CHAPTER 7

Power Factor Measurement Of Some Species Of Wood.
POWER FACTOR MEASUREMENT OF SOME SPECIES OF WOOD.

ABSTRACT:

The power factor \( S \) of eight species of wood commonly grown in the forests of M.P. has been measured along and across the grain. The former is found to vary from 0.005 to 0.002 and the latter from 0.004 to 0.002. The measurements have been made at 3000 C/s and room temperature 30°C.

INTRODUCTION.

Three very important quantities in connection with any dielectric are:

(a) Its "dielectric strength".
(b) Its "permittivity" or 'dielectric constant'.
(c) Its "dielectric loss angle" or 'power factor'.

First two properties have been discussed in Chapter - "Insulating Properties of some species of wood." The last property is being considered in this chapter.

When a potential is applied to the electrodes of a capacitor having a perfect dielectric, there is an initial displacement current which finally disappears. On discharge, a reverse current flows until the charge has been dissipated and current ceases. Where the dielectric has a finite resistance, the charging current is increased by the conduction current which persists after the charging current has died away, but which does not appear on discharge.
With some dielectrics, however, an appreciable time lapse before the current reaches the steady value of the conduction current, and after the potential has been withdrawn, it takes a considerable time for the charge to leak away even if there is external circuit. This phenomenon is known as absorption (Stubbs).

When a sinusoidal voltage is applied to a pure capacitor, the current in the circuit leads the voltage exactly by 90° but with many dielectrics (particularly solids) losses occur in the dielectric, partly due to conduction current and partly due to dielectric hysteresis absorption and other effects which are grouped as dielectric losses. These may be a thousand times greater than that due to conductivity, causing considerable heating. This may be the major cause of failure of the material, particularly at high frequencies. The loss currents are in phase with the applied voltage. Consequently as shown in Fig.1A, the total current in the circuit is no longer in quadrature with the applied voltage.

The angular difference from the vector of a perfect capacitor is termed the loss angle (sometimes defect angle) and is a measure of the dielectric loss. Power factor is generally expressed in terms of $\tan \delta$, if $\delta$ is small. The value obtained is usually qualified with reference to voltage, frequency, temperature, and moisture content if necessary (Golding, 1965).

It is difficult to generalize on the effect of frequency. But for insulating materials operating at high frequencies, it is of utmost importance that the power factor
and dielectric constant should be as small as possible.

For some purposes, the loss factor $\tan \delta$ is a more useful criterion than power factor when choosing a suitable dielectric not only for capacitors but for any frequency insulator.

Wood as an insulating material is frequently used in the electrical industry. Hence to evaluate completely the insulation value of wood, various species commonly grown in the forests of Raipur Division have been tested to evaluate their power factor, the available data on which is scanty.

THEORETICAL:

The power diagram indicator is a device in which the cathode ray tube is employed to trace diagrams, the areas of which are proportional to the power supplied to the load. The application of the device (also called the cyclograph) to the investigation of the behaviour of insulating materials has been developed by Minton and full circuit arrangements are given by Hartshorn. Fig.1B shows a simpler arrangement used for the measurement of dielectric loss.

In order to obtain the diagram, it is necessary to employ two sets of electrodes, one set is arranged to deflect the fluorescent spot along the X-axis on the screen, another along the Y-axis.

Referring to the Fig.2, $C_s$ is the dielectric sample and $C$ a loss free capacitor of much greater capacitance. The C.R. oscillograph plates X and Y are connected as shown (Fig.2).
On applying \( V_1 \) and \( V_2 \) to the \( Y \) and \( X \) plates of the oscillograph, an ellipse like that of Fig. 3 will be obtained. The phase angle between \( V_1 \) and \( V_2 \) is given by (Calthrop, 1952)

\[
\sin \beta = \frac{OD}{OC} = \frac{OE}{OF}
\]

To see this, let \( V_1 = A \sin wt \) and \( V_2 = B \sin (wt + \beta) \).

The maximum value of \( V_2 \) is \( B \) and this is proportional to the length \( OC \). When \( t = 0 \), \( V_1 = 0 \), \( V_2 = B \sin \beta \) and is proportional to the length \( OD \). Hence \( \sin \beta = OD/OC \) and similarly \( \sin \beta = OE/OF \), and calibration is avoided (Laws, 1938).

