Standard Test Method for Characterizing the Effect of Exposure to Environmental Cycling on Thermal Performance of Insulation Products[1]

This standard is issued under the fixed designation C1512; 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.

ε1 NOTE—Editorial changes were made throughout in September 2015.

1. Scope

1.1 This test method is applicable to preformed or field manufactured thermal insulation products, such as board stock foams, rigid fibrous and composite materials manufactured with or without protective facings. See Note 1 This test method is not applicable to high temperature, reflective or loose fill insulation.

NOTE 1—If the product is manufactured with a facer, test product with facer in place.

1.2 This test method involves two stages: preconditioning and environmental cycling. During the first stage, 25 mm (1 in.) thick specimens are used to separate two environments. Each of these environments has a constant but different temperature and humidity level. During the environmental cycling stage, specimens also divide two environments namely constant room temperature/humidity on one side and cycling temperature/ambient relative humidity on the other side.

1.3 This test method measures the ability of the product to maintain thermal performance and critical physical attributes after being subjected to standardized exposure conditions. A comparison is made between material properties for reference specimens stored in the laboratory for the test period and specimens subjected to the two-stage test method. To eliminate the effect of moisture from the comparison, the material properties of the latter test specimens are determined after they have been dried to constant weight. The average value determined for each of the two sets of specimens is used for comparison.

1.4 Different properties can be measured to assess the effect of environmental factors on thermal insulation. This test method requires that thermal resistance be determined based upon an average for three specimens measured after completing the test. Secondary elements of this test method include visual observations such as cracking, delamination or other surface defects, as well as the change in moisture content after each of the two stages of exposure prescribed by the test method.

1.5 Characterization of the tested material is an essential element of this test method. Material properties used for characterization will include either compressive resistance or tensile strength values. The compressive resistance or tensile strength is measured on two sets of specimens, one set conditioned as defined in 1.2 and a set of reference test specimens taken from the same material batch and stored in the laboratory for the whole test period. For comparison, an average value is determined for each of the two sets of specimens.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *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 requirements prior to use.*

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

C303 Test Method for Dimensions and Density of Preformed Block and Board–Type Thermal Insulation

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

[1] This test method is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.33 on Insulation Finishes and Moisture.

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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.

C870 Practice for Conditioning of Thermal Insulating Materials
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
D1621 Test Method for Compressive Properties of Rigid Cellular Plastics
D1623 Test Method for Tensile and Tensile Adhesion Properties of Rigid Cellular Plastics
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions*—Terms used in this test method are defined in Terminology C168 with the exceptions included as appropriate.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *compressive resistance*—the compressive load per unit of original area at the specified deformation. See Test Method C165.

3.2.2 *moisture accumulation*—an increase in the average moisture content resulting from a specified exposure to conditions facilitating moisture ingress into the material.

3.2.3 *preconditioning*—a procedure which subjects test specimens to standardized one directional thermal gradient.

3.2.4 *thermal performance*—comparison of thermal resistance of test specimens before and after cycling.

4. Summary of Test Method

4.1 To reduce the testing period, this procedure involves two stages:

4.1.1 *Stage 1*—Preconditioning under constant thermal gradient and relative humidity to accelerate ingress of moisture into the test specimen.

4.1.2 *Stage 2*—Exposure to constant temperature and relative humidity on one side of test specimens with cycling environmental conditions on the other side that include freeze-thaw exposure.

5. Significance and Use

5.1 Exposing a specimen to conditions of one-directional environmental cycling can increase its moisture content until a decrease in material properties occurs (at a specific number of cycles). Such a test could be inappropriate due to the number of cycles required to cause a decrease in material properties since product performance issues often arise only after many years of exposure. The use of a preconditioning procedure is not intended to duplicate expected field performance. Rather the purpose is to increase the moisture content of test materials prior to subjecting to them to environmental cycling.

