Designation: C411 – 11

Standard Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation[1]

This standard is issued under the fixed designation C411; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers the determination of the performance of commercial sizes of both block and pipe forms of thermal insulating materials when exposed to simulated hot-surface application conditions. The term "hot-surface performance" has reference to a simulated use-temperature test in which the heated testing surface is in a horizontal position.

1.2 This test method refers primarily to high-temperature insulations that are applicable to hot-side temperatures in excess of 200°F (93°C). It is used for materials such as preformed insulations, insulating cements, blankets, and the like, by proper laboratory preparation of the samples.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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]

C167 Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations

C168 Terminology Relating to Thermal Insulation

C356 Test Method for Linear Shrinkage of Preformed High-Temperature Thermal Insulation Subjected to Soaking Heat

3. Terminology

3.1 *Definitions*—Terminology C168 shall apply to the terms used in this test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *sag, n*—the extent of thickness loss of pipe insulation, at the top longitudinal center, due to material fatigue or decomposition due to elevated temperature.

4. Significance and Use

4.1 Performance in service is the final measure of value for a thermal insulation, but simulative service tests give useful indications. One type involves application for a specified time to a surface heated at a temperature approximately that of intended service, and noting during the test and afterward, changes in the material and its properties. Measurement of these changes are used for predicting what occurs in service as a result of exposure to temperatures corresponding to those of the tests.

5. Apparatus

5.1 *Heating Plate*—The heating plate shall consist of a corrosion-resistant and heat-resistant plate with a preferred exposed test area of 36 by 18 in. (914 by 457 mm), but having a minimum test area of 18 by 18 in. (457 by 457 mm). The heated area shall have an insulated, heated guard area having a minimum width of 3 in. (76 mm) around the entire periphery of the test area. The plate shall be supported in a horizontal plane at a sufficient number of points to prevent sagging. It shall be heated on the under side by gas or electricity. The surface temperature of the plate shall be measured by not less than five thermocouples. Four of the thermocouples shall be located along the diagonals that extend from the corners of the exposed area of the plate and at a distance of 6 in. (152 mm) in from each corner. A fifth thermocouple shall be located near the center of the test plate area. The temperature at no point of measurement shall vary more than ±5 % or ±25°F (±14°C), whichever is less, from the desired temperature. A heating chamber beneath the heating plate shall be formed to retain the heat generated by the heating means. A 6-in. thickness of insulation shall form the bottom and the sides, and the heating

[1] This test method is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.31 on Chemical and Physical Properties.

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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.

plate shall form the top of the chamber. Two suitable types of heating plates are shown in Fig. 1 and Fig. 2.

5.2 *Heating Pipe*—The heating pipe shall consist of a corrosion-resistant and heat-resistant pipe having a length of not less than 3 ft (0.9 m) and preferably 6 ft 6 in. (1.98 m). It shall be supported horizontally. The nominal diameter of the pipe shall preferably be 3 in. (76 mm). The pipe shall be heated electrically with a spiral heating coil placed along the inside of the pipe. Supplementary end heaters, and a guard section at least 3 in. long of the same insulation as that being placed on the test section, shall also be provided to guard against excessive losses from the ends of the test specimen. (Where possible, the use of standard thermal conductivity pipe test apparatus to serve as the heating pipe is recommended.) The surface temperature of the pipe shall be measured by means of thermocouples, not less than one for each 1 ft (0.3 m) of length of the test specimen, and located spirally around the pipe at 90° intervals. The test portion of the pipe shall be that area under a full length of a pipe insulation undergoing test. The temperature at any point of measurement on the test portion shall not vary more than ±5 % or ±25°F (±14°C), whichever is less, from the desired temperature.