**E X P E R I M E N T A L.**

The cathode ray oscillograph (GM 5655, Philips) enables a very rapid accurate comparative (Laws, 1938) test between condensers, to determine relative power factor or losses. The circuit used for such tests is shown in Fig. 2.

The two condensers, \( C \) being the standard and \( C_s \), being the unknown were so arranged that the voltage across the sample being tested developed the vertical deflection and the current through the sample developed the horizontal deflection so that current and voltage were \( 90^\circ \) apart. For the solid dielectric to be used, \( C_s \) was constructed from two circular metal discs 15 cm. diameter mounted parallel to each other, between which the dielectric samples in sheet form and larger than the condenser plates fitted closely. An oscillator (Honor model TE-22) supplied the test voltage at a predetermined frequency (3000 C/S). The connections were
arranged as symmetrically as practicable with respect to ground connection. Care was taken to use small shielded leads as to avoid pick-up and to reduce the ohmic resistance to practicable minimum value. The ohmic resistance between the terminals and the condenser proper was kept low in order that there may be no appreciable internal \( I^2R \) losses which cause an alternating current to lead the applied voltage by less than 90°. The linear sweep in the C.R. oscillograph was not used. Both horizontal and vertical deflections were secured with recourse to amplifiers (Ricer, 1947). Measurements were made by tracing the ellipse on graph paper. The axes of the figure were obtained by disconnecting the wire to the \( X \) and \( Y \) plates in turn.

By taking the mean value of \( OD/OC \) and \( OE/OF \), \( \xi \) was calculated. Three samples of each species along and across the grain were employed separately and the average values of the "Power factor" for the tested species are indicated in Table-1. The samples used were dry. Measurements were made at temperature 30°C.
<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Power factor (f=3000c/s) at temp. 30°C</th>
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<tbody>
<tr>
<td></td>
<td>Along grain</td>
<td>Across (Tang) grain</td>
</tr>
<tr>
<td>1.</td>
<td>Tectona Grandis (Teak.)</td>
<td>0.005</td>
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<tr>
<td>2.</td>
<td>Dalbergia Latifolia (Rosewood)</td>
<td>0.004</td>
</tr>
<tr>
<td>3.</td>
<td>Acacia Arabica (Babul)</td>
<td>0.004</td>
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<tr>
<td>4.</td>
<td>Shorea Robusta (Sal.)</td>
<td>0.003</td>
</tr>
<tr>
<td>5.</td>
<td>Petrocarpus Marsupium (Bija)</td>
<td>0.003</td>
</tr>
<tr>
<td>6.</td>
<td>Anogeissus Latifolia (Bhaura)</td>
<td>0.003</td>
</tr>
<tr>
<td>7.</td>
<td>Cleistathus Collinus (Karra)</td>
<td>0.002</td>
</tr>
<tr>
<td>8.</td>
<td>Diospyros Melanoxylon (Tendu)</td>
<td>0.002</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION:

The power factor for the various tested species along and across the grain for the dry samples are indicated in Table-1. The average values along and across the grain are found to vary from 0.005 to 0.002 and from 0.004 to 0.002 respectively. Above listed results show, that the power factor along and across the grain are nearly of the same magnitude.

Power factor of wood relative to other generally used insulating materials such as Steatite (0.002), Porcelain (0.005-0.01), Ebonite (0.005 to 0.01), Glass (plate, 0.006), Mycalex (0.002 to 0.005), dry paper (0.005) etc. seems to be comparable.
The essential requirements for the material to be used as a dielectric are:

(i) a high dielectric coefficient and capable of being used in very thin sheets,

(ii) an exceedingly high resistivity and a high dielectric strength,

(iii) should be clean and dry and not susceptible to moisture absorption; and

(iv) should be free from air pockets to reduce losses.

The wood as a suitable dielectric does not possess most of the above listed qualities. Dielectric strength of wood is low (Kakkar, 1979) and the reasons thereof have been discussed in Chapter 6.

Wood is highly susceptible to moisture absorption (Clark, 1962) which renders it unfit for dielectric purposes. Because of its high porosity (Perelvgin, 1965), it is not suitable for dielectric purposes. However, these properties can be improved upon by impregnation (Chapter 6).


5. KAKKAR, S. S. - Indian Forester Vol. XNI. I (1909) P. 55-60.


8. RIDER, F. JOHN - The cathode Ray Tube at Work Publisher, Inc. 404 Fourth Avenue, New York-16, N.Y. (1947).