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Standard Terminology Relating to Thermal Insulation[1]

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1. Scope

1.1 This standard provides definitions, symbols, units, and abbreviations of terms used in ASTM standards pertaining to thermal insulating materials, and to materials associated with them.

2. Referenced Documents

2.1 *ISO Standard:*

ISO 7345 Thermal Insulation—Physical Quantities and Definitions[2]

3. Terminology

3.1 *Definitions:*

absorptance, *n*—the ratio of the radiant flux absorbed by a body to that incident upon it.

absorption, *n*—transformation of radiant energy to a different form of energy by interaction with matter.

apparent thermal conductivity, λ_a, k_a, *n*—a thermal conductivity assigned to a material that exhibits thermal transmission by several modes of heat transfer resulting in property variation with specimen thickness, or surface emittance. See **conductivity, thermal**.

Discussion—Thermal conductivity and resistivity are normally considered to be intrinsic or specific properties of materials and, as such, should be independent of thickness. When nonconductive modes of heat transfer are present within the specimen (radiation, free convection) this may not be the case. To indicate the possible presence of this phenomena (for example, thickness effect) the modifier "apparent" is used, as in apparent thermal conductivity.

Discussion—Test data using the "apparent" modifier must be quoted only for the conditions of the measurement. Values of thermal conductance (material *C*) and thermal resistance (material *R*) calculated from apparent thermal conductivity or resistivity, are valid only for the same conditions.

Discussion—Test data labeled with "apparent" shall not include any equipment related measurement errors induced due to measurement attempts beyond an apparatus range or calibration.

Discussion—Use of the "apparent" modifier with system *C* or system *R* measurements is not permitted.

apparent thermal resistivity, r_a, *n*—a thermal resistivity assigned to a material that exhibits thermal transmission by several modes of heat transfer resulting in property variation with specimen thickness, or surface emittance. See **resistivity, thermal**.

Discussion—See entire discussion under **apparent thermal conductivity.**

blackbody, *n*—the ideal, perfect emitter and absorber of thermal radiation. It emits radiant energy at each wavelength at the maximum rate possible as a consequence of its temperature, and absorbs all incident radiance.

blanket insulation, *n*—a relatively flat and flexible insulation in coherent sheet form furnished in units of substantial area.

blanket insulation, metal mesh, *n*— blanket insulation covered by flexible metal-mesh facings attached on one or both sides.

block insulation, *n*—rigid insulation preformed into rectangular units.

board insulation, *n*—semirigid insulation preformed into rectangular units having a degree of suppleness particularly related to their geometrical dimensions.

calcium silicate, *n*—insulation composed principally of hydrous calcium silicate, and which usually contains reinforcing fibers.

cellular elastomeric, *n*—insulation composed principally of natural or synthetic elastomers, or both, processed to form a flexible, semirigid, or rigid foam which has a predominantly closed-cell structure.

cellular glass, *n*—insulation composed of glass processed to form a rigid foam having a predominantly closed-cell structure.

cellular polystyrene, *n*—insulation composed principally of polymerized styrene resin processed to form a rigid foam having a predominantly closed-cell structure.

cellular polyurethane, *n*—insulation composed principally of the catalyzed reaction product of polyisocyanate and polyhydroxy compounds, processed usually with fluorocarbon gas to form a rigid foam having a predominantly closed-cell structure.

[1] This terminology is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.94 on Terminology.

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[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

cellulosic fiber, *n*—insulation composed principally of cellulose fibers usually derived from paper, paperboard stock, or wood, with or without binders.

cement, finishing, *n*—a mixture of dry fibrous or powdery materials, or both, that when mixed with water develops a plastic consistency, and when dried in place forms a relatively hard, protective surface.

cement, insulating, *n*—a mixture of dry granular, flaky, fibrous, or powdery materials that when mixed with water develops a plastic consistency, and when dried in place forms a coherent covering that affords substantial resistance to heat transmission.

coating, *n*—a liquid or semiliquid that dries or cures to form a protective finish, suitable for application to thermal insulation or other surfaces in thickness of 30 mils (0.76 mm) or less, per coat.

conductance, film, *n*—the time rate of heat flow from a unit area of a surface to its surroundings, induced by a unit temperature difference between the surface and the environment.

DISCUSSION—The environment is a fluid (liquids or gases). *h* depends on the nature of fluid motion past the surface (laminar or turbulent). (*h* in SI units: $W/m^2 \cdot K$).

conductance, thermal, *C***,** *n*—the time rate of steady state heat flow through a unit area of a material or construction induced by a unit temperature difference between the body surfaces.

$$C = q/\Delta T$$

A conductance (*C*) associated with a material shall be specified as a material *C*. A conductance (*C*) associated with a system or construction of materials shall be specified as a system *C*. (*C* in SI units: W/m^2K.) (*C* in inch-pound units: $(Btu/h)/ft^2/F = Btu/h\ ft^2F$.)

