STUDIES IN THE ELECTRICAL INSULATION PROPERTIES OF NATURAL AND SYNTHETIC MATERIALS

Part II.—Analysis of the High and Low Voltage Measurements on humidified Wood and "Jutoid"

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The previously reported data on the variation of electrical conductance with applied voltage and absorbed water in some materials are analyzed more fully and the following approximate relationship is proposed for samples of jutoid, a jute-based bituminous composition,

$\log \gamma/\gamma^{\circ} = 0.045\ (CF + 0.02\ F^2) + 0.5 \times C$, where C is the weight % of water and F is the applied field in kilovolts/cm.

In part I of this paper, specific conductance measurements were described[1] on thin samples of paper, wood (2mm.) and jutoid (1.5 to 2.5mm.), a jute-based bituminous composition. The jutoid particularly was tested after soaking up various percentages of water, and the present communication presents a fuller analysis of these data, which are connected together by a simple equation involving water content and field strength.

1. Dependence of Low-field Specific Conductance on Water Content

It was observed[1] that the specific conductance of the jutoid samples extrapolated to zero field varied non-linearly with percentage water. A similar effect has previously been observed, particularly in the course of studies on Cotton-seed cake,[2] where the conductance was found to vary nearly exponentially with water content. Accordingly, Fig. 1 shows a semi-logarithmic plot of the data obtained on "jutoid" in part I, the solid circles corresponding to sample lot I and hollow circles to sample lot II. Both graphs are seen to be acceptably linear, at least below 2% water, thus confirming the exponential dependence of conductance on water content in both cases*.

While both samples apparently exhibit nearly the same specific conductance γ at zero water-content, the slopes of the two graphs are somewhat different, but are both comparable with that in the case of cottonseed cake, shown in Fig. 1 by the chain dotted line. This is significant in so far as it indicates that the dependence of electrical conductivity on water taken up is essentially the same in all the three cases, being non-linear and nearly exponential in each. It follows that $\log \gamma/\gamma_{\circ} \approx a \times C$, (1)

where 'C' is the concentration of water and 'a' is a constant. If C is measured as weight %, then $a \approx 0.5$.

2. Voltage Dependence of Specific Conductance

In the light of the above results, a similar analysis of the highly non-linear voltage dependence was undertaken, and Figure 2 (top) shows semilogarithmic plots of specific conductance against applied field-strength for wet and air-dry (15 mm. vapour pressure at 29°C.) 'deodar' wood, based on our previously observed data (cf. Fig. 2 in part 1). It is seen that these plots are linear upto quite high values of field strength.

Fig. 2 (bottom) shows similar plots for samples of "Jutoid", the C.S.I.R. Jute-based bituminous composition, measured under three different conditions of humidity. Only the graph

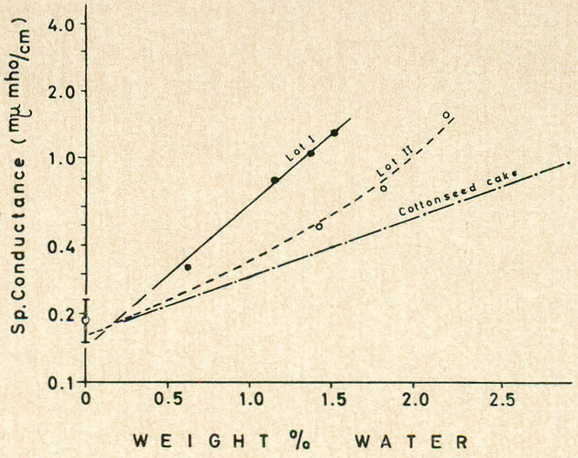

Fig. 1.— Semi-logarithmic plots of specific conductance (in milli-micro-ohms/cm.) against water % absorbed fo two lots of jutoid samples (solid and hollow circles), with graph for cottonseed cake (chain-dotted line) shown below for comparison.

* It is to be noted that in the corresponding Fig. 5 (b) in Part I, the point for the desiccated sample was incorrectly plotted.

