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Standard Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation[1]

This standard is issued under the fixed designation C591; 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 specification covers the types, physical properties, and dimensions of unfaced, preformed rigid cellular polyisocyanurate plastic material intended for use as thermal insulation on surfaces from –297°F (–183°C) to 300°F (149°C). For specific applications, the actual temperature limits shall be agreed upon by the manufacturer and purchaser.

1.2 This specification only covers "polyurethane modified polyisocyanurate" thermal insulation which is commonly referred to as "polyisocyanurate" thermal insulation. This standard does not encompass all polyurethane modified materials. Polyurethane modified polyisocyanurate and other polyurethane materials are similar, but the materials will perform differently under some service conditions.

1.3 This standard is designed as a material specification, not a design document. Physical property requirements vary by application and temperature. At temperatures below –70°F (–51°C) the physical properties of the polyisocyanurate insulation at the service temperature are of particular importance. Below –70°F (–51°C) the manufacturer and the purchaser must agree on what additional cold temperature performance properties are required to determine if the material can function adequately for the particular application.

1.4 This standard addresses requirements of unfaced preformed rigid cellular polyisocyanurate thermal insulation manufactured using blowing agents with an ozone depletion potential of 0 (ODP 0).

1.5 Except 6.2 and 8.2 – 8.4, which are related to the size and shape of fabricated parts, and 16.1, which is related to the storage of fabricated parts, the requirements in this standard specification apply to the polyisocyanurate insulation in the form of buns supplied by the insulation manufacturer.

1.6 When adopted by an authority having jurisdiction, codes that address fire properties in many applications regulate the use of the thermal insulation materials covered by this specification. Fire properties are controlled by job, project, or other specifications where codes or government regulations do not apply.

1.7 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] This specification is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.22 on Organic and Nonhomogeneous Inorganic Thermal Insulations.

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1.8 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *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]

C165 Test Method for Measuring Compressive Properties of Thermal Insulations
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
C272/C272M Test Method for Water Absorption of Core Materials for Sandwich Constructions
C303 Test Method for Dimensions and Density of Preformed Block and Board–Type Thermal Insulation
C335/C335M Test Method for Steady-State Heat Transfer Properties of Pipe Insulation
C390 Practice for Sampling and Acceptance of Thermal Insulation Lots
C411 Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation
C518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
C550 Test Method for Measuring Trueness and Squareness of Rigid Block and Board Thermal Insulation
C585 Practice for Inner and Outer Diameters of Thermal Insulation for Nominal Sizes of Pipe and Tubing
C871 Test Methods for Chemical Analysis of Thermal Insulation Materials for Leachable Chloride, Fluoride, Silicate, and Sodium Ions
C1045 Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions
C1058/C1058M Practice for Selecting Temperatures for Evaluating and Reporting Thermal Properties of Thermal Insulation
C1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus
C1303/C1303M Test Method for Predicting Long-Term Thermal Resistance of Closed-Cell Foam Insulation
C1363 Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus
C1763 Test Method for Water Absorption by Immersion of Thermal Insulation Materials
D883 Terminology Relating to Plastics
D1621 Test Method for Compressive Properties of Rigid Cellular Plastics
D1622/D1622M Test Method for Apparent Density of Rigid Cellular Plastics
D2126 Test Method for Response of Rigid Cellular Plastics to Thermal and Humid Aging
D2856 Test Method for Open-Cell Content of Rigid Cellular Plastics by the Air Pycnometer (Withdrawn 2006)[3]
D6226 Test Method for Open Cell Content of Rigid Cellular Plastics
E84 Test Method for Surface Burning Characteristics of Building Materials
E96/E96M Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials

3. Terminology

3.1 For descriptions of terms used in this specification, refer to Terminologies C168 and D883.

3.2 The term polyisocyanurate does not encompass all polyurethane containing materials (see 1.2).

3.3 The term "core specimen" refers to representative samples cut in accordance with the sampling procedure listed within each property test method.

3.4 *Definitions of Terms Specific to This Standard:*

3.4.1 *aged, v—in relation to thermal conductivity testing*, the act of delaying thermal conductivity testing for a specified time period after the final polymerization.

