



Standard Test Method for Using Heat Flow Meter Apparatus to Measure the Center-of-Panel Thermal Transmission Properties of Vacuum Insulation Panels¹

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1. Scope

1.1 This test method covers the measurement of steady-state thermal transmission through the center of a flat rectangular vacuum insulation panel using a heat flow meter apparatus.

1.2 Total heat transfer through the non-homogenous geometry of a vacuum insulation panel requires the determination of several factors, as discussed in Specification C1484. One of those factors is the center-of-panel thermal resistivity. The center-of-panel thermal resistivity is an approximation of the thermal resistivity of the core evacuated region.

1.3 This test method is based upon the technology of Test Method C518 but includes modifications for vacuum insulation panel applications as outlined in this test method.²

1.4 This test method shall be used in conjunction with Practice C1045 and Practice C1058.

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

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.*

2. Referenced Documents

2.1 ASTM Standards:³

C168 Terminology Relating to Thermal Insulation

C518 Test Method for Steady-State Thermal Transmission

¹ This test method 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 All references to particular sections of Test Method C518 within this document refer to the 2010 edition of Test Method C518.

³ 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.

Properties by Means of the Heat Flow Meter Apparatus
C740 Practice for Evacuated Reflective Insulation In Cryogenic Service

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

C1484 Specification for Vacuum Insulation Panels

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Terminology

3.1 *Definitions*—Terminology C168 applies to terms used in this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center-of-panel*—the location at the center of the largest planar surface of the panel, equidistant from each pair of opposite edges of that surface.

3.2.2 *center-of-panel apparent thermal resistivity*—the thermal performance of vacuum insulation panels includes an edge effect due to heat flow through the barrier material and this shunting of heat around the evacuated volume of the panel becomes more prevalent with greater barrier thermal conductivity, as shown in Fig. 1. For panels larger than a minimum size (as described in Annex A1), the center-of-panel apparent thermal resistivity is a close approximation of the intrinsic core thermal resistivity of the vacuum insulation panel. The effective thermal performance of a panel will vary with the size and shape of the panel.

3.2.2.1 *Discussion*—Thermal resistivity, the reciprocal of apparent thermal conductivity, is used when discussing the center-of-panel thermal behavior.

3.2.3 *core*—the material placed within the evacuated volume of a vacuum insulation panel. This material may perform any or all of the following functions: prevent panel collapse due to atmospheric pressure, reduce radiation heat transfer, and reduce gas-phase conduction. The apparent thermal conductivity of the core, or λ_{core} , is defined as the apparent thermal

