THE EFFECTS OF THE CIRCULATION OF INSULATING OILS UPON THEIR DIELECTRIC PROPERTIES

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Insulating oils are often used for the additional purpose of aiding in the dissipation of the heat generated in adjacent portions of the circuits. If, in such cases, the oil is forced to circulate or is left free to circulate by convection, the variations in motion, pressure, and temperature will affect the capacitance of the circuits. In those circuits in which the capacitance must be controlled with some degree of precision, as is especially necessary in high frequency circuits, the effects of the above named variations upon the dielectric properties of the oil may prove to be disturbing factors of some importance. Hence, when it became convenient in connection with some other work, the magnitudes of these effects were determined for a high grade, heavy, paraffin oil (specific gravity, .875; dielectric constant, 2.066).

Two test condensers were mounted in a steel cylinder which was connected to an oil reservoir of constant pressure head in such a way that the flow of oil through the condensers might be reversed. These condensers were constructed of heavy, circular, metal plates perforated by small holes which were symmetrically arranged and spaced so as not to decrease the rigidity of the plates. The condensers differed in insulation, metal, and construction so that a check of the effects produced in them eliminated all condenser characteristics. The oil flowed in a direction perpendicular to the plates and parallel to the electric field. The total capacities of the condensers were 147.3 mmf and 139.1 mmf, of which the amounts affected by the oil dielectric were 30.55 mmf and 36.41 mmf, respectively. A heterodyne method of measuring the changes in capacity was used in which a change of frequency of one cycle per second was easily observable. A frequency of 640 kc was used on the fixed frequency oscillator. The usual precautions were taken regarding shielding, temperature, vibrational disturbances, and sources of A and B potentials. Pressure gauges placed in the housing at the ends of the condensers gave the pressure drop through them and the mean pressure of the oil in each condenser. After the effects due to the flow were noted the condensers were placed under the same mean pressures with the oil stationary. The effects due to the pressure changes which produced the flow were thus obtained and deducted from the total effect. Fig. 2 shows the relation between pressure and capacity through a considerable range.

Fig. 1 shows the total effect of the flow of the oil upon the capacity and also the effect of the pressure reductions upon which the flow was consequent. A rate of flow of 10 cm. per sec. was sufficient to decrease the generalized dielectric constant by about .06 per cent. One-third of

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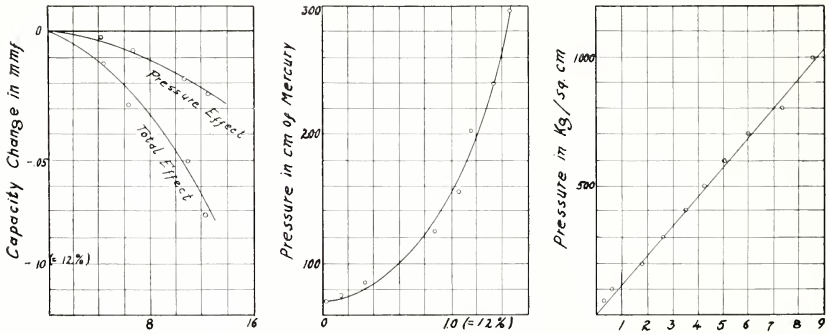
this change was due to the accompanying decrease in pressure. The remaining decrease in capacity indicates that the cause may be found in changes of the conductivity of the oil. In order to verify this the condensers were placed in an oscillating circuit in which the regenerative coupling had been adjusted until the current was independent of the frequency. The flow of oil was found to reduce the current. Since the current had been made independent of the capacity, this reduction in current was due to a decrease in the parallel resistance of the condenser, or, in other terms, to the increased conductivity of the oil. Numerous explanations of this increased conductivity suggest themselves, such as orientation phenomena, actual changes in the number of ions present, or the addition to the a. c. carried by the condenser of a d. c. component carried by the mass movement of the liquid.

The probability of any appreciable polarization in a straight-chain hydrocarbon of this type is very small,[1] but orientation losses due to



other causes[2] might be expected to increase with the rate of flow in condensers of this type. An increase in ionization seems very unlikely, the only condition possibly conducive to this being the very slight temperature variation during the flow. The effect of temperature upon the dielectric constant of paraffin oil has been investigated by Butman,[3] who found the relation to be linear with a change of slope at 50° C. There are two temperature variations which oppose one another during the flow. The very small temperature rise caused by the mechanical agitation during the flow tends to increase the capacity slightly. On the other hand, the flow is always accompanied by a decrease of pressure, and the temperature was found to vary directly with the pressure, as in Fig. 3. This was investigated by immersing a calibrated thermocouple in the paraffin oil in a high-pressure piezometer. As these temperature changes were small and tended to compensate, their effect upon ionization must have been negligible. It seems probable, therefore, that the chief factor in the production of increased conductivity was the mass

[1] F. Hamburger, Jr., Phy. Rev., 35:1119, 1930

[2] P. Debye, "Polar Molecules", p. 109.

[3] G. A. Butman, El. World, 71:812. 1918.

movement of the liquid along the electric field, such a flow being equivalent to an increase in the mobility of the ions present. In a condenser consisting of co-axial, cylindrical plates the maximum obtainable flow of 2.4 cm per second produced no effect upon the capacity except that produced by the decrease in pressure during the flow. As this flow was perpendicular to the electric field, the mass movement of the ions did not increase the conductivity.

Benzene was taken through the same procedure as was the paraffin oil and it exhibited similar characteristics. Its dielectric constant, however, was much more sensitive to pressure changes, a change of pressure of 45 cm of mercury producing a variation of .1 per cent in the dielectric constant.

In general, any motion given a liquid, whether by vibration, convection currents or forced circulation, considerably affects the generalized dielectric constant of the liquid, the chief effect being an increase in conductivity caused by the ionic current accompanying the flow.

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