



Standard Guide for Evacuated Reflective Insulation In Cryogenic Service¹

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1. Scope

1.1 This guide covers the use of thermal insulations formed by a number of thermal radiation shields positioned perpendicular to the direction of heat flow. These radiation shields consist of alternate layers of a low-emittance metal and an insulating layer combined such that metal-to-metal contact in the heat flow direction is avoided and direct heat conduction is minimized. These are commonly referred to as multilayer insulations (MLI) or super insulations (SI) by the industry. The technology of evacuated reflective insulation in cryogenic service, or MLI, first came about in the 1950s and 1960s primarily driven by the need to liquefy, store, and transport large quantities of liquid hydrogen and liquid helium. (1-6)²

1.2 The practice guide covers the use of these MLI systems where the warm boundary temperatures are below approximately 400 K. Cold boundary temperatures typically range from 4 K to 100 K, but any temperature below ambient is applicable.

1.3 Insulation systems of this construction are used when heat flux values well below 10 W/m² are needed for an evacuated design. Heat flux values approaching 0.1 W/m² are also achievable. For comparison among different systems, as well as for space and weight considerations, the effective thermal conductivity of the system can be calculated for a specific total thickness. Effective thermal conductivities of less than 1 mW/m-K [0.007 Btu-in/h-ft²·°F or R-value 143] are typical and values on the order of 0.01 mW/m-K have been achieved [0.00007 Btu-in/h-ft²·°F or R-value 14 300]. (7) Thermal performance can also be described in terms of the effective emittance of the system, or E_e .

1.4 These systems are typically used in a high vacuum environment (evacuated), but soft vacuum or no vacuum environments are also applicable. (8) A welded metal vacuum-jacketed (VJ) enclosure is often used to provide the vacuum environment.

1.5 The range of residual gas pressures is from $<10^{-6}$ torr to 10^{+3} torr (from $<1.33^{-4}$ Pa to 133 kPa) with or without different purge gases as required. Corresponding to the applications in cryogenic systems, three sub-ranges of vacuum are also defined: from $<10^{-6}$ torr to 10^{-3} torr (from $<1.333^{-4}$ Pa to 0.133 Pa) [high vacuum/free molecular regime], from 10^{-2} torr to 10 torr (from 1.33 Pa to 1333 Pa) [soft vacuum, transition regime], from 100 torr to 1000 torr (from 13.3 kPa to 133 kPa) [no vacuum, continuum regime]. (9)

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the 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 limitations prior to use.* For specific safety hazards, see Section 9.

2. Referenced Documents

2.1 ASTM Standards:

- B571 Practice for Qualitative Adhesion Testing of Metallic Coatings
- C168 Terminology Relating to Thermal Insulation
- E408 Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *cold boundary temperature (CBT)*—The cold boundary temperature, or cold side, of the MLI system is the temperature of the cold surface of the element being insulated. The CBT is often assumed to be the liquid saturation temperature of the cryogen. The CBT can also be denoted as T_c .

3.1.2 *cold vacuum pressure (CVP)*—The vacuum level under cryogenic temperature conditions during normal operation, but typically measured on the warm side of the insulation. The CVP can be from one to three orders of magnitude lower than the WVP for a well-designed cryogenic-vacuum system.

¹ This guide is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.21 on Reflective Insulation.

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² The boldface numbers in parentheses refer to a list of references at the end of this standard.