Electrical properties of crude oil

ELECTRICAL PROPERTIES

Understanding of how petroleum behaves and why different crude oils differ in properties is also possible with an atomistic understanding allowed by quantum mechanics. The combination of physics, chemistry, and the focus on the relationship between the properties of a material and its electrical properties allows uses to be designed and also provides a knowledge base for a variety of chemical and engineering applications.

CONDUCTIVITY

From the fragmentary evidence available, the electrical conductivity of hydrocarbons is quite small. For example, the normal hydrocarbons (from hexane up) have an electrical conductivity smaller than 10_16 V=cm; benzene itself has an electrical conductivity of 4.4×10^{-17} Ω/m, and cyclohexane has an electrical conductivity of 7×10^{-18} Ω/m. It is generally recognized that hydrocarbons do not usually have an electrical conductivity larger than 10^{-18} Ω/m. Available data indicate that the observed conductivity is frequently more dependent on the method of measurement and the presence of trace impurities than on the chemical type of the oil. Conduction through oils is not ohmic; that is, the current is not proportional to field strength: in some regions it is observed to increase exponentially with the latter. Time effects are also observed, the current being at first relatively large and decreasing to a smaller steady value. This is partly because of electrode polarization and partly because of ions removed from the solution. Most oils increase in conductivity with rising temperatures.

DIELECTRIC CONSTANT

The dielectric constant, «, of a substance may be defined as the ratio of the capacity of a condenser with the material between the condenser plates C to that with the condenser empty and under vacuum C_0:

$$£= \frac{C}{C_0}$$

The dielectric constant of petroleum and petroleum products may be used to indicate the presence of various constituents, such as asphaltenes, resins, or oxidized materials. Further, the dielectric constant of petroleum products that are used in equipment, such as condensers, may actually affect the electrical properties and performance of that equipment (ASTM D877). The dielectric constant of hydrocarbons, and hence most crude oils and their products, is usually low and decreases with an increase in temperature. It is also noteworthy that for hydrocarbons, hydrocarbons fractions, and products, the dielectric constant is approximately equal to the square of the refractive index. Polar materials have dielectric constants greater than the square of the refractive index.

DIELECTRIC LOSS AND POWER FACTOR

A condenser insulated with an ideal dielectric shows no dissipation of energy when an alternating potential is applied. The charging current, technically termed the circulating current, lags exactly 908 in phase angle of the applied potential, and the energy stored in the condenser during each half-cycle is completely recovered in the next. No real dielectric material exhibits this ideal behavior; that is, some energy is dissipated under alternating stressand appears as heat. Such a lack of efficiency is broadly termed dielectric loss.

Ordinary conduction comprises one component of dielectric loss. Here the capacitance-held charge is partly lost by short circuit through the medium. Other effects in the presence of an alternating field occur, and a dielectric of zero conductivity may still exhibit losses. Suspended droplets of another phase undergo spheroidal oscillation by electrostatic induction effects and dissipate energy as heat as a consequence of the viscosity of the medium. Polar molecules oscillate as electrets and dissipate energy on collision with others. All such losses are of practical importance when insulation is used in connection with alternating-current equipment. The measure of the dielectric loss is the power factor. This is defined as the factor k in the relation:

$$K=\frac{W}{EI}$$

W is the power in watts dissipated by a circuit portion under voltage E and passing current I. The power factor of pure hydrocarbons is extremely small. Traces of polar impurities, however, cause a striking increase. All electrical oils, therefore, are drastically refined and handled with care to avoid contamination; insoluble oxidation products are particularly undesirable.