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# Standard Terminology Relating to Electrical Insulating Liquids and Gases[1]

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## INTRODUCTION

The definitions contained in this terminology pertain to terms as they are used in conjunction with fluid insulating materials. Insofar as possible, the definitions are consistent with accepted general usage, and may also contain additional information deemed to be of value in testing of fluid insulating materials.

## 1. Referenced Documents

1.1 *ASTM Standards:*[2]

D611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents

D2007 Test Method for Characteristic Groups in Rubber Extender and Processing Oils and Other Petroleum-Derived Oils by the Clay-Gel Absorption Chromatographic Method

D2140 Practice for Calculating Carbon-Type Composition of Insulating Oils of Petroleum Origin

D2300 Test Method for Gassing of Electrical Insulating Liquids Under Electrical Stress and Ionization (Modified Pirelli Method)

D2500 Test Method for Cloud Point of Petroleum Products

D3117 Test Method for Wax Appearance Point of Distillate Fuels

E355 Practice for Gas Chromatography Terms and Relationships

## 2. Terminology



**ac**—symbol used to designate an electric voltage or current whose amplitude varies periodically as a function of time, its average value over one complete period being zero. One complete repetition of the wave pattern is referred to as a CYCLE, and the number of cycles occurring in one second is called the FREQUENCY, measured in hertz (Hz). For example, the electricity supplied by commercial utility companies in the United States is, in most localities, 60 Hz, although other frequencies may be encountered.

**acid treating**—a refining process in which an unfinished petroleum insulating oil is contacted with sulfuric acid to improve its color, odor, stability, and other properties.

**ac loss characteristics**—those properties of a dielectric or insulation system (such as dissipation factor, power factor, and loss index) that may be used as a measure of the power or energy losses that would result from the use of such material in an ac electric field.

**additive**—a chemical compound or compounds added to an insulating fluid for the purpose of imparting new properties or altering those properties which the fluid already has.

**ambient temperature**—the temperature of the surrounding atmosphere as determined by an instrument shielded from direct or reflected rays of the sun.

**aniline point**—the minimum temperature for complete miscibility of equal volumes of aniline and the sample under test. See Test Methods D611. In comparing two samples of similar molecular weight, the aniline point can be used as a means of comparing aromatic content of the two samples. A product of high aniline point will be low in aromatics and naphthenes, and therefore high in paraffins.

**API gravity**—an arbitrary scale developed by the American Petroleum Institute and frequently used in reference to petroleum

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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.

insulating oil. The relationship between API gravity and specific gravity 60/60°F is defined by the following:

$$\text{Deg API Gravity at } 60°F = 141.5/(\text{sp gr } 60/60°F) - 131.5$$

**aromatics—**that class of organic compounds which behave chemically like benzene. They are cyclic unsaturated organic compounds that can sustain an induced electronic ring current due to delocalization of electrons around the ring.

Discussion—Empirically, the aromatic portion of a mineral insulating oil can be estimated by correlation with physical properties (See Test Method D2140), or by selective adsorption on clay-gel (See Test Method D2007).

**askarel—**a generic term for a group of synthetic, fire-resistant, chlorinated aromatic hydrocarbons used as electrical insulating liquids. They have a property under arcing conditions such that any gases produced will consist predominantly of noncombustible hydrogen chloride with lesser amounts of combustible gases.

**atomic absorption—**the absorption of radiant energy by ground state atoms. Substances when dispersed as an atomic vapor will absorb characteristic radiations identical to those which the same substances can emit. This property is the basis for analysis by atomic absorption spectroscopy.

*capacitivity***—**the same as **permittivity, relative.**

**color—**a quality of visible phenomena of insulating fluids, the numerical value for which is derived by comparing this quality using transmitted light with that of a series of numbered reference standards.

**combustible gases—**flammable gases formed from breakdown (partial or complete) of some insulating materials subjected to electrical or thermal stress, or both.

**conductance—**the ratio of the current carried through a material to the difference in potential applied across the material. It is the reciprocal of *resistance* . The unit is: (ohm) $^{-1}$ or siemens.