3.4.1.1 *Discussion—*
Unfaced preformed rigid cellular polyisocyanurate thermal insulation samples are aged because the thermal conductivity of this

[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.

material increases with time, primarily due to changes in the composition of the gas contained within the closed cells. The rate of this thermal conductivity increase diminishes with time so an aging time prior to testing is selected to reasonably represent the long-term performance of the material. The aging time for thermal conductivity test specimens of material covered by this standard is typically 180 days.

3.4.2 *conditioned, v*—the act of putting specimens in specified temperature and humidity conditions immediately prior to testing to allow the specimens to reach temperature and moisture content equilibrium.

3.4.2.1 *Discussion—*
Samples are conditioned for a fairly short time period (typically 12 to 24 h) during which the test lab holds the sample at standard lab conditions (see 11.3) immediately prior to testing. If specimens are aged (see 3.4.1) for thermal conductivity testing at the same conditions specified for conditioning and kept at these conditions until the time of testing, then a separate conditioning period at the end of the aging period is not necessary.

3.4.3 *final polymerization, n*—the final chemical reaction and cooling that occurs immediately following primary manufacturing of unfaced preformed rigid cellular polyisocyanurate thermal insulation materials created using a simultaneous blowing and exothermic polymerization process.

3.4.3.1 *Discussion—*
Unfaced preformed rigid cellular polyisocyanurate thermal insulation materials created using a simultaneous blowing and exothermic polymerization process are formed into a shape such as a bun during manufacture. This shape reaches its final form and size during primary manufacturing and is at a temperature substantially above ambient. This shape continues to undergo final polymerization and cooling for a time period ranging from a few hours to several days. This period of final polymerization and cooling is part of the manufacturing process and samples are not taken for testing or quality control until the end of this period is reached.

3.4.4 *insulation fabricator, n*—a company that machines, cuts, grinds, or otherwise transforms the unfaced polyisocyanurate bun insulation received from an insulation manufacturer into various shapes such as boards, blocks, pipe shells, tank segments, and elbows/fittings.

3.4.4.1 *Discussion—*
It is possible for a company to function as both an insulation fabricator and an insulation manufacturer. In this standard specification the insulation fabricator is also referred to simply as the fabricator.

3.4.5 *insulation manufacturer, n*—a company engaged in primary manufacturing of unfaced polyisocyanurate foam.

3.4.5.1 *Discussion—*
It is possible for a company to function as both an insulation manufacturer and an insulation fabricator. In this standard specification the insulation manufacturer is also referred to simply as the manufacturer.

3.4.6 *ozone depletion potential (ODP), n*—a relative index indicating the extent to which a chemical product causes ozone depletion.

3.4.6.1 *Discussion—*
The reference level of 1 is the potential of trichlorofluoromethane (R-11 or CFC-11) to cause ozone depletion. ODP 0 is an ozone depletion potential of zero.

3.4.7 *primary manufacturing, n*—the initial manufacturing step of unfaced preformed rigid cellular polyisocyanurate thermal insulation materials that begins with the mixing of the precursor chemicals and ends with the formation of the final bun shape.

4. Classification

4.1 Unfaced, preformed rigid cellular polyisocyanurate thermal insulation covered by this specification is classified into six types as follows:

4.1.1 *Type I*—Compressive resistance of 20 lb/in^2 (137 kPa), minimum.

4.1.2 *Type IV*—Compressive resistance of 22 lb/in^2 (150 kPa), minimum.

4.1.3 *Type II*—Compressive resistance of 35 lb/in^2 (240 kPa), minimum.

4.1.4 *Type III*—Compressive resistance of 45 lb/in^2 (310 kPa), minimum.

4.1.5 *Type V*—Compressive resistance of 80 lb/in^2 (550 kPa), minimum.

4.1.6 *Type VI*—Compressive resistance of 125 lb/in^2 (862 kPa), minimum.

4.2 Unfaced, preformed rigid cellular polyisocyanurate thermal insulation covered by this specification is classified into one grade as follows:

4.2.1 Grade 2–Service temperature range of -297°F (-183°C) to 300°F (149°C).

5. Ordering Information

5.1 Orders for materials purchased under this specification shall include the following:

5.1.1 Designation of this specification and year of issue,

5.1.2 Product name or grade/type, or both,

5.1.3 Apparent thermal conductivity and specific thickness required,

5.1.4 Product dimensions,

5.1.5 Quantity of material,

5.1.6 Special packaging or marking, if required, and

5.1.7 Special requirements for inspection or testing, or both.

6. Materials and Manufacture

6.1 Unfaced, preformed rigid cellular polyisocyanurate thermal insulation is produced by the polymerization of polymeric polyisocyanates in the presence of polyhydroxyl compounds, catalysts, cell stabilizers, and blowing agents.

