# SHORT COMMUNICATIONS

## OBSERVATIONS ON THE VOLTAGE DEPENDENCE OF THE INSULATION RESISTANCE OF SOME INSULATING MATERIALS

S. Nurul Ahmad and Mazhar M. Qurashi

*Physical Research Division, Central Laboratories, Pakistan Council of Scientific and Industrial Research, Karachi*

(Received December 2, 1960)

In the course of testing the electrical insulating properties of several materials prepared in the Central Laboratories, from indigenous ingredients, it was considered of interest to measure their insulation resistance at various voltages below the breakdown limit. The tests were carried out with A. C. voltages and the apparatus used for these measurements was put together from components obtained locally. The set up is shown diagrammatically in Fig. 1. The special features are the limiting resistor $R_1$ in the primary circuit of the high-tension transformer and the current measuring resistor $R_2$ in parallel with the voltmeter V on the earthed side of the sample under test in the high-tension secondary circuit. The resistor $R_1$ serves to limit the primary current to one Ampere so as to prevent overloading of the high tension transformer when the sample under test breaks down, while $R_2$ (about 20 kilo-Ohms) does double duty as a current measuring resistor (before breakdown), and as a safety resistor ensuring continuous permanent contact on the earth side (e.g. when changing ranges on the meter in parallel with R2). The current 'I' is calculated by the simple formula

$$I = V\left(\frac{1}{R_2}+\frac{1}{R_V}\right)$$

$$= \frac{V}{R_2}\left(1 + \frac{R_2}{R_V}\right)$$

where $R_V$ is the internal resistance of the voltmeter, and $(R_2/R_V) << 1$, except when the voltmeter is on the lowest 10 volt range. The r. m.s. kilovolts were read directly on the 'kV' meter the series resistances of which are connected across the high-tension secondary; a small correction for the voltage drop 'V' was made in the few cases just before breakdown where it was significant. The test electrodes were of the standard type described in B. S. S. No. 634: 1935, the lower one being a flat brass disc 3 inches diameter and 1 inch thick, and the upper one a solid brass cylinder 1½ inches diameter and 1½ inches high. The various sharp edges were rounded to the recommended radius.

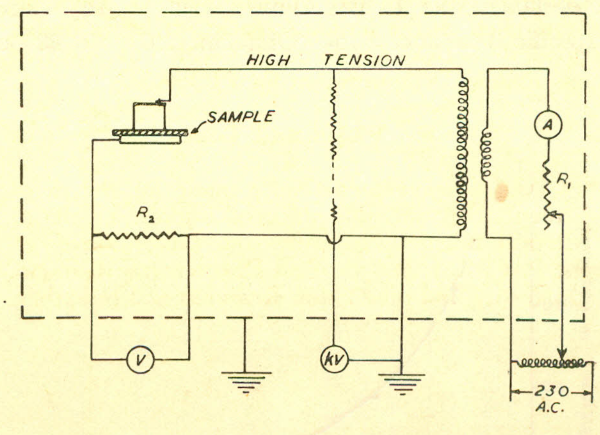


Fig. 1.—Diagrammatic sketch of the apparatus used for measuring the resistance of insulating materials upto their breakdown limit.

A set of measurements taken with a 2.45 mm. thick sample of "Jutoid", a rubberoid type of material based on jute and developed in the C. S. I. R. laboratories, are given in Table 1, while the graphs of Fig. 2(a) and (b) show plots of insulation resistance against kilovoltage obtained with two differently prepared samples of this type of material. The points at the very lowest applied tension of one kilovolt are subject to a rather large experimental error because of the very small currents, and the range of this error is indicated by the short vertical lines in Fig. 2.

The graphs of Figs. 2(a) and (b) both show the interesting feature that, after the initial rapid drop in resistance, there is an extended region in which the resistance varies linearly with applied voltage. What is more, this straight line when extrapolated towards zero resistance yields a voltage that is of the same order as the breakdown voltage. The ratio of the Breakdown Voltage to this extrapolated voltage is $0.88 \pm 0.05$ for the particular samples tested in the two graphs of Fig. 2. Further evidence for this linear variation of resistance is provided by the graphs of Fig. 3, which show the experimental results obtained with two different compositions for insulating varnish, applied on a standard paper to give a total thick-

TABLE 1.—MEASURED INSULATION RESISTANCE FOR A 2.4 MM. SAMPLE OF "JUTOID" WHICH BROKE DOWN AT 5.1 KILO VOLTS.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Applied Voltage (kV) | 1.0 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 4.75 | 5.0 |
| Current = I (in milliamps) | 0.031 | 0.104 | 0.154 | 0.231 | 0.319 | 0.428 | 0.66 | 0.86 | 1.13 |
| Resistance = (kV/I) Meg Ohms | 32 | 19 | 16.2 | 13.0 | 11.0 | 9.3 | 6.6 | 5.6 | 4.9 |
| Specific Resistance $\times 10^{-9}$ (Ohm cm.) | 1.6 | 0.88 | 0.75 | 0.60 | 0.51 | 0.43 | 0.31 | 0.26 | 0.23 |