Discussion—1—**Conductance** is a general term. Specific reference may be made to **conductance dc** and **conductance ac.**

Discussion—2—For dielectrics the conductance may be dependent on the **electrification time.**

**conductance, apparent dc—**the dc conductance measured at the end of a specific electrification time. The "apparent dc conductance" is the reciprocal of the "apparent dc resistance." The unit is: (ohm) $^{-1}$ or siemens.



Discussion—The term "apparent dc conductance" is used to distinguish the current-voltage relationship found in electrical insulating materials, where the current (leakage plus absorption) usually decreases with time, from the relationship found in metallic conductors where the steady-state current is reached in a fraction of a second.

**conductance, dc—**the ratio of the total current (in amperes) passing through a material to the dc voltage (in volts) applied between two electrodes that are in contact with, or immersed in a specimen. The "dc conductance" is the reciprocal of the "dc resistance." The unit is: (ohm) $^{-1}$ or siemens.

**conductivity—**the ratio of the current density carried through a specimen to the potential gradient paralleling the current. This is numerically equal to the conductance between opposite faces of a unit cube of liquid. It is the reciprocal of **resistivity.**



Discussion—1—**Conductivity** is a general term. Specific reference may be made to **conductivity, dc.**

Discussion—2—For dielectrics the conductivity may be dependent on the **electrification time.** (See also **conductivity, apparent dc volume** and **conductivity, dc volume.**)

**conductivity, apparent dc volume—**the "dc volume conductivity" measured at the end of a specified electrification time. It is the reciprocal of the apparent dc volume resistivity. The unit most commonly used is: (ohm-centimetre) $^{-1}$ or siemens per centimetre. The SI unit is (ohm-metre) $^{-1}$.

**conductivity, dc—**the ratio of the current density passing through a specimen at a given instant of time and under prescribed conditions, to the dc potential gradient paralleling the current. It is the reciprocal of the dc resistivity. In common practice the "dc conductivity" is numerically equal to the "dc conductance" between opposite faces of a centimetre cube of liquid. The unit is: (ohm-centimetre) $^{-1}$ or siemens per centimetre. The SI unit is: (ohm-metre) $^{-1}$ .

Discussion—The "dc conductivity" may contain components of both surface conductance and volume conductance, but, in general, surface effects are not common in measurements on fluid dielectrics. The property most commonly measured is either the "dc volume conductivity" or the "apparent dc volume conductivity."

**conductivity, dc volume—**the property of a material that permits the flow of electricity through its volume. It is numerically equal to the ratio of the steady-state current density to the steady direct voltage gradient parallel with the current in the material. The dc volume conductivity is the reciprocal of the dc volume resistivity. The unit commonly used is: (ohm-centimetre) $^{-1}$ or siemens per centimetre. The SI unit is (ohm-metre) $^{-1}$.

Discussion—For electrical insulating materials the time required for the steady-state current to be reached may be very long; from several minutes to several months may be required.

**corona—**a luminous discharge due to ionization of the air surrounding an electrode, caused by the high electric field strength in the vicinity of the electrode, exceeding a certain critical (that is, threshold) value.

**corona effect—**light emitted in the UV range of the electromagnetic spectrum by electronically excited molecules that have reached a singlet state and have not consumed the absorbed energy by other physical process.

**corona (partial discharge) inception voltage,** *CIV*—the lowest voltage at which continuous partial discharge (or corona) exceeding a specified intensity is observed as the applied voltage is gradually increased. Where the applied voltage is alternating, the *CIV* is expressed as $1/\sqrt{2}$ of the peak voltage.

**corona (partial discharge) extinction voltage,** *CEV*—the highest voltage at which partial discharge (or corona) no longer exceeds a specified intensity as the applied voltage is gradually decreased from a value above the corona inception voltage. Where the applied voltage is alternating the CEV is expressed as $1/\sqrt{2}$ of the peak voltage.

**corrosive sulfur**—*n*, elemental sulfur and thermally unstable sulfur compounds in electrical insulating oil that can cause corrosion of certain transformer metals such as copper and silver.

**dc**—symbol used to designate an electric voltage or current whose amplitude does not vary periodically with respect to time, as for example the output of a chemical cell or that of a thermocouple. The term is also applied to the output of such devices as dynamos and rectifiers, whose amplitude is not strictly time-invariant.