5.2 The most important aspect of the preconditioning procedure is non-uniform moisture distribution in the specimen. The heat flow is one directional causing moisture flow towards the cold side resulting in zones of dry material on the warm side and high moisture content on the cold side. (Whether the high moisture content zone is located right at the cold surface of the specimen or at some distance from this surface depends upon temperature oscillation and ability of the cold surface to dry outwards). Because the preconditioning procedure involves thermal gradient, this preconditioning procedure results in a distribution of moisture content that may occur under field exposure conditions. However, the resulting moisture content may differ significantly from that which may be demonstrated in typical product applications.

5.3 The preconditioning results in accumulation of moisture in the thermal insulation resulting from the simultaneous exposure to a difference in temperature and water vapor pressure. This test method is not intended to duplicate field exposure. It is intended to provide comparative ratings. As excessive accumulation of moisture in a construction system may adversely affect its performance, the designer should consider the potential for moisture accumulation and the possible effects of this moisture on the system performance.

6. Apparatus

6.1 The room where the apparatus is placed shall be maintained at a temperature and relative humidity of 24 ± 3°C (75 ± 5°F) and 50 ± 10 %.

6.2 *Freeze-Thaw Chamber,* capable of maintaining an air temperature of -15 ± 3°C (5 ± 5°F) over an extended period of time. The design of the apparatus should ensure that the temperature of the upper surface of the sheet metal located below the insulation specimen (measured in the center of the pan) be not higher than -4°C (25°F) when the freezer's air temperature reaches its lower limit. This can be achieved by placing thermal insulation between the metal pan and the specimen frame and/or mixing of air in the cold chamber.

6.3 *Sheet Metal Pan,* placed below the specimens. This pan performs two functions: it equalizes temperature and reduces diffusion of water vapor into the freeze-thaw chamber. The distance between the cold surface of the specimen and the sheet metal should be no less than 6.35 mm (0.25 in.) and no more than 12.7 mm (0.5 in). The required space is normally maintained by attaching a support of the required height that is made from 6.35 mm (0.25 in.) thick Plexiglas or other non-absorbing materials on the inside surface of the specimen frame (see Fig. 2).

6.4 *Frame,* that is placed in the door opening of the freezer (see Figs. 1 and 2) or other means of specimen support. Test frames used are made from 6.35 ± 0.5 mm (0.25 ± 0.02 in.) thick Plexiglas or other non-absorbing material. These frames are used to mount individual test specimens. The selection of the test frame (size of the test specimen) may vary based upon the thermal testing apparatus that is used.

6.5 *Warm Chamber,* above the test specimens that is provided with a heater and a temperature controller capable of maintaining a temperature of 24 ± 2°C (75 ± 3°F) and a humidifier capable of maintaining humidity in the warm chamber of 90 ± 5 %RH.

6.6 *Sensors,* for measuring temperature of the freeze-thaw and warm chambers and relative humidity in the warm chamber.

