



Standard Practice for Evacuated Reflective Insulation In Cryogenic Service¹

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1. Scope

1.1 This practice 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.

1.2 The practice covers the use of these insulation constructions where the warm boundary temperatures are below approximately 450 K.

1.3 Insulations of this construction are used when apparent thermal conductivity less than $0.007 \text{ W/m}\cdot\text{K}$ ($0.049 \text{ Btu}\cdot\text{in./h}\cdot\text{ft}^2\cdot^\circ\text{F}$) at 300K are required.

1.4 Insulations of this construction are used in a vacuum environment.

1.5 This practice covers the performance considerations, typical applications, manufacturing methods, material specification, and safety considerations in the use of these insulations in cryogenic service.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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 8.

2. Terminology

2.1 Symbols:

- a = accommodation coefficient, dimensionless
 b = exponent, dimensionless
 d = distance between confining surfaces, m

- q = heat flow per unit time, W
 A = unit area, m^2
 n = number of radiation shields
 σ = Stefan-Boltzmann constant, $5.67 \times 10^{-8} \text{ W/m}^2\cdot\text{K}^4$
 T = temperature, K; T_h at hot boundary, T_c at cold boundary
 E = emittance factor, dimensionless; E_{eff} , system effective emittance
 e = total hemispherical emittance of a surface, dimensionless; e_h at hot boundary, e_c at cold boundary
 t = distance between the hot boundary and the cold boundary, m
 k = thermal conductivity, $\text{W/m}\cdot\text{K}$
 R = shielding factor, dimensionless; equivalent to $1/E$
 D = degradation factor, dimensionless
 P = mechanical loading pressure, Pa

2.2 Definitions:

2.2.1 *evacuated reflective insulation*—Multilayer composite thermal insulation consisting of radiation shield materials separated by low thermal conductivity insulating spacer material of cellular, powdered, or fibrous nature designed to operate at low ambient pressures.

2.2.2 *ohms per square*—The electrical resistance of a vacuum metallized coating measured on a sample in which the dimensions of the coating width and length are equal. The ohm-per-square measurement is independent of sample dimensions.

3. Insulation Performance

3.1 Theoretical Performance:

3.1.1 The lowest possible heat flow is obtained in an MLI when the sole heat transfer mode is by radiation between free floating shields of low emittance and of infinite extent. The heat flow between any two such shields is given by the relation:

$$q/A = E(\sigma T_h^4 - \sigma T_c^4) \quad (1)$$

3.1.1.1 (Refer to Section 2 for symbols and definitions.) The emittance factor, E , is a property of the shield surfaces facing one another. For parallel shields, the emittance factor is determined from the equation:

$$E = 1/(1/e_h + 1/e_c - 1) = e_h e_c / e_h + (1 - e_h) e_c \quad (2)$$

3.1.1.2 When these opposing surfaces have the same total hemispherical emittance, Eq 2 reduces to:

¹ This practice 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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