



Designation: C1728 – 17

Standard Specification for Flexible Aerogel Insulation¹

This standard is issued under the fixed designation C1728; 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 specification covers the classification and performance of flexible aerogel thermal insulation. This will cover the range of continuous exposure operating temperatures from -321°F (-196°C) up to 1200°F (649°C).

1.2 For satisfactory performance, properly installed protective vapor retarders or barriers shall be used on below ambient temperature applications to reduce movement of moisture through or around the insulation to the colder surface. Failure to use a vapor retarder or barrier could lead to insulation and system non-performance.

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 The following safety hazards caveat pertains only to the test methods described in this specification. *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

- C165 Test Method for Measuring Compressive Properties of Thermal Insulations
- C167 Test Methods for Thickness and Density of Blanket or Batt Thermal Insulations
- C168 Terminology Relating to Thermal Insulation

¹ This specification is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.23 on Blanket and Loose Fill Insulation.

Current edition approved Feb. 1, 2017. Published February 2017. Originally approved in 2012. Last previous edition approved in 2013 as C1728 – 13. DOI: 10.1520/C1728-17.

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.

- C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
- C303 Test Method for Dimensions and Density of Preformed Block and Board-Type Thermal Insulation
- C335 Test Method for Steady-State Heat Transfer Properties of Pipe Insulation
- C356 Test Method for Linear Shrinkage of Preformed High-Temperature Thermal Insulation Subjected to Soaking Heat
- C390 Practice for Sampling and Acceptance of Thermal Insulation Lots
- C411 Test Method for Hot-Surface Performance of High-Temperature Thermal Insulation
- C447 Practice for Estimating the Maximum Use Temperature of Thermal Insulations
- C518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
- C795 Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel
- C1045 Practice for Calculating Thermal Transmission Properties Under Steady-State Conditions
- C1058 Practice for Selecting Temperatures for Evaluating and Reporting Thermal Properties of Thermal Insulation
- C1101/C1101M Test Methods for Classifying the Flexibility or Rigidity of Mineral Fiber Blanket and Board Insulation
- C1104/C1104M Test Method for Determining the Water Vapor Sorption of Unfaced Mineral Fiber Insulation
- C1114 Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus
- C1338 Test Method for Determining Fungi Resistance of Insulation Materials and Facings
- C1617 Practice for Quantitative Accelerated Laboratory Evaluation of Extraction Solutions Containing Ions Leached from Thermal Insulation on Aqueous Corrosion of Metals
- C1763 Test Method for Water Absorption by Immersion of Thermal Insulation Materials
- E84 Test Method for Surface Burning Characteristics of Building Materials

E2231 Practice for Specimen Preparation and Mounting of Pipe and Duct Insulation Materials to Assess Surface Burning Characteristics

2.2 Other Standards:³

CAN/ULC-S102 Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies

3. Terminology

3.1 *Definitions*: For definitions used in this specification, see Terminology A3.

3.1.1 *flexible aerogel insulation, n*—a flexible insulation containing a composite of aerogel, fibrous carrying media, or reinforcements, or a combination thereof.

3.1.1.1 *Discussion*—Opacifiers are sometimes added as either fibers or powders.

3.2 Abbreviations:

3.2.1 N/A—Not applicable.

4. Classification

4.1 Flexible aerogel insulation shall be classified into three Types based on the maximum use temperature:

4.1.1 Type I — 257°F (125°C)

4.1.2 Type II — 390°F (200°C)

4.1.3 Type III — 1200°F (649°C)

4.2 Type I is subdivided as Grade 1 (tested in flat configuration) and Categories A or B by thermal conductivity.

4.3 Type II comprises a Grade 1 (tested in flat configuration) and Category A.

4.4 Type III is subdivided into two Grades 1 and 2 whereby Grade 1 is tested in a flat configuration using Test Method C177 and Grade 2 is tested only in a pipe configuration using Test Method C335.

5. Ordering Information

5.1 The Type, Grade, Category, dimensions, and thickness shall be specified by the purchaser. A product certification (if required) shall be specified in the purchase order.