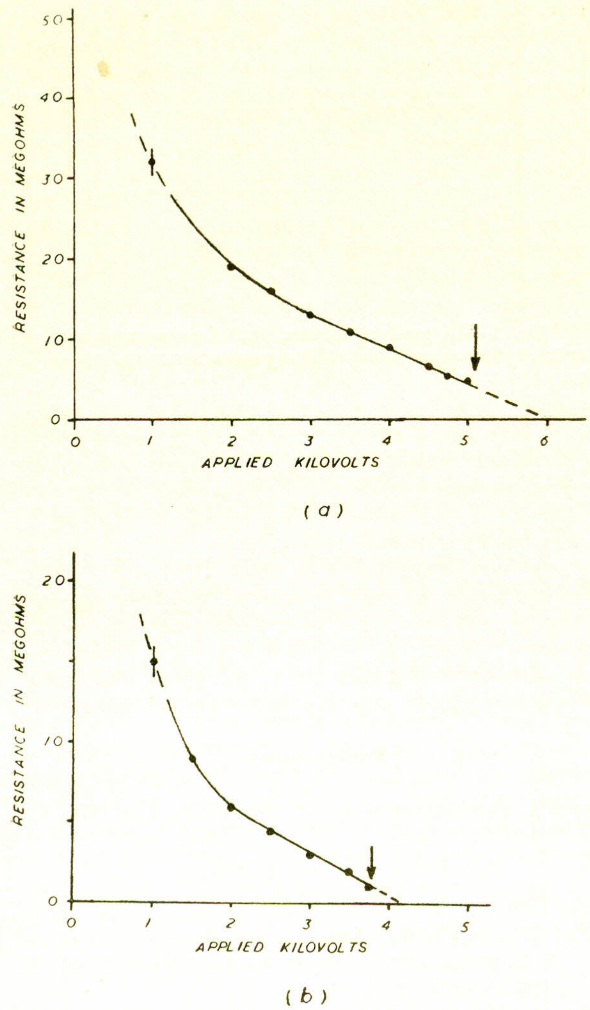


Fig. 2.—Graphs showing the variation of insulation resistance against applied kilovolts for two differently prepared samples of Jutoid, about 2.4 mm. thick. The vertical arrows indicate the breakdown voltages.

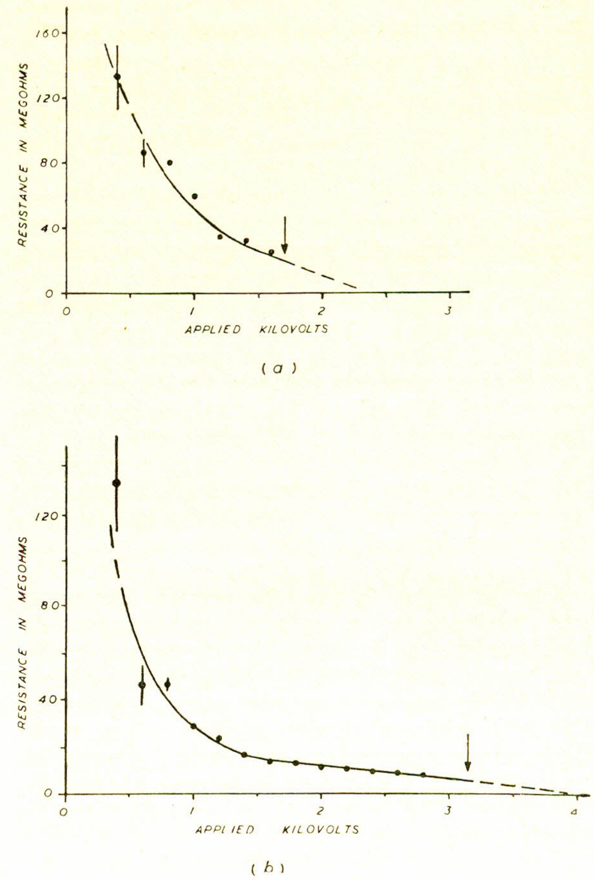


Fig. 3.—Plots of resistance against applied kilovolts for two samples of insulating varnish applied on standard thickness of paper. The vertical arrows indicate the breakdown voltages.

ness of very nearly 5 mills. In this case, the breakdown voltage is nearly $0.76 \pm 0.05$ times the linearly extrapolated value. Thus, on the basis of Figs. 2 and 3, a mean value for this factor would be $0.82 \pm 0.06$.

These findings indicate the possiblity of using this type of extrapolation as an easy means of non-destructively obtaining a measure of breakdown voltage, *i.e.*, electrical insulation strength. Further tests on other materials are in hand with a view to generalizing this and studying the precise laws of the variation of insulation resistance for a variety of materials.

The samples used in the above tests were kindly provided by Mr. M. Aslam of the Paints and Plastics Division of the Central Laboratories.