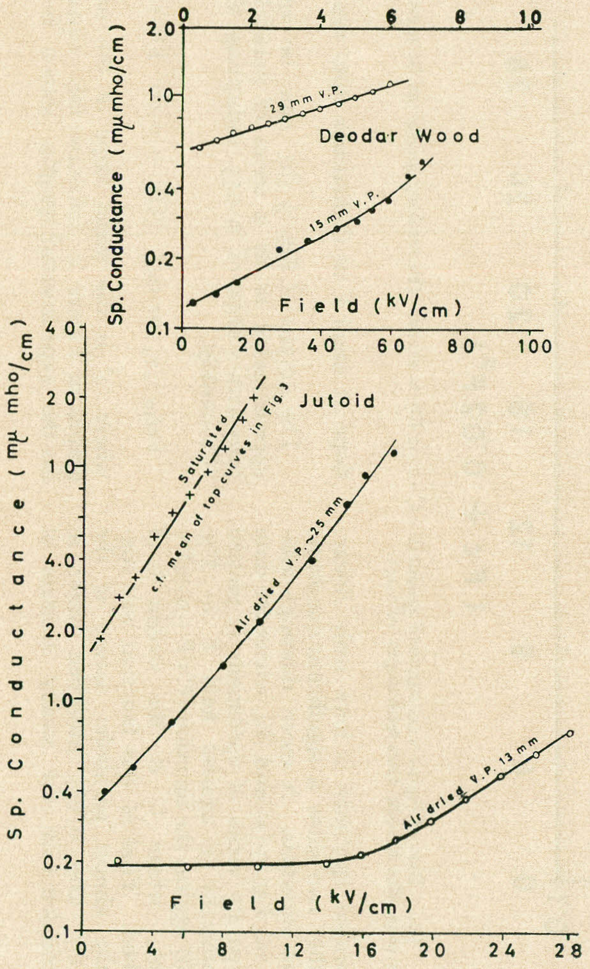

Fig. 2.—Semi-logarithmic plots of specific conductance versus applied field in kilovolts/cm. for (top) deodar wood at two different relative humidities, and (bottom) jutoid samples in three different states of wetness.