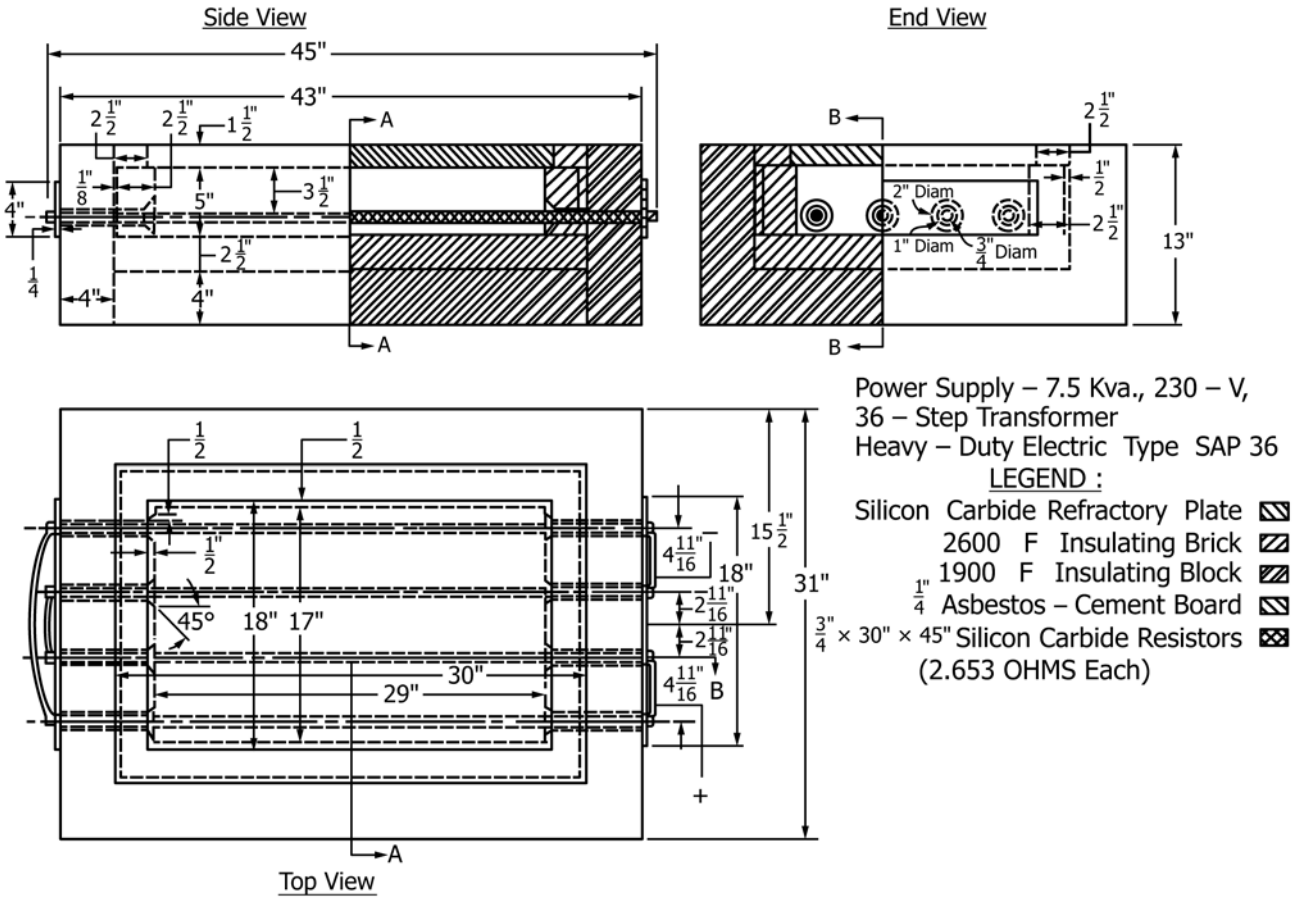
5.3 *Temperature Measurement*—Thermocouples shall be used to measure the surface temperature of the heating plate and the heating pipe. They shall be applied either by peening the individual wires into small holes drilled into the surface and separated by not more than ⅛ in. (3 mm) or by joining the wires with a welded bead and cementing them in grooves with the bead tangent to the surface but not projecting above it. The thermocouples shall be made from wires having a size not greater than No. 22 Awg (0.644 mm), and preferably not larger than No. 26 Awg (0.405 mm). The combination of the thermocouple and measuring instrument used shall ensure an accuracy of temperature measurement of ±1 %.