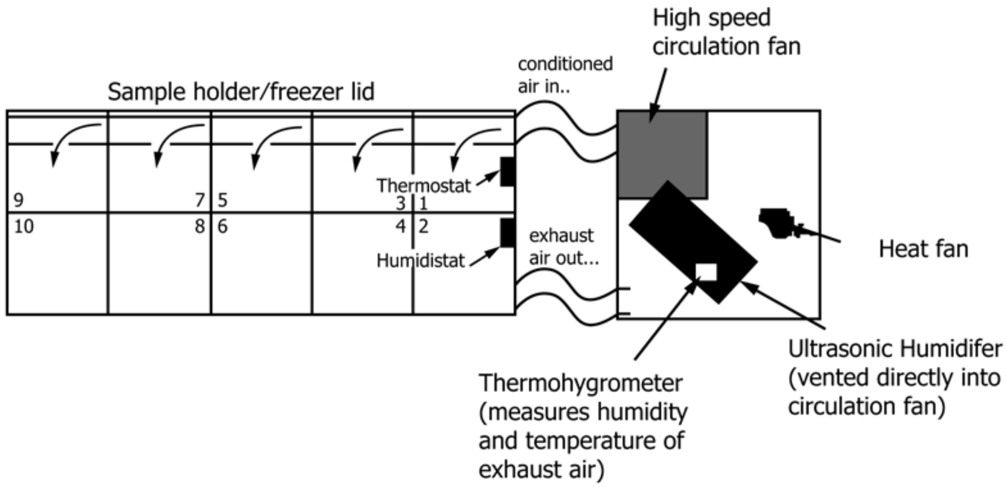

FIG. 1 Plan View of Test Equipment Setup

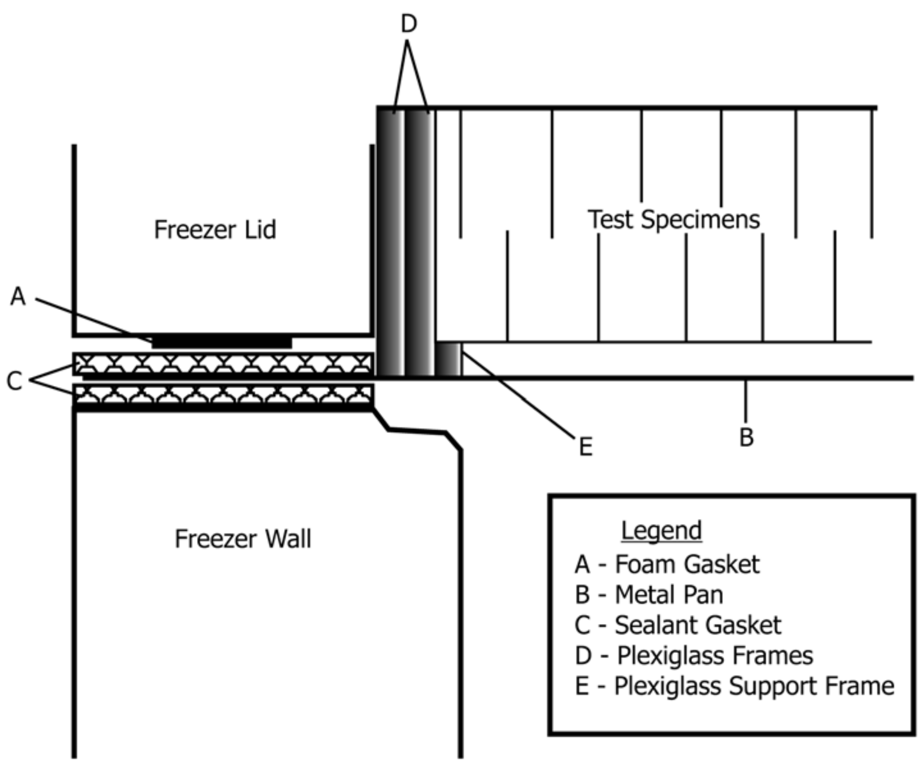

FIG. 2 Vertical Section at Interface Between Freezer Wall and Lid Illustrating Placement of Test Specimens in the Test Frame

6.7 *Balance,* capable of weighing mass of maximum 1 kg with precision of 0.01 g.

7. Test Specimens

7.1 Test specimens shall be square in cross-section with a minimum area of 645 cm^2 (100 $in.^2$) and a maximum of 3716 cm^2 (576 $in.^2$). The standard specimen thickness shall be 2.54 cm (1 in.). Care should be taken so that the top and bottom surfaces of the specimens exposed to thermal gradient are parallel with one another and perpendicular to the sides.

7.2 All surfaces of the specimens shall be free from visible flaws or imperfections.

7.3 For comparison, two test specimen sets each consisting of a minimum of three specimens are tested. One set of test specimens are tested after preconditioning and after environmental cycling as described in Section 9. A second set of reference test specimens are stored in the laboratory for the duration of preconditioning and environmental cycling test before thermal resistance and compressive resistance or tensile strength testing.

8. Conditioning

8.1 Condition the test specimens before testing at 23 ± 2°C (73 ± 4°F) and 50 ± 5 %RH relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice C618.

9. Procedure

9.1 Condition specimens to constant mass in accordance with Practice C870 before testing. Measure the dimensions and mass of each specimen in accordance with Test Method C303. Record the initial mass of each specimen prior to subjecting to preconditioning procedure.