DISCUSSION—The average temperature of a surface is the area-weighted temperature of that surface.

DISCUSSION—When the surfaces of a mass type thermal insulation are not of equal areas, as in the case of thermal transmission in the radial direction, or are not of uniform separation (thickness), the surface area and thickness to which the conductance is assigned must be defined.

DISCUSSION—"Total'' or "areal'' thermal conductance are often used as synonyms for thermal conductance.

DISCUSSION—Thermal conductance and thermal resistance are reciprocals of one another.

DISCUSSION—See Discussion under **resistance, thermal.**

conductivity, thermal, λ or *k***,** *n*—the time rate of steady state heat flow through a unit area of a homogeneous material induced by a unit temperature gradient in a direction perpendicular to that unit area. (λ or *k* in SI units: $(W/m^2)/(K/m) = W/m\ K$.) (λ or *k* in inch-pound units: $(Btu/h)/ft^2/(F/ft) = Btu/h\ ft\ F$) or $(Btu/h)/ft^2/(F/in.) = Btu\ in./h\ ft^2\ F$.) (See discussion under **apparent thermal conductivity**.)

DISCUSSION—Thermal conductivity testing is usually done in one of two apparatus/specimen geometries: flat-slab specimens with parallel heat flux lines, or cylindrical specimens with radial heat flux lines. The operational definitions of thermal conductivity for these two cases are given as follows:

$$\text{Flat-slab geometry } \lambda = \frac{Q}{A}\frac{L}{\Delta T} \tag{1}$$

where:
Q = heat flow rate,
A = area through which *Q* passes, and
L = thickness of the flat-slab specimen across which the temperature difference ΔT exists.

The $\Delta T/L$ ratio approximates the temperature gradient.

$$\text{Cylindrical geometry } \lambda = \frac{Q}{2\pi l \Delta T}\log_e\frac{r_2}{r_1} \tag{2}$$

where:
l = length,
r_2 = the outer radius, and
r_1 = the inner radius of the cylinder.

Eq 1 and Eq 2 are actually special-case simplifications of the more general definition:

thermal conductivity, λ—a tensor property defined by the tensor equation:

$$q = -\lambda \Delta T \tag{3}$$

where *q* is the heat flux vector, and Δ *T* (grad *T*) is the temperature gradient vector. Except in theoretical discussions, this generalized form of the definition is seldom used. For experimental situations, the geometry of the testing apparatus and the specimen are chosen such that Eq 3 reduces to the one-dimensional scalar equation:

$$Q = -A\lambda\frac{dT}{du} \tag{4}$$

where:
Q = heat flow rate,
A = area through which *Q* passes,
λ = thermal conductivity, and
dT/du = the temperature gradient in the direction of heat flow.

At steady state, Eq 1 and Eq 2 are consistent with Eq 4 if Δ *T* is sufficiently small. If ΔT is not sufficiently small, then Eq 1 and Eq 2 define a mean thermal conductivity over the ΔT range, and this range in addition to the mean temperature should be stated.

DISCUSSION—If the measured thermal property indicates that other than conductive heat flows are present, as evidenced by dependence on specimen thickness, air flow, or emittance of bounding surfaces, then this definition does not apply. See also, **apparent thermal conductivity.**

DISCUSSION—Thermal conductivity and thermal resistivity are reciprocals of one another.

DISCUSSION—As an additional reference and discussion along similar lines, see the International Standard ISO 7345 Annex.

coverage, *n*—the area to be covered per unit volume of coating to obtain specified dry thickness and desired performance.

covering capacity, dry, *n*—the area covered to a dry thickness of 1 in. (25 mm) by 100 lb (45.4 kg) of dry cement when mixed with the recommended amount of water, molded and dried to constant weight.

covering capacity, wet, *n*—the area covered to a wet thickness of 1 in. (25 mm) by 100 lb (45.4 kg) of dry cement when mixed with the recommended amount of water, and molded.

density, apparent (of applied insulation), *n*—the mass per unit volume of in-place mass thermal insulation.

dewpoint temperature, *n*—the temperature at which condensation of water vapor in a space begins for a given state of humidity and pressure as the vapor temperature is reduced; the temperature corresponding to saturation (100 % relative humidity) for a given absolute humidity at constant pressure.

diatomaceous silica, *n*—insulation composed principally of diatomaceous earth with or without binders, and which usually contains reinforcing fibers.