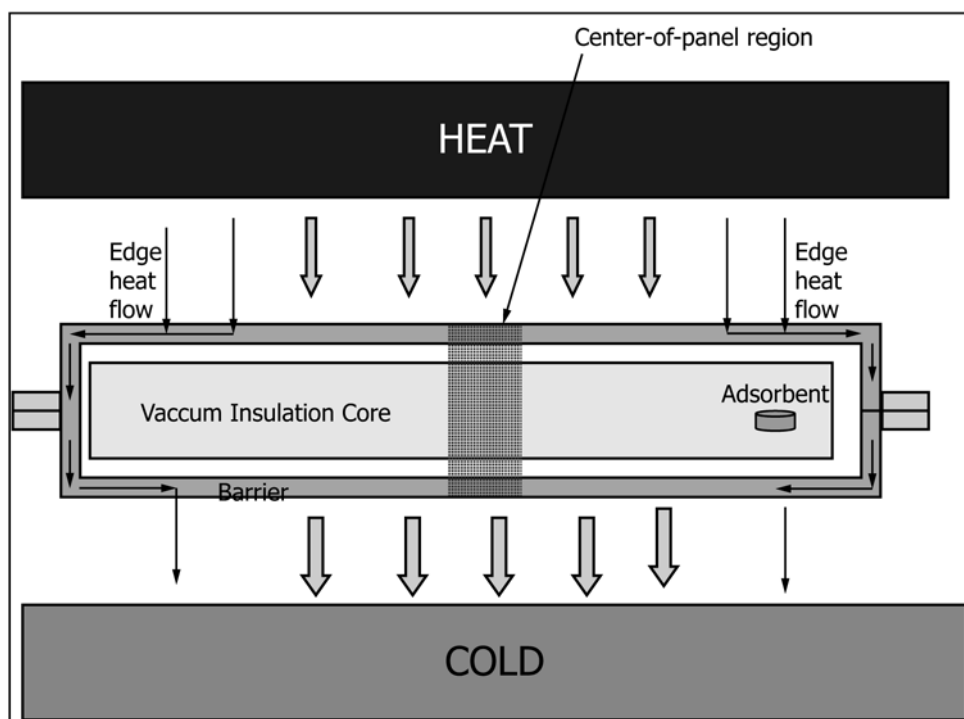


FIG. 1 Side View of a Vacuum Insulation Panel Showing Edge Heat Flow and the Center-of-Panel Region

conductivity of the core material under the same vacuum that would occur within a panel, but without the barrier material. This is the apparent thermal conductivity that would be measured in a vacuum chamber without the barrier material.

3.2.4 *effective panel thermal resistance (effective panel R-value)*—this value reflects the total panel resistance to heat flow, considering heat flow through the evacuated region and through the barrier material. Depending on the thermal conductivity of the barrier material and the size of the panel, the effective thermal resistance may be significantly less than the product of the center-of-panel apparent thermal resistivity and the panel thickness. The effective thermal resistance is based on the edge-to-edge area covered by the vacuum insulation panel, that is, the entire panel. The effective thermal resistance will also vary with the panel mean temperature.

3.2.4.1 *Discussion*—Thermal resistance, the reciprocal of thermal conductance, is used when discussing the effective thermal performance of the panel. This value includes the effect of the actual panel dimensions, including the panel thickness.

3.2.5 *evacuated or vacuum insulations*—insulation systems whose gas phase thermal conductivity portion of the overall apparent thermal conductivity has been significantly reduced by reduction of the internal gas pressure. The level of vacuum will depend on properties of the composite panel materials, and the desired effective panel thermal resistance.⁴

3.2.6 *panel barrier*—the material that envelops the evacuated volume and is used to separate the evacuated volume from the environment and to provide a long term barrier to gas and vapor diffusion.

3.2.7 *seal*—any joint between two pieces of barrier material.

3.3 *Symbols and Units:* $A_{barrier}$ = area of the barrier perpendicular to the largest panel faces, m²

A_{core} = area of the largest panel face covering the core material, m²

C = calibration standard conductance, W/m²-K

E = heat flux transducer output, V

L_{panel} = panel thickness, m

$L_{calibration\ standard}$ = thickness of a single layer of the calibration standard material, m

$L_{calibration\ standard,\ target}$ = target total thickness of the calibration standard material, m

q = heat flux through the panel, W/m²

$Q_{barrier}$ = heat flow through the barrier material, W

$Q_{center-of-panel}$ = estimated heat flow at the transducer (as calculated by the model), W

Q_{core} = heat flow through the core region, W

$R_{calibration\ standard}$ = thermal resistivity of the calibration standard, m-K/W

$R_{center-of-panel}$ = center of panel thermal resistivity, m-K/W

S = calibration factor, (W/m²)/V

T_c = specimen cold surface temperature, K

T_h = specimen hot surface temperature, K

$t_{barrier}$ = thickness of the barrier material, m

W_1, W_2 = panel width, panel length, m

u_c = combined standard uncertainty

⁴ For further discussion on heat flow mechanisms in evacuated insulations, see Practice C740 on Evacuated Reflective Insulation in Cryogenic Service.

u_n = uncertainty component, for example, standard uncertainty for the measurement

Z_{edge} = an approximate estimate of the ratio of the heat flow through the barrier material to the heat flow through the core material, dimensionless

$\lambda_{barrier}$ = thermal conductivity of the barrier material, W/m-K

λ_{core} = apparent thermal conductivity of the core region, W/m-K

4. Summary of Test Method

4.1 This test method describes a modified application of Test Method C518 to evacuated panels. These panels fall outside the scope of Test Method C518, both in their non-homogeneity and in the current lack of specimens having an accepted reference value that are of similar size and have the necessary thermal characteristics. Therefore, modifications are necessary in the areas of apparatus calibration, plate separation, test procedures, precision and bias, and reporting.