6. Materials and Manufacture

6.1 *Composition*—Flexible aerogel insulation is a composite of an amorphous silica-based aerogel, a fibrous carrying media, or reinforcements, or a combination thereof, that allow the construct to be flexible.

6.1.1 A fibrous carrying media or reinforcement, or both, consists of the following: fibers, batts, strips, sheets, or some combination thereof.

6.1.1.1 This fibrous carrying media or reinforcement material, or both, is either organic, such as polyester, or inorganic, such as glass fibers. Additionally, some flexible aerogel insulation contains additives such as a water resistant treatment or opacifiers, or both.

7. Physical, Mechanical and Chemical Property Requirements

NOTE 1—Performance requirements for flexible aerogel insulation (Type I Grade 1 Category A, Type I Grade 1 Category B, Type II Grade 1 Category A, Type III Grade 1 Category A, and Type III Grade 2 Category A) are given in Table 1.

7.1 *Maximum Use Temperature*—When tested in accordance with Test Method C411 in a flat configuration and the hot surface performance of Practice C447 in a flat configuration at the insulation's maximum use temperature at a thickness of 80 mm or manufacturer's maximum recommended thickness, the flexible aerogel insulation shall not warp, flame, or glow during hot surface exposure. No evidence of melting or fiber degradation shall be evident upon post-test inspection.

7.2 *Thickness and Density*—The thickness and density shall be determined and reported in accordance with Test Methods C167 or C303.

7.3 Apparent Thermal Conductivity:

7.3.1 Determine the thermal conductivity as a function of temperature for the representative specimens with data obtained from a series of thermal tests utilizing Test Methods C177, C518, C1114, or C335 as appropriate for the material under study. Specimen shall be tested unfaced and, for Type III, Grade 2 (pipe configuration per Test Method C335), test at a minimum of 4 layers. Each layer shall have a minimum thickness of 0.2 in (5 mm). The test report shall state the barometric pressure at the time of the tests. See Note 2 below.

7.3.2 As specified in Practice C1045, the range of test conditions must include at least one test where the hot surface temperature is greater than, or equal to, the hot limit of the temperature range of desired data and at least one test where the cold temperature is less than, or equal to, the cold limit of the temperature range desired. At least two additional tests shall be performed and distributed evenly over the rest of the temperature range.

7.3.3 Final analysis of the thermal data shall be conducted in accordance with Practice C1045 to generate a thermal conductivity versus temperature relationship for the specimen.

7.3.4 The final step of Practice C1045 analysis is to calculate the thermal conductivity using the equations generated at a set of mean temperatures for comparison to the specification.

7.3.5 Practice C1058 shall be used to obtain recommended test temperature combinations for testing purposes.

7.4 *Flexibility*—When tested at the installed thickness in accordance with the Test Methods C1101/C1101M, the sheet must qualify as flexible.

7.5 *Corrosiveness to Steel*—When tested in accordance with Practice C1617, the mass loss corrosion rate of the unfaced insulation extract shall not exceed that of the 5-ppm chloride solution. Test the composite insulation material (with facing and adhesive) when a facing is factory adhered by the manufacturer or the fabricator.

7.6 *Water Vapor Sorption*—When tested in accordance the Test Method C1104/C1104M, the water vapor sorption of the flexible insulation shall be not more than 5 % by weight.

³ Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, <http://www.ul.com>.

TABLE 1 Performance Requirements for Types I, II, and III Flexible Aerogel Insulation