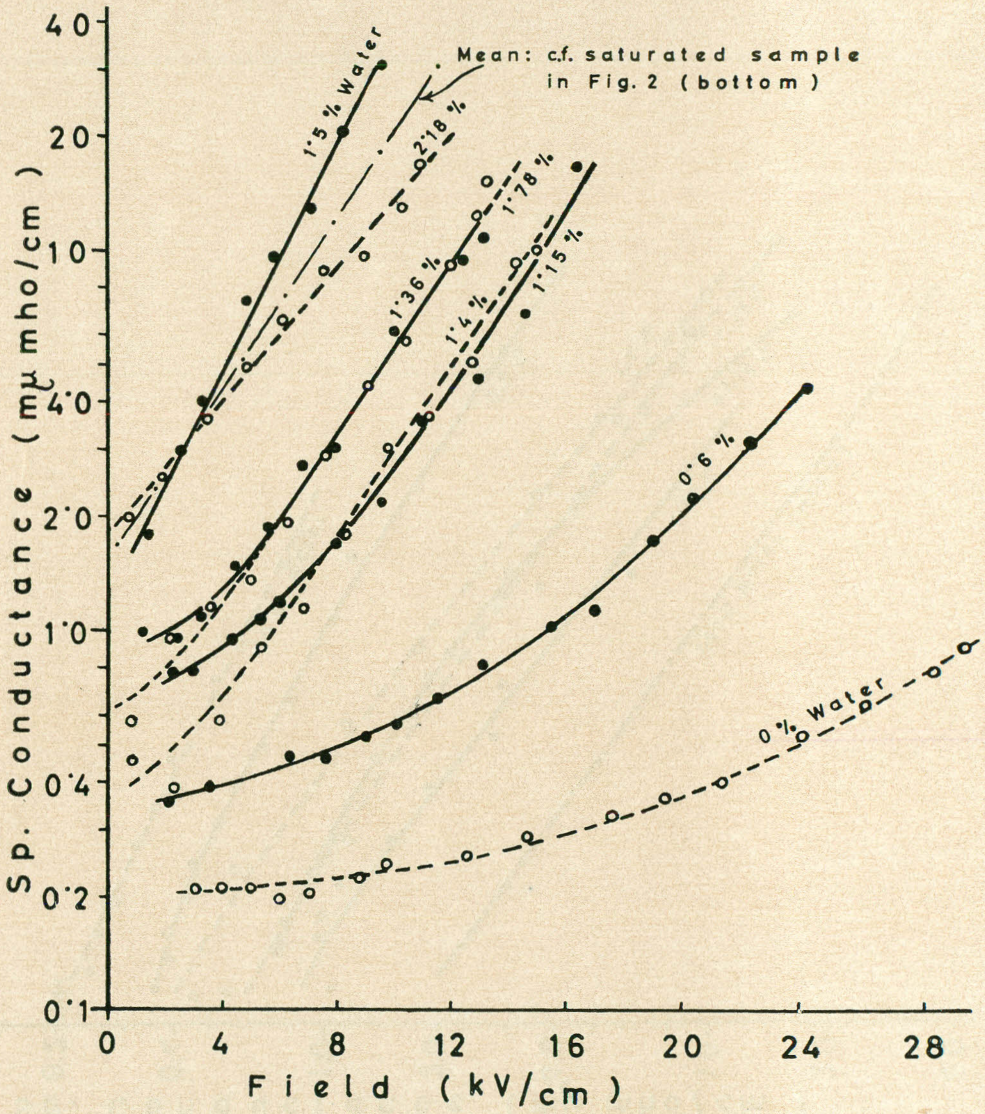

Fig. 3. (*a*). — Two series of semi-logarithmic plots of specific conductance versus applied field for variously humidified samples of jutoid. Solid circles and full lines, first series; hollow circles and broken lines, second series. The chain-dotted line is the mean of the top-most plots for the two sets, and is in excellent agreement with the plot for saturated jutoid in Fig. 2 (bottom).