diffusivity, thermal, *n*—the ratio of thermal conductivity of a substance to the product of its density and specific heat. (In SI units: $(W/(m•K))/((kg/m^3)•(J/(kg•K))) = m^2/s$.) (In inch-pound units: $(Btu/(hr•ft) F)/((lb/ft^3)(Btu/(lb•F)) = ft^2/hr)$)

emittance, ϵ, *n*—the ratio of the radiant flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions.

emittance, directional $\epsilon(\theta; \phi)$, *n*—the ratio of the radiance from a surface in a particular direction to the radiance from a blackbody at the same temperature under the same conditions.

emittance, hemispherical ϵ_H or $\epsilon(2\pi)$, *n*—the average directional emittance over a hemispherical envelope covering a surface.

emittance, spectral ϵ_λ or $\epsilon(\lambda; \theta; \phi)$, *n*—an emittance based on the radiant energy emitted per unit wavelength interval (monochromatic radiant energy).

DISCUSSION—Where necessary to avoid confusion, emittances should be designated by subscripts, for example: ϵ_{HT}, $\epsilon_{H\lambda}$, $\epsilon_{N\lambda}$, $\epsilon_{\theta\lambda}$, ϵ_{HT}. For most engineering purposes, the hemispherical total emittance ϵ_{HT} suffices.

emittance, total ϵ_T or $\epsilon(t)$, *n*—an emittance that is an integrated average over all wavelengths of radiant energy emitted.

facing, *n*—a protective or decorative (or both) surface applied as the outermost layers of an insulation system.

graybody, *n*—a body having the same spectral emittance at all wavelengths.

heat flow; heat flow rate, *Q*, *n*—the quantity of heat transferred to or from a system in unit time. (Q in SI units: *W*.) (Q in inch-pound units: Btu/h.)

DISCUSSION—See **heat flux** for the areal dependence.

DISCUSSION—This definition is different than that given in some textbooks, which may use $\dot{Q}$, or q to represent heat flow rate. The ISO definition uses Φ.

heat flux, *q*, *n*—the heat flow rate through a surface of unit area perpendicular to the direction of heat flow.

(q in SI units: W/m^2)

(q in inch-pound units: $Btu/h/ft^2 = Btu/h\ ft^2$)

DISCUSSION—This definition has been used as heat flux density, or density of heat flow rate (defined as areal density of heat flow rate by ISO).

heat flux transducer, HFT, *n*—a device containing a thermopile (or equivalent) that produces an output which is a function of the heat flux.

DISCUSSION—In the past this device may also have been known as a heat flow meter, heat flux meter, heat flow sensor, or heat flux sensor.

DISCUSSION—The HFT output may also be a function of mean temperature, attachment, application, and environmental situation.

homogeneous material, *n*—a material in which relevant properties are not a function of the position within the material.

DISCUSSION—Homogeneity depends on the scale of the volume element used to examine the material. The purposes of Committee C-16 are best suited if a macroscopic viewpoint is taken such that the standard insulating materials are considered homogeneous (for example, fibrous and cellular insulations), at least in the heat flow direction and time frame involved in a thermal test.

DISCUSSION—Relevant properties may be a function of such variables as time, direction, or temperature.

humidity, absolute, *n*—the mass of water vapor per unit volume.

humidity, relative, *n*—the ratio of the mol fraction of water vapor present in the air to the mol fraction of water vapor present in saturated air at the same temperature and barometric pressure. Approximately, it equals the ratio of the partial pressure or density of the water vapor in the air to the saturation pressure or density, respectively, at the same temperature.

jacket, *n*—a form of facing applied over insulation.

DISCUSSION—It may be integral with the insulation, or field-applied using sheet materials.

loose fill insulation, *n*—insulation in granular, nodular, fibrous, powdery, or similar form designed to be installed by pouring, blowing, or hand placement.

mastic, *n*—a material of relatively viscous consistency that dries or cures to form a protective finish, suitable for application to thermal insulation in thickness greater than 30 mils (0.76 mm) per coat.

mean specific heat, *n*—the quantity of heat required to change the temperature of a unit mass of a substance one degree, measured as the average quantity over the temperature range specified. (It is distinguished from true specific heat by being an average rather than a point value.) (In SI units: J/kg•K) (In inch-pound units: Btu/lb•F)

microporous insulation, *n*—material in the form of compacted powder or fibers with an average interconnecting pore size comparable to or below the mean free path of air molecules at standard atmospheric pressure. Microporous insulation may contain opacifiers to reduce the amount of radiant heat transmitted.

mineral fiber, *n*—insulation composed principally of fibers manufactured from rock, slag, or glass, with or without binders.

overall coefficient of heat transfer—See **transmittance, thermal**.