NOTE 1—Primary calibration standards, using vacuum insulation panels, have not been prepared for this class of products due to uncertainties about their long-term stability characteristics.

5. Significance and Use

5.1 Heat flow meter apparatus are being used to measure the center-of-panel portion of a vacuum insulation panel, which typically has a very high value of thermal resistivity (that is, equal to or greater than 90 m-K/W). As described in Specification C1484, the center-of-panel thermal resistivity is used, along with the panel geometry and barrier material thermal conductivity, to determine the effective thermal resistance of the evacuated panel.

5.2 Using a heat flow meter apparatus to measure the thermal resistivity of non-homogenous and high thermal resistance specimens is a non-standard application of the equipment, and shall only be performed by qualified personnel with understanding of heat transfer and error propagation. Familiarity with the configuration of both the apparatus and the vacuum insulation panel is necessary.

5.3 The center-of-panel thermal transmission properties of evacuated panels vary due to the composition of the materials of construction, mean temperature and temperature difference, and the prior history. The selection of representative values for the thermal transmission properties of an evacuated panel for a particular application must be based on a consideration of these factors and will not apply necessarily without modification to all service conditions.

6. Apparatus

6.1 Follow Test Method C518, Section 5 except use Section 8 of this test method for calibration.

7. Specimen Preparation

7.1 Vacuum insulation panels are typically rigid and the shape cannot be modified for testing purposes. However, to obtain representative thermal values for the panel, the two primary surfaces must be parallel and have limited surface irregularities.

7.2 If none of the standard product sizes are appropriate for the heat flow meter apparatus used in this test, then representative test specimens must be produced so that they accurately represent both the same average performance as the production product and the same typical product variability.

7.3 The specimens shall be of the same thickness as the average thickness to be applied in use.

7.4 The minimum panel size for this test is determined by the size of the heat flux transducer in the heat flow meter apparatus, the overall maximum specimen size limit for the apparatus, the thermal conductivity of the barrier, the thickness of the barrier, and the thermal conductivity of the core. Annex A1 contains a procedure to estimate the minimum acceptable panel size.

7.4.1 Preferably, specimens shall be of such size as to fully cover the plate assembly surfaces, with an allowance of up to 6 mm on each side to allow room for panel seals.

7.4.2 If the width or length, or both, of the specimen are smaller than the apparatus compartment, surround the specimen with high thermal resistance insulation. This surrounding material will reduce edge heat transfer and prevent air circulation around the specimen.

7.5 For panels with smooth parallel surfaces, the specimen thickness is represented by the plate separation.

7.6 For panels with irregular surfaces, to insure thermal contact with the apparatus surfaces, it is necessary to:

7.6.1 Measure the panel thickness with an accuracy of ± 0.05 mm in at least five locations distributed over the surface of the panel and use the average of the local values. Care shall be taken so that the contact between the caliper jaws or the length meter's pressure foot does not damage the specimen surface.

7.6.2 Record the output of one thermocouple placed on the center of the top and one thermocouple placed on the center of the bottom of the panel. The temperatures recorded by the thermocouples, not the hot and cold plate temperatures, shall be used to calculate the center-of-panel apparent thermal resistivity.

7.6.3 Place one sheet (approximately 3 mm thick) of an elastomeric or soft foam rubber between each side of the panel and the corresponding apparatus plate. This sheet will improve contact between the controlled temperature plates and prevent air circulation between the panel and the plates.

8. Calibration

8.1 The apparatus shall be calibrated according to Test Method C518 sections 6.1 to 6.5.

8.2 Specimens having an accepted reference value with physical and thermal characteristics similar to vacuum insulation panels are not yet available. The linearity of the heat flux transducers at very low levels of heat flux must be verified using another method. The apparatus calibration must include the addition of at least one of the modified calibration procedures described in 8.5 and 8.6, that is Modified Calibration Procedure A or B. As described in 8.7, the two modified procedures can be combined if necessary to meet uncertainty