Type	I	I	II	III	III
Grade	1	1	1	1	2
Category	A	B	A	A	A
Maximum use temperature, °F (°C)	257 (125)	257 (125)	390 (199)	1200 (649)	1200 (649)
Minimum use temperature, °F (°C)	-321 (-196)	-321 (-196)	-321 (-196)	75 (24)	75 (24)
Minimum / Maximum Composite Density, lbs/ft ³ (kg/m ³)	1.9 to 6.3 (30 to 100)	5.0 to 11.2 (80 to 180)	4.7 to 9.4 (75 to 150)	10.0 to 15.0 (160 to 240)	10.0 to 15.0 (160 to 240)
Apparent thermal conductivity, max, Btu•in/ft ² •°F (W/m•K) Mean Temperature, °F (°C)					
-200 (-129)	0.098 (0.014)	0.096 (0.014)	0.073 (0.011)	N/A	N/A
-100 (-73.3)	0.12 (0.017)	0.10 (0.015)	0.091 (0.013)	N/A	N/A
0 (-17.8)	0.14 (0.021)	0.11 (0.016)	0.11 (0.016)	N/A	N/A
75 (23.9)	0.17 (0.024)	0.12 (0.017)	0.13 (0.019)	0.14 (0.021)	0.16 (0.023)
100 (37.8)	0.17 (0.025)	0.12 (0.017)	0.14 (0.020)	0.15 (0.022)	0.17 (0.024)
200 (93.3)	0.21 (0.030)	0.13 (0.019)	0.18 (0.025)	0.16 (0.023)	0.18 (0.024)
300 (149)	NA	NA	0.22 (0.032)	0.18 (0.025)	0.21 (0.028)
400 (204)	NA	NA	NA	0.20 (0.029)	0.24 (0.033)
500 (260)	NA	NA	NA	0.22 (0.032)	0.28 (0.035)
600 (316)	NA	NA	NA	0.25 (0.036)	0.33 (0.040)
700 (371)	NA	NA	NA	0.30 (0.043)	0.39 (0.048)
Compressive resistance, min, @ 10% deformation, psi (kPa)	0.75 (5.2)	5 (34.5)	5 (34.5)	3 (20.7)	3 (20.7)
Surface burning characteristics: Flame spread index, max Smoke developed, max	Not Rated	25 50	Not Rated	5 10	5 10
Exothermic temperature rise, maximum, with no facings or jacketing of any type, run at maximum recommended thickness	NA	NA	NA	200°F (111°C)	200°F (111°C)
Water absorption, maximum % by weight					
Before conditioning at 600°F (316°C) for 24 h	150 %	8 %	8 %	8 %	8 %
After conditioning at 600°F (316°C) for 24 h				16 %	16 %

7.7 Fungi Resistance—When tested in accordance with the fungi resistance Test Method **C1338**, the test specimens shall have no growth.

7.8 Surface Burning Characteristics—Test in accordance with Test Method **E84** using the specimen preparation and mounting techniques of Practice **E2231**. For Canada, test in accordance with Test Method CAN/ULC-S102.

NOTE 2—The thermal transmission properties of flexible aerogel insulation, both flat and in a pipe configuration, may vary with temperature, temperature gradient, moisture content, thickness, and shape.

Note that the apparent thermal conductivity requirements in **Table 1** are based on samples tested under the conditions specified in the test procedure given in **7.3.1** above. These are comparative values for establishing specification compliances. In some cases they do not represent the installed performance of the insulation under use conditions since those may differ substantially from the test conditions.

7.9 Maximum Exothermic Temperature Rise—For Type III material only (that is, those used at service temperatures greater than 390°F (199°C)), when tested in accordance with Test Method **C411** and Practice **C447** at the maximum thickness specified by the manufacturer, no internal temperature at

TABLE 2 Acceptable Dimensions And Tolerances On Sheets Of Flexible Aerogel Insulation

Nominal Thickness Inches (mm)	Length, ft (m)			Width, in (mm)			Thickness, in (mm)		
	Type			Type			Type		
	I	II	III	I	II	III	I	II	III
0.2 (5)	275 ± 20 % (83.8 ± 20 %)	275 ± 20 % (83.8 ± 20 %)	310 ± 5 % (94.5 ± 5 %)	58 ± 5 % (1473 ± 5 %)	58 ± 3.5 % (1473 ± 5 %)	58 ± 5 % (1473 ± 5 %)	0.2 ± 20 % (5 ± 20 %)	0.2 ± 20 % (5 ± 20 %)	0.2 ± 20 % (5 ± 20 %)
0.4 (10)	130 ± 40 % (39.6 ± 40 %)	130 ± 40 % (48.8 ± 40 %)	176 ± 5 % (53.6 ± 5 %)	58 ± 5 % (1473 ± 5 %)	58 ± 3.5 % (1473 ± 5 %)	58 ± 5 % (1473 ± 5 %)	0.4 ± 20 % (10 ± 20 %)	0.4 ± 20 % (10 ± 20 %)	0.4 ± 25 % (10 ± 25 %)

any time shall exceed the hot surface temperature by more than 200°F (111°C) with thermocouples installed between each material layer. This criterion applies during heat-up, as well as, steady state conditions.

