dimensions of the thermal apparatus, the orientation of the specimen, and the direction of heat flow,

10.1.9 The mean specimen temperature, and test temperature difference,

10.1.10 The test thickness(s) and the density(s) of the specimen.

10.1.11 The specimen thermal resistance and the thermal resistivity for each test density,

10.1.12 An estimate of the precision and accuracy of the test results (see Section 11),

10.1.13 Any other pertinent observations or remarks.

NOTE 8—Unless otherwise specified, all values shall be reported in both SI and inch-pound units.

11. Precision and Bias

11.1 The precision and bias of the test results obtained using this practice include the effects of: *(1)* adherence to the test procedures, *(2)* performance characteristics of the test apparatus, *(3)* variability of the material or product, and *(4)* sampling and specimen preparation. The influence of the material or product variability and the test imprecision are interactive. The characteristics of the specimen affect the test accuracy while characteristics of the test apparatus (for example, the test area size) affect the apparent variability of the material or product. Larger platen areas are expected to provide better accuracy when specimens are thick and variable in character.

11.2 As a minimum requirement for this practice, estimates shall be made of the precision and bias of the test apparatus used. Guidance on estimates of these values is given in Test Methods C177, C518, C1114, and C1363.

11.3 Estimates of the precision and bias of the results, as representative of the materials or product, must be based on sufficient experiments to determine the variability and the effect of sampling and specimen preparation upon it.

12. Keywords

12.1 insulation; loose-fill; thermal resistance

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