**dew-point temperature**—the temperature (above 0°C) to which a gas or vapor must be cooled at constant pressure and constant water-vapor composition in order for saturation to occur.

Discussion—At temperatures below 0°C, vapor may first be noticed in the form of frost. It is common to refer to the temperature at which this occurs as the frost-point temperature. Dew-point temperatures also exist for other gas or vapor systems in which saturation with respect to a substance other than water vapor can occur.

**dielectric**—a medium in which it is possible to maintain an electric field with little supply of energy from outside sources. The energy required to produce the electric field is recoverable, in whole or in part. A vacuum, as well as any insulating material is a dielectric.

**dielectric breakdown voltage**—the potential difference at which electrical failure occurs in an electrical insulating material or insulation structure, under prescribed test conditions.

*dielectric constant*— See **dielectric constant, relative** (especially Note 2). (See also **permittivity** (especially Note 2).)

*dielectric constant, absolute*—the same as **permittivity.**

*dielectric constant, relative*—the same as **permittivity, relative.**

Discussion—1—Current practice including international usage is to prefer the term *relative permittivity.*

Discussion—2—Common usage has been to drop the term "relative" and simply use dielectric constant when the dimensionless ratio is the quantity being referred to.

**dielectric failure**—the failure of an element in a dielectric circuit that exists when the insulating element becomes conducting. This event may take the form of a gradual increase in current exceeding a specified value, but it usually takes the form of an almost instantaneous charge transfer accompanied by collapse of the insulating properties and partial of complete localized destruction of the dielectric medium. In the case of liquids and gases the failure may be self-healing.

**dielectric strength**—a property of an insulating material described by the average voltage gradient at which electric breakdown occurs under specific conditions of test.

**dissipation factor,** *D*—the ratio of the loss index to its relative permittivity or

$$D = \kappa''/\kappa'$$

It is also the tangent of its loss angle, δ, or the cotangent of its phase angle, θ. The dissipation factor is related to the power factor, *PF*, by the following equation:

$$D = PF/\sqrt{1 - (PF)^2}$$

Discussion—It may be expressed as $D = \tan \delta = \cot \theta =$

$$G/\omega C_p = 1/\omega C_p R_p = \omega R_s C_s$$

where $G$ is the equivalent parallel ac conductance, $C_p$ is the parallel capacitance, $R_p$ is the equivalent parallel ac resistance, $C_s$ is the series capacitance, and $R_s$ is the equivalent series resistance.

*dissipation factor, dielectric*—same as **dissipation factor.**

**dissolved water**—water that is in solution interspersed between molecules of insulating liquid.

*electric constant*— the same as **permittivity of free space.**

**electric creepage strength**—the average voltage gradient under specific conditions of test and for a specific electrode configuration, at which dielectric failure occurs along the interface between a solid insulating material and the fluid in which it is immersed, or at the interface between two solids that are in close physical contact with each other but are not bonded chemically. Dielectric creepage failure may result in tracking.

**electrical discharge**—a discontinuous movement of electrical charges through an insulating medium, initiated by electron avalanches and supplemented by secondary processes.

**electrification time**—the time during which a steady direct potential is applied to electrical insulating materials before the current is measured.

**emulsified water**—water that is suspended in insulating liquid as clusters of water molecules. It usually gives insulating liquid a milky appearance.

**ester-based insulating fluid**—an insulating fluid that may be either synthetic or natural-based. Synthetic ester fluids are produced by the reaction of an organic acid with an alcohol, usually a diol, triol, or tetraol. Natural ester fluids are derived from an animal or agricultural (vegetable or seed) source. They are generically referred to as triglycerides, being a combination of glycerol and various organic acids of varying molecular weights.

**fire point**—the lowest temperature at which a specimen will sustain burning for 5 s under specified conditions of test.

**flash point**—the lowest temperature corrected to a barometric pressure of 101.3 kPa (760 mm Hg), at which application of a test flame causes the vapor of a specimen to ignite under specified conditions of test.

**fluorescence**—photoluminescence in which the emitted optical radiation results from direct transitions from a photo–excited singlet energy level to a lower singlet level, these transitions taking place generally within 10 nanoseconds after excitation.

