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Standard Terminology Relating to Thermophysical Properties¹

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1. Scope

1.1 This is a compilation of terms and corresponding definitions commonly used in the study of thermophysical properties. Terms that are generally understood or defined adequately in other readily available sources are either not included or their sources identified.

1.2 A definition is a single sentence with additional information included in a *Discussion*. It is reviewed every five years, and the year of the last review or revision is appended.

1.3 Definitions identical to those published by another standards organization or ASTM Committee are identified with the abbreviation of the name of the organization or the identifying document and ASTM Committee; for example, ICTA is the International Confederation for Thermal Analysis.

1.4 Definitions of terms specific to a particular field (such as *dynamic mechanical measurements*) are identified with an italicized introductory phrase.

2. Referenced Documents

2.1 *ASTM Standards*:²

D 2160 Test Method for Thermal Stability of Hydraulic Fluids

D 4092 Terminology Relating to Dynamic Mechanical Measurements on Plastics

E 7 Terminology Relating to Metallography

3. Terminology

3.1 *Terms and Definitions*:

admittance, Y — the reciprocal of impedance.

alpha (α) loss peak—*in dynamic mechanical measurement*, first peak in the damping curve below the melt, in order of

decreasing temperature or increasing frequency, (**D 4092, D-20**), (1988).

angular frequency, ω —the number of radians per second traversed by a rotating vector that represents any periodically varying quantity.

DISCUSSION—Angular frequency, ω , is equal to two π times the frequency, f .

anti-thixotropy—an increase of the apparent viscosity under constant shear stress or shear rate followed by a gradual recovery when the stress or shear rate is reduced to zero.

arrhenius equation—a mathematical relationship between the specific reaction rate and the temperature given as

$$k = Ae^{-E/RT} \quad (1)$$

where:

k is the reaction rate constant, A is the frequency factor, E is the energy of activation, R is the gas constant, and T is the absolute temperature, (1990).

beta (β) loss peak—*in dynamic mechanical measurement*, second discrete peak in damping curve below the melt, in order of decreasing temperature or increasing frequency, (**D 4092, D-20**), (1988).

boiling pressure—at a specific temperature, the value of the vapor pressure of the liquid at which it is equal to the external pressure, (1988).

boiling temperature—at a specific pressure, the temperature at which the vapor pressure of the liquid is equal to the external pressure, (1988).

capacitance—that property of a system of conductors and dielectrics that permits the storage of electrical charge when a potential difference exists between the conductors.

DISCUSSION—Capacitance is the ratio of a quantity of electric charge, Q , to a potential difference, V . A capacitance value is always positive. The unit of capacitance is the farad, F , which is equivalent to one coulomb per volt.

Celsius—designation of the degree on the International Practical Temperature Scale; also used for the name of the scale, as “Celsius Temperature Scale.” Formerly (prior to 1948) called “Centigrade.” The Celsius temperature scale is related

¹ This terminology is under the jurisdiction of ASTM Committee E37 on Thermal Measurements and are the direct responsibility of Subcommittee E37.03 on Nomenclature and Definitions.

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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.

to the International Kelvin Temperature Scale by the equation $T_c = T - 273.16K$, (1988).

Centigrade—see **Celsius**.

coefficient of expansion— see **coefficient of linear thermal expansion**.

coefficient of linear thermal expansion, α_l —change in length, relative to the length of the specimen, accompanying a unit change of temperature, at a specified temperature, (1988).

coefficient of viscosity—the ratio between an infinitesimally small increase in stress and the corresponding increase in strain rate.

coefficient of volume thermal expansion α_v —for a solid or liquid, the change in volume, relative to the volume of the specimen, accompanying a change of temperature at a specified temperature, (1988).

color temperature—temperature in degrees Kelvin (K) at which a black body must be operated to give a color equal to that of the source in question, (1988).

complex modulus, E^* , G^* , or K^* —ratio of the stress to strain where each is a factor that may be represented by a complex number as follows: $E^* = E' + iE''$, $G^* = G' + iG''$, and $K^* = K' + iK''$.

where:

E^* = complex modulus, measured in tension or flexure,

E' = storage modulus, measured in tension or flexure,

E'' = loss modulus, measured in tension or flexure,

G^* = complex modulus, measured in shear,

G' = storage modulus, measured in shear,

G'' = loss modulus, measured in shear,

K^* = complex modulus, measured in compression,

K' = storage modulus, measured in compression

K'' = loss modulus, measured in compression, and

$i = \sqrt{-1}$, measured in compression.