NOTE 1—This requires different thermocouples and measuring instruments for high-temperature tests than for moderate-temperature tests.

5.4 *Straightedge and Rule*—A straightedge having a length of at least 36 in. (0.9 m) and a small rule divided in 1/64 or 1/10 of 1 in. shall be used to determine warpage.

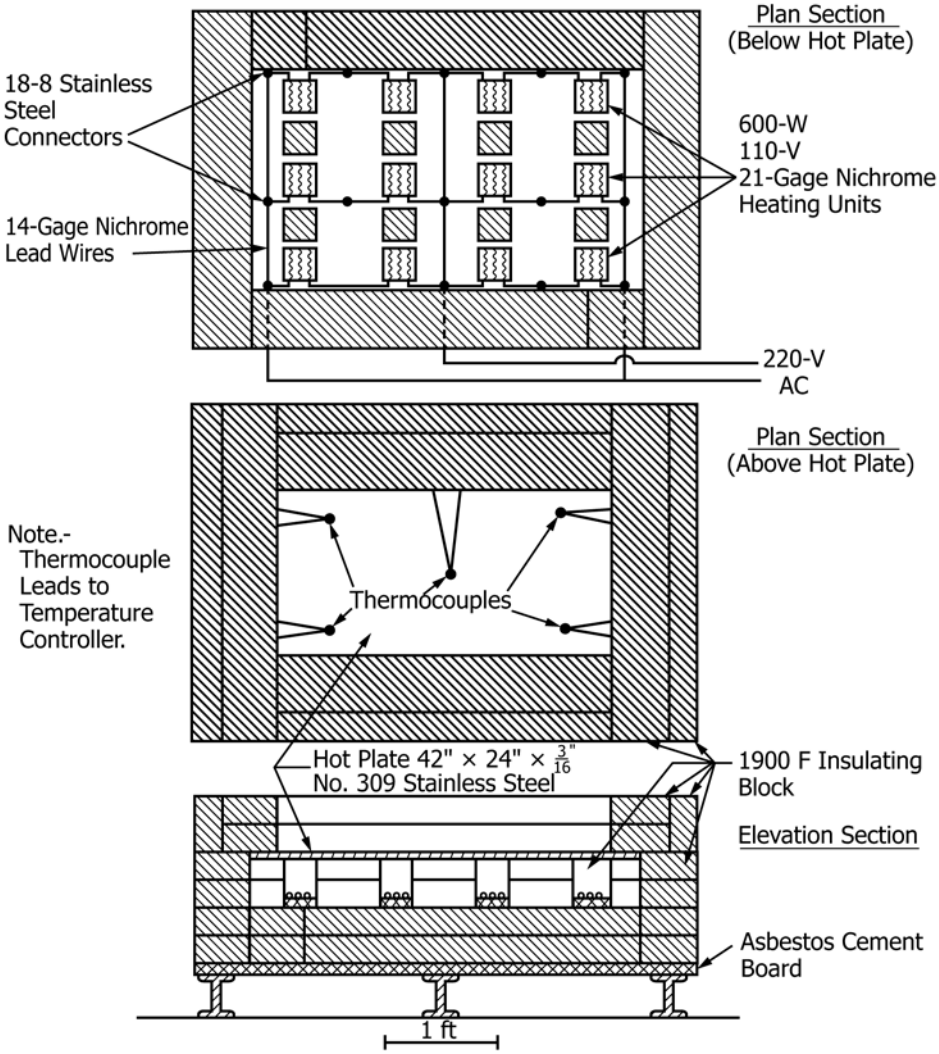
6. Sampling and Preparation of Test Specimens

6.1 All samples that are required to complete the tests shall be selected at one time and in such a manner so as to be fully



in.	⅛	¼	½	¾	1	1½	2	2½	2 11/16	3½	4	4 11/16	5	13	15½	17	18	29	30	31	43	45
mm	3	6	13	19	25	38	51	64	68	89	102	119	127	330	394	432	457	737	762	787	1092	1143

FIG. 1 Type A Heating Plate for Hot-Surface Performance Test



NOTE 1—Thermocouple leads to temperature controller.