7.10 *Water Absorption*—Specifications are based on a 10 mm material thickness.

7.10.1 For Types I and II materials, test in accordance with Test Method C1763, Procedure B. The water absorption after immersion shall be ≤8 % by weight as given in Table 1.

7.10.2 For Type III materials, test in accordance with Test Method C1763, Procedure B, after preheating the sample for 24 h at 600°F (316°C) and cooling to room temperature. The water absorption after immersion shall be ≤16 % by weight (8 % by weight when tested before preheating the sample) as given in Table 1.

7.10.2.1 Samples shall be cooled in a desiccator prior to performing initial weight measurements to ensure a constant mass is achieved.

7.11 *Stress Corrosion Performance for Use on Austenitic Stainless Steel*—Compliance with Specification C795 is necessary only when requested to assess corrosivity when the insulation is applied to austenitic stainless steel surfaces.

7.12 *Compressive Resistance*—Test in accordance with Test Method C165 with preloading.

7.13 *Linear Shrinkage after exposure to maximum use temperature*—When tested in accordance with Test Method C356, linear shrinkage shall be less than 2% in length and width directions.

7.14 *Sag Resistance*⁴—Test material in a pipe configuration in accordance with Test Method C411. The percent thickness change shall be less than or equal to 5 %.

8. Qualification Requirements

8.1 *Qualification Requirements*—The following requirements shall be employed for the purpose of initial product qualification:

- 8.1.1 Maximum use temperature,
- 8.1.2 Linear shrinkage after exposure to maximum use temperature,
- 8.1.3 Compressive resistance, at 10% deformation,
- 8.1.4 Apparent thermal conductivity,
- 8.1.5 Density, for design purposes only,
- 8.1.6 Flexibility,
- 8.1.7 Corrosiveness to steel,

8.1.8 Water vapor sorption,

8.1.9 Fungi resistance,

8.1.10 Surface burning characteristics,

8.1.11 Maximum exothermic temperature rise

8.1.12 Water absorption after immersion,

8.1.13 Compliance with Specification C795 is necessary when requested to assess corrosivity only when the insulation is applied to austenitic stainless steel pipe, and

8.1.14 Sag resistance.⁴

9. Dimensions and Permissible Variations

9.1 The sizes and tolerances of flexible aerogel insulation shall either be agreed upon between the purchaser and the supplier or as given in Table 2.

10. Workmanship, Finish, and Appearance

10.1 The insulation shall have good workmanship and shall not have defects, which adversely affect its installation and service qualities.

11. Sampling

11.1 Sampling of the insulation shall be in accordance with criteria in Practice C390. Specific provisions for sampling shall be agreed upon between the purchaser and the supplier.

12. Inspection

12.1 The following requirements are employed for purposes of acceptance sampling of lots or shipments of qualified insulation:

- 12.1.1 Dimensions.
- 12.1.2 Workmanship.

13. Rejection

13.1 Failure to conform to the requirements in this specification shall constitute cause for rejection. Rejection shall be reported to the manufacturer or seller promptly and in writing. The manufacturer and supplier have the right to verify rejected products.

14. Packaging and Marking

14.1 *Packaging*—Unless otherwise specified, the manufacturer shall package the insulation in standard containers.

14.2 *Package Marking*—The markings shall be clear and legible. Unless otherwise specified, the manufacturer shall mark each container with their name, address, and telephone number; and product name, Type, Grade, and Category, and manufacturer's lot or date code identification for the material in the container.

⁴ For Type III Grade 2 material (tested in a pipe configuration).

15. Keywords

15.1 aerogel; blanket; composite; flexible; insulation; pipe
insulation; sheet; thermal conductivity; water retention

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