The complex modulus may be measured in tension or flexure, (E^*), compression, (K^*), or in shear, (G^*), (D 4092, D-20), (1988).

complex shear compliance, J^* —reciprocal of complex shear modulus, where $J^* = 1/G^*$, (D 4092, D-20), (1988).

complex tensile compliance, D^* —reciprocal of complex tensile modulus, where $D^* = 1/E^*$, (D 4092, D-20), (1988).

complex viscosity, η^* —the complex modulus divided by the imposed frequency in rad/s.

compliance, J —the strain divided by the corresponding stress.

DISCUSSION—Compliance is the reciprocal of modulus.

composition—quantity of the components of a mixture; usually expressed in terms of the weight percentage, or the atomic percentage of each of the components in the mixture, (E 7, E-4), (1988).

conductivity, electrical (volume), σ —the ratio of the current density ($A \cdot cm^{-2}$) through a specimen to the potential gradient (V/cm) in the same direction as the current.

DISCUSSION—Conductivity is normally expressed in units (ohm-cm)⁻¹, but the correct SI units are Siemen-m.

congruent phases—those states of matter of unique composition that co-exist at equilibrium at a single point in temperature and pressure; for example, the two coexisting phases of a two-phase equilibrium (E 7, E-4), (1988).

congruent transformation—an isothermal, or isobaric, phase change in which both of the phases concerned have the same composition throughout the process; the order of a system becomes unary at a composition of congruency, (E 7, E-4), (1988).

constitutional diagram—graphical representation of the compositions, temperatures, pressures, or combinations thereof at which the heterogeneous equilibria of a system occur, (1988).

cooling curve—graphical representation of specimen temperature or temperature change as a function of time or decreasing environment temperature, (1988).

cooling rate—average slope of the time-temperature curve taken over a specific time and temperature interval as the temperature is decreased, (1988).

critical curve—in a binary, or higher order, phase diagram, a locus of points along which two or more phases exist in stable thermodynamic equilibrium.

critical point—in a binary phase diagram, that specific value of composition, temperature, pressure, or combinations thereof at which the phases of a heterogeneous equilibrium become identical, (1989).

critical pressure—that pressure at the critical point; (1990).

critical surface—in a ternary or higher order phase diagram, the area upon which the phases in equilibrium become identical, (E 7, E-4), (1988).

critical temperature—that temperature at the critical point, (1990).

crystal—solid composed of atoms, ions, or molecules, arranged in a pattern which is periodic in three dimensions, (E 7, E-4), (1988).

crystallinity—regular arrangement of the atoms of a solid in space, (1988).

DISCUSSION—In most materials, this state is usually imperfectly achieved. The crystalline regions (ordered regions) are submicroscopic volumes in which there is more or less regularity of arrangement of the component molecules.

crystallite—crystalline grain not bounded by habit planes, (E 7, E-4), (1988).

crystallization—arrangement of previously disordered material segments of repeating patterns into geometric symmetry, (1988).

crystallization temperature—that temperature at which a specimen undergoes crystallization upon cooling, (1988).

Curie point—see **Curie temperature**.

Curie temperature—temperature above which a ferromagnetic or ferroelectric material becomes paramagnetic, or paraelectric, respectively (1997).

DISCUSSION—There may be more than one if there are multiple materials.

damping—loss in energy, dissipated as heat, that results when a material or material system is subjected to an oscillatory load or displacement, (D 4092, D-20), (1988).

devitrification—crystallization of an amorphous substance, (E 7, E-4), (1988).

dielectric constant— see **permittivity, relative**.

dielectric dissipation factor, D —the ratio of the loss factor, ϵ'' , to the absolute permittivity, ϵ' , or

$$D = \epsilon''/\epsilon' \quad (2)$$

DISCUSSION—The dielectric dissipation factor is numerically equal to the tangent of the dielectric loss angle and may be referred to as the loss tangent, $\tan \delta$, or the cotangent of the phase angle, θ .

dielectric loss angle—the angle whose tangent is the dissipation factor or $\arctan \epsilon''/\epsilon'$.

DISCUSSION—It is also the difference between 90 degrees and the phase angle.

differential thermocouple— see **differential thermopile**.

differential thermopile—a number of temperature sensors connected in series-opposing and arranged so that there is an increase in output signal for a given temperature difference between alternate junctions maintained at a reference temperature and the measured temperature, (1989).

dipole relaxation time, γ —the exponential decay time required for the electric polarization of any point of a suitably charged dielectric to fall from its original value to $1/e$ of that value, due to the loss of dipole orientation.