6.2 The material covered by this specification shall be supplied in "bun" form by the manufacturer. From these buns, a fabricator shall transform and supply boards, blocks, pipe shells, tank segments, elbows/fittings, or special shapes as agreed upon by the fabricator and end-user.

7. Physical Properties

7.1 Unfaced, preformed rigid cellular polyisocyanurate thermal insulation shall conform to the requirements shown in Table 1. See Note 1. For each physical property requirement, the average from testing the number of test specimen(s) required by 11.4 of this specification shall be used to determine compliance.

NOTE 1—It is the responsibility of the user of this standard to determine the technical requirements for their specific applications and to select an appropriate Type of material.

7.2 Polyisocyanurate thermal insulation is an organic material and is combustible. Do not expose this insulation to flames or other ignition sources. The fire performance of the material shall be addressed through fire test requirements established by the appropriate governing authority. The manufacturer shall be contacted for specific data as fire performance characteristic will vary with grade, type, and thickness.

7.3 Not all physical properties at temperatures below -70°F (-51°C) have been fully tested. Where these properties are critical, the user shall consult the manufacturer for properties and performance at these lower temperatures.

TABLE 1 Physical Property Requirements
Grade 2: Operating Temperature Range -297°F (-183°C) to 300°F (149°C)[A]

NOTE 1—Grade 1, which was specific to PIR for use at operating temperatures of -70°F (-51°C) to 300°F (149°C) , was deleted in 2009 because this material was no longer produced. Grade 2 was not renumbered to minimize conflict with various global engineering and end-user specifications which require the use of materials complying with, "ASTM C591, Grade 2".

Property	Type I	Type IV	Type II	Type III	Type V	Type VI
Density, min lb/ft^3 (kg/m ^{3})	1.8 (29)	2.0 (32)	2.5 (40)	3.0 (48)	4.0 (60)	6.0 (96)
Compressive resistance at 10 % deformation or yield whichever occurs first, parallel to rise, min, lb/in^2 (kPa)	20 (137)	22 (150)	35 (240)	45 (310)	80 (550)	125 (862)
Apparent thermal conductivity, max Btu-in/h-ft ^{2} -°F (W/m-K), at a mean temperature of:						
-200°F (-129°C)	.13 (.019)	.13 (.019)	.13 (.019)	.14 (.020)	.14 (.020)	.15 (.022)
-150°F (-101°C)	.15 (.022)	.15 (.022)	.15 (.022)	.16 (.023)	.16 (.023)	.17 (.025)
-100°F (-73°C)	.17 (.025)	.17 (.025)	.17 (.025)	.18 (.026)	.18 (.026)	.19 (.027)
-50°F (-46°C)	.19 (.027)	.19 (.027)	.19 (.027)	.20 (.029)	.20 (.029)	.21 (.030)
0°F (-17°C)	.19 (.027)	.19 (.027)	.19 (.027)	.20 (.029)	.20 (.029)	.22 (.032)
50°F (10°C)	.18 (.026)	.18 (.026)	.18 (.026)	.19 (.027)	.19 (.027)	.21 (.030)
75°F (24°C)	.19 (.027)	.19 (.027)	.19 (.027)	.20 (.029)	.20 (.029)	.22 (.032)
150°F (66°C)	.23 (.033)	.23 (.033)	.23 (.033)	.24 (.035)	.24 (.035)	.26 (.037)
200°F (93°C)	.26 (.037)	.26 (.037)	.26 (.037)	.27 (.039)	.27 (.039)	.30 (.044)
Water absorption, max, % by volume	2.0	2.0	1.0	1.0	1.0	0.8
Water vapor permeability, max, perm-in (ng/Pa-s-m)	4.0 (5.8)	4.0 (5.8)	3.5 (5.1)	3.0 (4.4)	2.5 (3.7)	2.0 (2.9)
Dimensional stability, max % linear change, 1 week exposure						
158 ± 4°F (70 ± 2°C), 97 + 3 % relative humidity	4	4	4	4	4	4
-40 ± 6°F (-40 ± 3°C), ambient relative humidity	1	1	1	1	1	1
212 ± 4°F (100 ± 2°C), ambient relative humidity	2	2	2	2	2	2
Closed cell content, min	90	90	90	90	90	90
Hot-surface performance, at 300°F (149°C)[B]	Pass	Pass	Pass	Pass	Pass	Pass