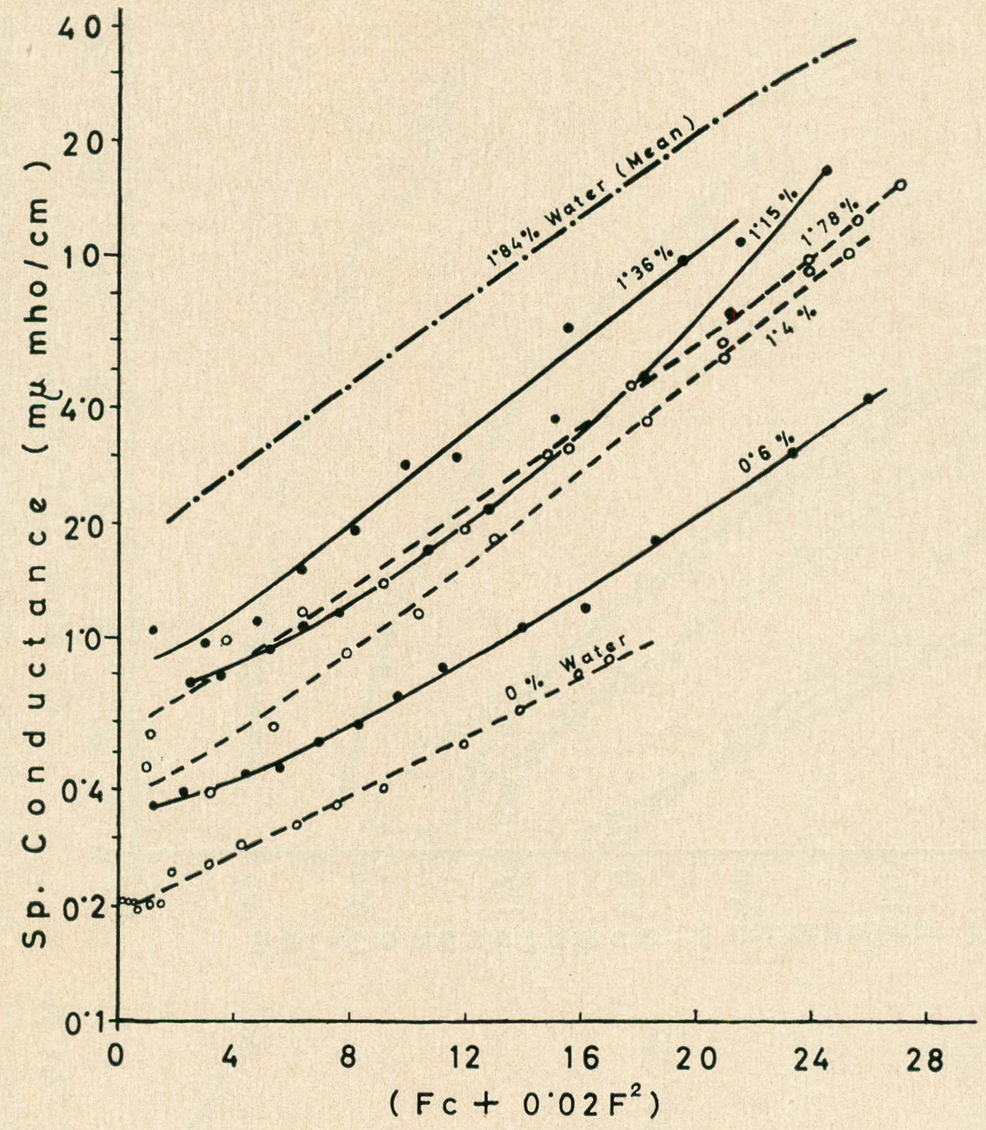

Fig. 3. (*b*).— Data of Figure 3 (a) replotted against ($F \times C + 0.02\ F^2$) as abcissa. The resulting graphs can be approximated to by a family of parallel straight lines with slopes of 0.045.

for the saturated specimen is here truly linear, while the other two show a significant quadratic component of variation. A more thorough analysis is seen in Fig. 3 (a) and (b), where the data from two separate series of specimens is plotted semi-logarithmically (i) against field F in Fig. 3 (a), and (ii) against the function ($C \times F + 0.02F^2$) in Fig. 3 (b), where C is the weight % of water absorbed. Trial of this function was suggested by the almost parabolic nature of the graphs for 0% and 0.6% absorbed water in Fig. 3 (a), coupled with the steady increase of slope at small F as C increases upto nearly 2.

The graphs of Fig. 3 (b) can be reasonably approximated to by a series of parallel straight lines with a slope of 0.045 indicating the simple relationship,

$$\log_{10} \gamma/\gamma_0 = 0.045 \quad (CF + 0.02\ F^2) + a \times C \quad (2)$$

where 'a' is the mean slope of the two upper graphs of Figure 1. (ofcourse this equation also fits the experimental graphs shown in Fig. 2, bottom). Comparing this result with the approximate Townsend equation for conduction in a gas at pressure p,

$$\ln \gamma/\gamma_0 \approx \beta' p \exp[-\beta p\, E/Fe],$$

and with $\ln \gamma = A - \mathbf{E}/kT$, (3)

which is known[3] to hold for many semi-conductors and insulators, (E being an energy gap), we may conjecture that quite possibly equation (3) holds with $A_c = A_0 + a \times C$, and $E = E_0 - b(CF + 0.02\,F^2)$; it is certainly tempting to interpret the term $0.045\,(CF + 0.02\,F^2)$ as a consequence of changes produced in the energy gap E. Further experiments on various types of wood, paper and similar materials are being carried out for elucidation of these interesting relations.

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References

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