9.2 *Testing of Specimens Before and After Environmental Cycling:*

9.2.1 Three specimens shall be tested for thermal resistance value before and after environmental cycling using Test Method C518 or C177.

9.2.2 Where applicable, nine specimens shall be tested for compressive resistance before and after environmental cycling using Test Method C165 or D1621.

9.2.3 Where applicable, nine specimens shall be tested for tensile strength before and after environmental cycling using Test Method D1623.

9.3 *Preconditioning:*

9.3.1 Test specimens are preconditioned for 28 days to increase moisture content. This is achieved under conditions of water vapor diffusion associated with a constant thermal gradient. The specimens are dividing two environments, namely:

9.3.1.1 Temperature of 24 ± 2°C (75 ± 3°F) and relative humidity of 90 ± 5 % on warm side, and

9.3.1.2 Temperature of -15 ± 3°C (5 ± 5°F) and ambient relative humidity (uncontrolled relative humidity) on the cold side.

9.3.2 If the specimens are provided with facing, stucco lamina or other protective finishes, these finishes should be placed on the cold side during the preconditioning exposure.

9.3.3 Weigh each specimen after initial preconditioning. Moisture content (% by volume) of the specimen is calculated after completing the preconditioning exposure. Normally the specimens are returned to the same equipment but conditions on the cold side are changed and cycling under environmental conditions which include freeze-thaw cycling on the cold side proceeds.

9.4 *Environmental Cycling Conditions:*

9.4.1 Place test specimens in the test frame (Fig. 2) and seal the edges of the test specimens to prevent passage of air around the edges.

9.4.2 Test specimens shall be placed for 20 days (40 cycles) separating two environments:

9.4.2.1 Warm chamber where temperature and relative humidity are maintained at 24 ± 2°C (75 ± 3°F) and 90 ± 5 %RH; and

9.4.2.2 Environmental cycling chamber where conditions require temperature cycling between two levels: -15 ± 3°C (5 ± 5°F) and 15 ± 3°C (59 ± 5°F). The total cycling period is twelve hours, divided equally into cold and warm exposures. The warm exposure (at least 4 h at temperature higher than 5°C (40°F) is ended with the transition period of no longer than 2 h. During the cold exposure stage of the cycle, air in the chamber is cooled to -15 ± 3°C (5 ± 5°F). The cold exposure period is ended with a similar transition period (to reach an air temperature higher than 5°C (40°F) during a period of 2 h.

9.4.3 Weigh each specimen after completion of environmental cycling and calculate moisture content (% by volume). Condition specimens to constant mass in accordance with 9.1 and subject to testing in accordance with 9.2.

10. Report

10.1 The test report shall include the following information, including references to applicable test methods:

10.1.1 The date of the report.

10.1.2 The name, address and identification of the testing laboratory.

10.1.3 The manufacturer of the material, the date of manufacture and the date of receiving samples.

10.1.4 Number of samples received and the number of specimens tested in respective categories.

10.1.5 The name or identification of the material tested and description of facers (if any).

10.1.6 The method of specimen preparation.

10.1.7 The type and size of the preconditioning set-up and the preconditioning conditions.

10.1.8 The moisture content (% by volume) of each test specimen after preconditioning and cycling.

10.1.9 Average and standard deviation of these values at the end of preconditioning stage.

10.1.10 The method of sealing around the test specimen.

10.1.11 Average of the test conditions such as minimum and maximum temperatures in the freezing cabinet, the difference in temperature of air in the freezing cabinet and the surface of the sheet metal facing test specimens.

10.1.12 Moisture content (% by volume) for each test specimen and the average and standard deviation of these values at the end of the testing stage.

10.1.13 Individual and average thermal resistance values after drying for three specimens (tested material) subjected to preconditioning and environmental cycling.

10.1.14 Individual and average thermal resistance values for three specimens (reference material) from the same production batch stored in the laboratory for the period of testing.

10.1.15 The method of Heat Flow Meter Apparatus calibration.

10.1.16 The compressive resistance of nine specimens cut from Series 1 specimens and nine specimens cut from Series 2 specimen.