[A] This specification does not purport to address all the performance issues associated with its use. It is the responsibility of the user of this standard to establish appropriate performance criteria.
[B] Pass ⁄fail criteria found in 12.4.

8. Dimensions and Tolerances

8.1 The polyisocyanurate bun dimensions shall be as agreed upon by the purchaser and the manufacturer. Polyisocyanurate buns are commonly available in lengths up to 144 in. (3.66 m), widths up to 48 in. (1.22 m), and thicknesses from 12 in. (305 mm) to 24 in. (610 mm).

8.2 *Insulation Board (cut from buns by a fabricator):*

8.2.1 Dimensional tolerances for boards shall be as follows:

Dimension	Tolerance, in. (mm)
Length	±1⁄8 (3.2)
Width	±1⁄16 (1.6)
Thickness	±1⁄32 (0.8)

8.2.2 *Edge Trueness*—Determine in accordance with Test Method C550. The maximum deviation from the edge trueness shall not be greater than 1⁄32 in./ft (2.6 mm/m) of length or width.

8.2.3 *Face Trueness*—Determine in accordance with Test Method C550. The maximum deviation from flatness shall not be greater than 1⁄16 in./ft (5.2 mm/m) of length or width.

8.2.4 *Corner Squareness*—Determine in accordance with Test Method C550. The maximum deviation from corner squareness shall not be greater than 1⁄8 in. (3.2 mm) for all board thicknesses.

8.2.5 *Edge Squareness*—Determine in accordance with Test Method C550. The maximum deviation from edge squareness shall not be greater that 1⁄16 in. (1.6 mm) for all board thicknesses.

8.3 *Pipe Insulation (cut from buns by a fabricator)*—Material supplied for pipe insulation shall have dimensions and tolerances that are in accordance with Practice C585.

8.4 Other parts or special shapes (cut from buns by a fabricator) shall have dimensions and tolerances agreed upon by the purchaser and fabricator.

9. Workmanship and Appearances

9.1 The polyisocyanurate thermal insulation shall have no defects that will adversely affect its service qualities.

10. Sampling

10.1 Unless otherwise specified, the polyisocyanurate thermal insulation shall be sampled and inspected for acceptance of material in accordance with Practice C390.

10.2 *Inspection Requirements*—The requirements for density shown in Table 1, the dimensional requirements described in Section 8, and the workmanship and appearance requirements described in Section 9 are defined as inspection requirements (refer to Practice C390).

10.3 *Qualification Requirements*—The physical requirements shown in Table 1 except density are defined as qualification requirements (refer to Practice C390). Density is defined as an inspection requirement.

11. Specimen Selection and Preparation

11.1 Prior to the cutting of any test specimens, a period of at least 72 h shall elapse from the end of primary manufacturing to allow for final polymerization (see 3.4.7 and 3.4.3). The test specimens shall be cut from the buns of material as required by Annex A1 for the reasons described in Appendix X1.

11.2 All test specimens shall be homogeneous per the definition of "homogeneous material" in Terminology C168. All test specimens shall be free of joints unless the size of the specimen required precludes it being cut from a single 3 ft long bun.

11.3 Unless otherwise specified, the test specimens shall be conditioned (see 3.4.2) at 73 ± 4°F (23 ± 2°C) and 50 ± 5 % relative humidity for at least 24 h prior to testing.

11.4 Number of specimens to test for each required property for continuous bunstock PIR (see A1.2):

11.4.1 *Density*—Test three specimens.

11.4.2 *Compressive Resistance*—Test six specimens.

11.4.3 *Apparent Thermal Conductivity*—Test three specimens at mean temperature of 75°F (24°C) and one specimen at the other mean temperatures listed in Table 1.