FIG. 2 Type B Heating Plate for Hot-Surface Performance Test

representative of the average of the material. Test specimens for any one test condition shall be selected from the original sample lot so as to be as representative as possible. The test specimens shall be commercial pieces. For pipe insulation, the full-size, commercial pipe sections shall be selected. Any diameter pipe insulation for which equipment is available is potentially tested. However, only pipe insulation of 3-in. (76-mm) nominal inside diameter need to be tested.

7. Procedure

7.1 Use the heating plate for testing the flat or block form of insulation. Use the heating pipe for pipe insulation. The thickness of the layers in multilayer insulation and the total thickness of insulation applied to the hot surface for a test shall be that recommended by the manufacturer for the temperature of the hot surface in question, or as agreed between the manufacturer and the purchaser. When multi-layer applications are to be tested, stagger each joint between adjacent test pieces in the same layer with respect to the joint in the next layer. Equally dispose about that joint the test piece in the next layer that covers a joint of the preceding layer.

7.2 *Assembly of Specimen on Heating Plate*—Specimens for testing on a heating plate shall be 6 by 18 in. (152 by 457 mm) with the thickness as described in 7.1. Check each block for flatness and measure and record any initial warpage. Cover the test area of the heating plate with the test blocks. If any blocks have initial warpage, place the concave face toward the hot

side. Apply additional layers to the first layers when necessary to give the total required thickness.

7.3 *Assembly of Specimen on Heating Pipe*—Apply a full length of pipe insulation to the test pipe. If the test pipe is longer than the specimen, the latter can advantageously be centered on the pipe and the ends covered with sawed lengths of the insulation being tested so as to help guard the full length specimen from end losses. The thickness of the test specimen shall be as required in 7.1. Apply additional layers of insulation as necessary to give the required total thickness. Apply the various layers of insulation and secure tightly around the pipe by the usual recommended practice.

7.3.1 Specimen shall be mounted using aluminum bands or wiring, which shall be tightened until snug. Three bands shall be used. Band positions shall be at 3, 18, and 33 in. (76, 457, and 838 mm) from the end of the 36 in. (914 mm) long specimen.

7.3.2 When the sag measurement is required by the material specification, measure the starting thickness using a pin gage, as described by Test MethodC167. The pin gage shall be vertically inserted through the top longitudinal center of the insulation to obtain tip contact with the pipe surface. The pin gage shall be read with a steel rule to the nearest 1⁄32 in. (1 mm). Using the center band [18 in. (457 mm)] as a reference point, measure the starting thickness at 2, 5, and 10 in. (51, 127, 254 mm) from center band in both directions.

7.4 Use the appropriate heat-up procedure as specified in the material standard. If a heat-up procedure is not specified in the material standard, the heat-up procedure in 7.4.1 shall be used.

7.4.1 Start the test with the heating surface at room temperature. The average temperature rise shall not exceed 300°F/hr (167°C/hr) as described in Test Method C356.

7.4.2 For materials that require a heat-up schedule, start the test with the heating surface at room temperature. Follow the time-temperature recommendations of the manufacturer for heat-up.

7.4.3 For materials that require the test to begin on a preheated test apparatus (slap-on), use a sacrificial piece of the test material to bring the test equipment to the target temperature. Once the target temperature has been reached, remove and rapidly replace the sacrificial piece with the test specimen to begin test.

7.5 During the heating period, make qualitative observations to detect visible evidence of flaming, glowing, smoldering, and smoking. After the hot surface has reached the desired test temperature, begin a period of exposure of 96 h. At the completion of the test period, turn off the source of heat and allow the assembly to cool to about room temperature before any specimens are removed.

NOTE 2—Ambient conditions on the exposed surface of the test insulation shall be at room temperature.