10.1.17 The average and standard deviation for compressive resistance values measured on each series.

11. Precision and Bias

11.1 The precision of this test method is based on an interlaboratory study of C1512 – 07, Standard Test Method for

Characterizing the Effect of Exposure to Environmental Cycling on Thermal Performance of Insulation Products, conducted in 2009. Each of three laboratories tested three different expanded polystyrene (EPS) insulation materials. Every "test result" represents an individual determination. All laboratories were asked to report five replicate test results from a single operator, for every material. Except for the limited number of laboratories involved, and the inability of all participants to report all requested material/analysis/replicate combinations, Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. C16-1036.[3]

11.1.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "r" value for that material; "r" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

11.1.1.1 Repeatability limits are listed in Tables 1-3 below.

11.1.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C16-1036.

11.1.2.1 Reproducibility limits are listed in Tables 1-3 below.

11.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

11.1.4 Any judgment in accordance with statements 11.1.1 and 11.1.2 would normally have an approximate 95% probability of being correct, however the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of materials tested and laboratories reporting all requested replicate results guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95% probability limit would imply. Consider the repeatability limit and the reproducibility limit as general guides, and the associated probability of 95% as only a rough indicator of what can be expected.

11.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

11.3 The precision statement was determined through statistical examination of 247 results, from three laboratories, performing seven analyses, on three materials.

11.4 To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material.

12. Keywords

12.1 environmental cycling; thermal insulation

TABLE 1 EPS Insulation Material, Type A

Analysis	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	s_R	r	R
Moisture Content % by Volume After Pre-conditioning	2.67	0.384	2.26	1.07	6.32
Moisture Content % by Volume After Conditioning and Freeze/Thaw Cycle	1.93	0.356	1.67	1.00	4.68
Thermal Resistance (F·ft^2·h/Btu per inch) Control as Received	3.74	0.013	0.013	0.037	0.037
Thermal Resistance (F·ft^2·h/Btu per inch) After Conditioning and Freeze/Thaw Cycle	3.70	0.023	0.026	0.064	0.074
Compressive (psi) Control as Received	13.2	0.223	0.260	0.624	0.729
Compressive (psi) After Conditioning and Freeze/Thaw Cycle	13.5	0.400	0.697	1.12	1.95

[A]The average of the laboratories' calculated averages

TABLE 2 EPS Insulation Material, Type B

Analysis	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	s_R	r	R
Moisture Content % by Volume After Pre-conditioning	2.85	0.694	1.05	1.94	2.94
Moisture Content % by Volume After Conditioning and Freeze/Thaw Cycle	3.27	1.25	2.13	3.50	5.97
Thermal Resistance (F·ft^2·h/Btu per inch) Control as Received	4.01	0.018	0.058	0.051	0.163
Thermal Resistance (F·ft^2·h/Btu per inch) After Conditioning and Freeze/Thaw Cycle	3.99	0.028	0.072	0.078	0.203
Compressive (psi) Control as Received	22.6	1.92	3.38	5.38	9.46
Compressive (psi) After Conditioning and Freeze/Thaw Cycle	21.7	0.636	1.94	1.78	5.42

[A]The average of the laboratories' calculated averages

TABLE 3 EPS Insulation Material, Type C

Analysis	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	s_R	r	R
Moisture Content % by Volume After Pre-conditioning	1.90	0.413	0.729	1.16	2.04
Moisture Content % by Volume After Conditioning and Freeze/Thaw Cycle	2.21	0.915	1.22	2.56	3.42
Thermal Resistance (F·ft^2·h/Btu per inch) Control as Received	4.32	0.111	0.172	0.312	0.481
Thermal Resistance (F·ft^2·h/Btu per inch) After Conditioning and Freeze/Thaw Cycle	4.29	0.032	0.121	0.090	0.338
Compressive (psi) Control as Received	34.1	1.02	2.47	2.85	6.91
Compressive (psi) After Conditioning and Freeze/Thaw Cycle	32.0	0.515	1.08	1.44	3.02

[A]The average of the laboratories' calculated averages