**free electrons**—an electron, not directly associated with the structure of an atom or molecule, free to move under the influence of an applied electric or magnetic field.

**free radical**—an atom or a diatomic or polyatomic molecule which possesses one unpaired electron. Free radicals act a initiators or intermediates in such basic phenomena as oxidation, combustion, photolysis, and polymerization.

**free water**—water that is high enough in concentration to form water droplets and separate from the insulating liquid.

**furanic compounds**—a class of chemical compounds characterized by the presence of heterocyclic structures consisting of a five-membered ring containing four carbon atoms and one oxygen atom. These compounds may be found dissolved in electrical insulating fluids, either as residual contaminants of refinery extraction processes in which furfural is used, or from the degradation of cellulose insulation.

**gas chromatography,** GC—all chromatographic methods in which the moving phase is gaseous. The stationary phase may be either a dry granular solid or a liquid supported by the granules or by the wall of the column, or both. Separation is achieved by differences in the partition-distribution of the components of a sample between the mobile and stationary phases, causing them to move through the column at different rates and from it at different times. (E355)

**gas–liquid chromatography,** GLC—gas chromatographic method utilizing a liquid as the stationary phase, which acts as a solvent for the sample components.

**gas–solid chromatography,** GSC—gas chromatographic method utilizing an active (absorbant) solid as the stationary phase.

**gassing tendency**—the capability of an insulating liquid either to absorb or generate gases when exposed to voltage stress. The measure of the gassing tendency is the volume of gas evolved or absorbed per unit time by an insulating liquid subjected to electrical stress under prescribed conditions (by Test Method D2300). It is commonly expressed in units of microlitres per minute (µL/min) with a positive value indicating gas is evolved and a negative value indicating gas is absorbed. The SI unit is cubic millimetres per minute ($mm^3$/min).

DISCUSSION—The term *gassing* is sometimes used synonymously with either *gassing tendency* or *average gassing coefficient*, AGC.

**guard electrode**—one or more electrically conducting elements, arranged and connected in an electrical instrument or measuring circuit so as to divert unwanted conduction or displacement currents from, or confine wanted currents to, the measuring device.

**hank**—specifically, a coiled or looped bundle (as of yarn, rope or wire) ususally containing a definite aggregate measure of the material.

**hydrogen treating**—a refining process in which an unfinished petroleum insulating oil is contacted with hydrogen gas at elevated temperatures and pressures in the presence of a catalyst, to improve its color, odor, stability, and other properties.

**inhibitor**—any substance which when added to an electrical insulating fluid retards or prevents undesirable reactions.

**insulating liquid, fluid or gas**—a fluid (liquid or gaseous) which does not readily conduct electricity. Electrical insulating fluids typically provide both electrical insulation and heat transfer in electrical equipment.

**insulating material**—a material of relatively low electrical conductivity and high dielectric strength, usually used to support or provide electrical separation for conductors, in which a voltage applied between two points on or within the material produces a small and sometimes negligible current.

**interfacial tension,,** *n*—the force existing in a liquid-liquid phase interface that tends to diminish the area of the interface. This force, which is analogous to the surface tension of liquid-vapor interfaces, acts at each point on the interface in the plane tangent at that point. (*Compilation of ASTM Standard Definitions*, 7th Edition.)

**loss angle,** δ— the angle whose tangent is the dissipation factor or arctan $\kappa''/\kappa'$. It is also the difference between 90 deg and the phase angle.

*loss angle, dielectric*— same as **loss angle.**

*loss index*—the same as **loss index, dielectric.**

**loss index, dielectric,** $\kappa''(\varepsilon_r'')$ —the product of the "relative permittivity" and the dissipation factor and is a measure of the ac dielectric loss. It is also the magnitude of the imaginary part of the "relative complex permittivity."

DISCUSSION—It may be expressed as:

$$\kappa'' = \kappa' D = \text{power loss}/(E^2 \times f \times \text{volume} \times \text{constant})$$

When SI units of watts, volts per metre, hertz, and cubic metres are used the constant has the value: $5.556 \times 10^{-15}$. More commonly, when units of watts, volts per centimetre, hertz, and cubic centimetres are used the constant has the value: $5.556 \times 10^{-13}$.

*loss tangent*—same as **dissipation factor.**