DISCUSSION—Under conditions of an alternating applied field and in systems with a single dipole relaxation time, it is equal to $1/\omega$ at the loss factor peak in cases where the peak is caused by a dipole mechanism.

dissipation factor— see **tangent delta**.

dissociation—as applied to heterogeneous equilibria, the transformation of one phase into two or more new phases, all of different composition, (E 7, E-4), (1988).

dynamic modulus—see **complex modulus**.

elasticity—that property of materials that causes them to return to their original form or condition after the applied force is removed, (D 4092, D-20), (1988).

elastic modulus—see **complex modulus and storage modulus**.

enthalpy—a thermodynamic *function* defined by the equation $H = U + PV$ where H is the enthalpy, U is the *internal energy*, P is the pressure, and V the volume of the system.

DISCUSSION—At constant pressure the change in enthalpy measures the quantity of heat exchanged by the system and its surrounding.

equilibrium diagram— see **constitutional diagram**.

eutectic point—see **eutectic**.

eutectic—mixture of two or more substances which solidifies as a whole when cooled from the liquid state, without change in composition, (1988).

DISCUSSION—The temperature at which the eutectic mixture solidifies is called the eutectic point. This temperature is constant for a given composition, and represents the lowest melting point of the system.

Fahrenheit—designation of a degree on the Fahrenheit temperature scale that is related to the International Practical Temperature Scale by means of the equation: $T_F = 1.8 T_C + 32$.

where:

T_F is the temperature in degree Fahrenheit and T_C is the temperature in degrees Celsius, (1988).

freezing temperature— see **crystallization temperature**.

frequency, f —the number of cycles per unit time of periodic process.

DISCUSSION—The unit is Hertz (Hz) which is equal to 1 cycle per/s.

frequency profile—in *dynamic mechanical measurement*, plot of the dynamic properties of a material, at a constant temperature, as a function of test frequency, (D 4092, D-20), (1988).

gamma (γ) loss peak—in *dynamic mechanical measurement*, third peak in the damping curve below the melt, in the order of decreasing temperature or increasing frequency, (D 4092, D-20), (1988).

Gibbs Phase Rule—maximum number of phases (P) that may coexist at equilibrium is equal to two, plus the number of components (C) in the mixture, minus the number of degrees of freedom (F): $P + F = C + 2$ (E 7, E-4), (1989).

glass transition—reversible change in an amorphous material or in amorphous regions of a partially crystalline material, from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle one, (1988).

DISCUSSION—The glass transition generally occurs over a relatively narrow temperature region and is similar to the solidification of a liquid to a glassy state. Not only do hardness and brittleness undergo rapid changes in this temperature region, but other properties, such as coefficient of thermal expansion and specific heat capacity, also change rapidly. This phenomenon sometimes is referred to as a second order transition, rubber transition, or rubbery transition. When more than one amorphous transition occurs in a material, the one associated with segmental motions of the backbone molecular chain, or accompanied by the largest change in properties is usually considered to be the glass transition.

glass transition temperature—a temperature chosen to represent the temperature range over which the glass transition takes place, (1989).

DISCUSSION—The glass transition temperature can be determined readily by observing the temperature region at which a significant change takes place in some specific electrical, mechanical, thermal, or other physical property. Moreover, the observed temperature can vary significantly depending on the property chosen for observation and on details of the experimental technique (for example, heating rate, frequency of test). Therefore, the observed T_g should be considered valid only for that particular technique and set of test conditions.

heat capacity—quantity of heat necessary to change the temperature of an entity, substance or system by one Kelvin of temperature.

DISCUSSION—The SI units of measurement are J/K (1995).

impedance, Z —the ratio of the time dependent voltage, $v(t)$, across a circuit, a circuit element, or material to the time dependent current, $i(t)$, through it; that is:

$$Z = v(t)/i(t) \quad (3)$$

DISCUSSION—The impedance of a circuit, circuit element, or material is a measure of its ability to oppose the transmission of an alternating current. It is expressed in ohms. Its value depends on the angular frequency, ω , of the measurement.

invariant equilibrium—stable state among a number of phases exceeding by two the number of components in the system and in which more of the external variables (pressure, temperatures, or concentrations) may be varied without