11.4.4 *Hot Surface Performance*—Test one specimen.

11.4.5 *Water Absorption*—Test three specimens as prescribed in Test Method C272/C272M, Procedure A with sample size 12 by 12 by 1 in. (305 by 305 by 25 mm) or Test Method C1763, Procedure C.

11.4.6 *Water Vapor Permeability*—Test three specimens as prescribed in Test Method E96/E96M.

11.4.7 *Dimensional Stability*—Test three specimens.

11.4.8 *Closed Cell Content*—Test three specimens.

11.5 Number of specimens to test for each bun tested for each required property for box-pour bunstock PIR. Due to the possible variability from bun to bun within a batch of box-pour bunstock PIR, it is necessary to test three buns from a given batch (see A1.3):

11.5.1 *Density*—Test three specimens.

11.5.2 *Compressive Resistance*—Test six specimens.

11.5.3 *Apparent Thermal Conductivity*—Test three specimens at mean temperature of 75°F (24°C) and one specimen at the other mean temperatures listed in Table 1.

11.5.4 *Hot Surface Performance*—Test one specimen.

11.5.5 *Water Absorption*—Test three specimens as prescribed in Test Method C272/C272M, Procedure A with sample size 12 by 12 by 1 in. (305 by 305 by 25 mm) or Test Method C1763, Procedure C.

11.5.6 *Water Vapor Permeability*—Test three specimens as prescribed in Test Method E96/E96M.

11.5.7 *Dimensional Stability*—Test three specimens.

11.5.8 *Closed Cell Content*—Test three specimens.

12. Test Methods

12.1 *Density*—Determine in accordance with Test Method D1622/D1622M or C303.

12.2 *Compressive Resistance*—Determine in accordance with Test Method C165, Procedure A or Test Method D1621, at a crosshead speed of 0.1 in/min (2.5 mm/min) for each 1 in. (25 mm) of specimen thickness. See Note 2.

NOTE 2—Polyisocyanurate insulation can be anisotropic and, therefore, strength properties can vary with direction. The manufacturer should be consulted if additional information is required.

12.3 *Apparent Thermal Conductivity*—Determine in accordance with Test Method C177, C518, C1114 or C1363 in accordance with Practice C1045 using the small temperature differences indicated in Practice C1058/C1058M, Table 3 with the specimen cut so that the induced direction of heat flow is parallel to the rise (height) direction of the bun. In some cases where this insulation is used in pipe applications, Test Method C335/C335M is applicable. Core 1 in. (25 mm) thick test specimens shall be cut from buns after the final polymerization (see 3.4.3 and 11.1) is complete, be aged (3.4.1) at 73 ± 4°F (23 ± 2°C) and 50 ± 5 % relative humidity for 180 ± 5 days from time of specimen cutting, be conditioned if necessary (see 3.4.2), and then tested following these aging (and conditioning if present) periods. In case of dispute, Test Method C177 shall be the referee method. The apparent thermal conductivity of the material tested shall not be greater than the maximum value identified in Table 1. The apparent thermal conductivity of individual specimens tested shall not be greater than 110 % of the maximum value identified in Table 1. Compliance with qualification requirements shall be in accordance with Practice C390. ~~It is possible that Test Method C1303/C1303M will provide useful information for estimating long term changes in thermal resistance. See Note 3.~~

~~NOTE 3—The core thickness has an impact on measured thermal resistance; as thickness increases the thermal resistance increases, as thickness decreases the thermal resistance decreases. The thermal resistance of polyisocyanurate thermal insulation may be significantly influenced by installation and service-related variables such as age, encapsulation within gas-barrier materials, environmental conditions, and mechanical abuse and may be reduced from measured values after exposure to conditions of use. For specific design recommendations using a particular product, consult the manufacturer.~~

12.4 *Hot-Surface Performance*—Determine in accordance with Test Method C411. Pass criteria is defined as ≤ 0.25 in. (6 mm) warpage, and no cracking, flaming, glowing, smoldering, or smoking when tested with a white background. Discoloration of the sample during this test is not an indication of failure. All specimens shall be of the same size and shall be 6 by 18 by 1 to 2 in. (152 by 457 by 25 to 51 mm) with the 6 in. (152 mm) being the bun cross-machine (width) direction, the 18 in. (457 mm) being