7.6 After test and prior to removal, examine the specimens very carefully to detect any tendency toward cracking. Note the number of cracks and the extent or depth of cracking. Also note any tendency toward delamination. Record other discernible changes, such as any evidence of melting, flaming, glowing, smoldering, or smoking that can be observed by visual inspection.

7.6.1 *Warpage*—Measure the block or pipe specimens for warpage by placing a straightedge along the length of the block or pipe and measuring the maximum warpage at the center of the specimen with a steel rule.

7.6.2 *Sag*—The sag measurement portion of C411 is required only when specifically mentioned by a material standard. When the sag measurement is specifically required by the material specification, the thickness shall be measured before the beginning of the C411 hot surface testing and before the specimens are removed at the end of the C411 hot surface testing. Measure final thickness of pipe insulation using a pin gage, as described by test method C167. The pin gage shall be vertically inserted through the top longitudinal center of the insulation to obtain tip contact with the pipe surface. The pin gage shall be read with a steel rule to the nearest 1⁄32 in. (1 mm). Using the center band [18 in. (457 mm)] as a reference point, measure the final thickness at 2, 5, and 10 in. from center band in both directions

8. Calculation

8.1 Calculate the amount of warpage due to heating as follows:

$$W = W_2 - W_1 \quad (1)$$

where:

W = warpage developed during the test, in in. (or mm), (measured in accordance with 7.6),
W_1 = initial measured warpage, in in. (or mm), and
W_2 = final measured warpage, in in. (or mm).

8.2 Calculate the amount of thickness sag as follows:

$$\%\ Change = ((t_1 - t_2) / (t_1) \times 100 \quad (2)$$

where:

t_1 = starting thickness (average of 6)
t_2 = final thickness (average of 6)

9. Report

9.1 Report the following information:

9.1.1 Name and any other identification of the material tested,

9.1.2 Kind of insulation tested, sectional, segmental, or block,

9.1.3 Number of layers of insulation applied,

9.1.4 Size and thickness of each layer,

9.1.5 Details of application,

9.1.6 Temperature of test,

9.1.7 Warpage,

9.1.8 Sag (average of 6),

9.1.9 Extent of cracking,

9.1.10 Amount of delamination,

9.1.11 Other visible changes,

9.1.12 Any evidence of flaming, glowing, smoldering, smoking, melting or dripping, and

9.1.13 Details of any heat up schedule if used and whether specimen was applied to a cold or hot surface.

10. Precision and Bias

10.1 *Warpage*[3]:

10.1.1 *Precision*—Precision of the warpage test method was determined by a round robin with four participating laboratories. The product tested was faced rigid cellular polyisocyanurate board with embedded glass mesh, and a density of approximately 1.86 lb/ft^3 (29.80 kg/m^3). Facer was removed from both sides prior to test. Orientation of the embedded glass mesh did not affect the test results. Temperature of exposure was 300°F (149°C), which was above the product use temperature, to achieve measurable warpage and measurable test method variation. The test results are not intended to be indicative of product performance under recommended service conditions.

10.1.2 *Precision Results:*

95% Repeatability ($2.8S_r$)	=0.088 in. (2.24 mm)
95% Reproducibility ($2.8S_R$)	=0.232 in. (5.89mm)

10.2 *Sag*[4]:

10.2.1 *Precision*—Precision of the sag test method was determined by a round robin with four participating laboratories. The product was unfaced fiber glass pipe insulation, 3 in. (75 mm) IPS×4 in.(100mm) thick ×36 in. (910 mm). Test was performed at 850°F (454°) for 96 h.

95% Repeatability ($2.8S_r$)	=2.0%
95% Reproducibility ($2.8S_R$)	=1.9%

10.3 *Bias*—No information can be presented on the bias of the procedure in this test method because no material having an accepted reference value is available.

11. Keywords

11.1 cracking; delamination; high temperature insulation; hot-surface performance; sag; temperature tests; thermal insulating materials; warpage

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C16-1031.

[4] Supporting data pending being filed at ASTM International Headquarters.