

## ELECTRICAL PROPERTIES OF INDIAN MICA : II. THE EFFECT OF VARYING RELATIVE HUMIDITY

By P. C. MAHANTI,\* M. K. MUKHERJEE AND P. B. ROY.

**ABSTRACT.** In continuation of the previous work, the effect of varying relative humidity on the permittivity, power factor and power loss of three typical qualities of Bengal ruby and Madras green mica has been studied. The results are in conformity with those obtained by previous workers in the line

### INTRODUCTION

In a previous communication (Datta, Sen Gupta and Mahanti, 1942) the results of power factor measurements on different kinds of mica available in different parts of India were reported. In the present paper a comparative study of the effect of varying relative humidity on permittivity, power factor and dielectric loss factor of three typical qualities of Bengal ruby and Madras green micas has been made.

The same technique as has been described previously was employed in preparing the test condenser, which was kept under suitable pressure for about twenty-four hours before being put to use for capacitance and power factor measurements at a desired value of humidity. The measurements have been done by the method of substitution, using the same standard air condenser and the same Schering bridge. It is however of interest to describe the method which has been used in the present investigation to control the relative humidity (hereafter stated very often as humidity) of the experimental chamber in which the test condenser was housed.

### METHOD OF CONTROLLING HUMIDITY

Various methods have been used in the past by different investigators to control the humidity of an enclosed space. It is found that a saturated aqueous solution in contact with a definite solid phase, such as  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ ;  $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ ;  $\text{CaSO}_4 \cdot 5\text{H}_2\text{O}$ , etc. maintains constant humidity at a definite temperature within an enclosed space surrounding it. Hence by selecting a proper salt, it is possible to secure almost any desired value of humidity at a given temperature. It is evident that this method is convenient when any definite value of humidity is desired within an enclosed space for a particular purpose. But when it is required to vary the humidity over a wide range of values at a given temperature and maintain it constant at each such value, this method becomes tedious in as much as one has to use different salts for obtaining different values of

\* Fellow of the Indian Physical Society.

humidity. Moreover, the fact that the value of humidity set up by a particular salt depends upon the temperature at which the solution is kept presents further difficulties. Another method utilises the fact that sulphuric acid at different concentrations exerts different vapour tensions. It is thus possible to set up conveniently any desired value of humidity in the chamber by varying simply the concentration of the acid. But the corrosive effect of the acid prevents its use in our case. Very recently a very simple and convenient method (Grover and Nicol, 1940) of controlling the humidity within a comparatively small enclosed space has been found by using solutions of glycerine in water at different dilutions. This method possesses many advantages over the previous ones. A solution of glycerine in water is non-corrosive and can be easily standardised by measuring its refractive index. It is easily recovered or re-concentrated, if desired, by boiling or simply by exposing it to warm and dry atmosphere. The most important and useful point is however the fact that the relative vapour pressure of glycerine solution is substantially independent of temperature over the range  $0^{\circ} - 70^{\circ}\text{C}$ . Hence if a solution is standardised at a given temperature it can be used to give a definite value of humidity without appreciable error even if the temperature undergoes any change at any subsequent period.

In the present investigation we have used, therefore, glycerine solutions of different concentrations for obtaining different values of humidity as desired. The refractive index of each solution was measured with the help of an Abbe refractometer. A curve showing the variation of humidity with refractive index is given in Fig. 1. In actual practice a vacuum desiccator, with its glass stopper

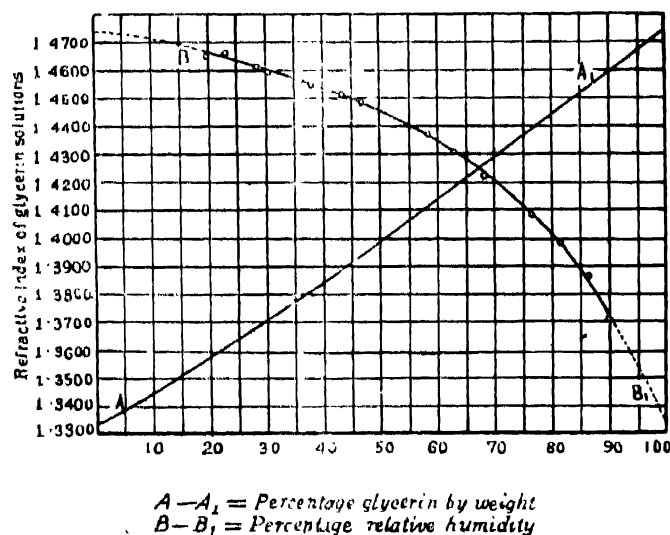


FIG. 1

replaced by a tight-fitting velvet cork, was conveniently used as the experimental chamber in which the desired value of humidity was set up by placing inside it a basin containing the glycerine solution of proper concentration. In order to check the value of humidity thus set up, an Edney paper hygrometer was also placed inside the chamber. The agreement was found very satisfactory in each

case. It was noticed further that it took about 2 hours to attain a steady value of humidity within the chamber.

EXPERIMENTAL

It has been noted already that capacitance and power factor measurements in the present investigation were carried out by the method of substitution, using a standard air condenser and a Schering bridge operating at 220 volts a.c. at one kilocycles per second as described in the previous communication (*loc. cit.*). The test condenser was connected to the bridge by means of two short lengths of V.I.R. copper wire which passed through the velvet cork at the mouth of the chamber and were kept fixed in position throughout subsequent measurements. Before making our final measurements on the test condensers, it was thought of importance, firstly, to determine with definiteness the capacitance of the leads as well as the power factor of their insulation including that of the velvet cork and their variation, if any, with humidity, and secondly, to ascertain whether the time of conditioning a test condenser at any desired value of humidity has any effect on its capacitance and power factor values. In the latter case it was found that conditioning the test condenser for about two hours at any value of humidity not exceeding 80% was sufficient to arrive at a steady value of its capacitance or of its power factor. But above 80% humidity, the time of conditioning increased considerably. Hence in making measurements on the different test condensers, bridge readings at a desired value of humidity were taken at an interval of two hours until they were steady within the limits of experimental error. All measurements were done at a constant temperature of 36°C. With each test condenser observations were made firstly, with increasing humidity to a maximum value of 95%, and then with decreasing values. At each value the two sets of bridge readings were found to agree within allowable limits and their mean was taken to compute as follows the capacity and power factor of the test condenser, after making due allowance for the effects of leads, etc.

It is easily seen that when the bridge is balanced, firstly, with the bridge standard condenser alone in the third arm and then with the test condenser connected across it, we have

firstly, 
$$\frac{C}{C_s} = \frac{R_2}{R_1} \quad \dots (1)$$

and 
$$\phi - \phi_s = \phi_2 - \phi_1 \quad \dots (2)$$

and secondly, 
$$\frac{C}{C'_s + C_r} = \frac{R_2}{R_1} \quad \dots (3)$$

and 
$$\phi - \phi'_r = \phi'_2 - \phi_1 \quad \dots (4)$$

where C and  $\phi$  = capacity and power factor of the standard air condenser in the fourth arm of the bridge respectively;

$C_s$  and  $C'_s$  = capacity of the bridge standard condenser in the third arm before and after substitution of the test condenser respectively ;

$C_T$  = capacity of the test condenser ;

$\phi_s$  = power factor of the bridge standard condenser ;

$\phi'_T$  = effective diluted power factor of the test condenser ;

$R_2/R_1$  = ratio of resistances in ratio arms of the bridge ;

$\phi_2 - \phi_1$  and  $\phi'_2 - \phi'_1$  = difference of power factor of the balancing arms of the bridge (*i.e.*, power factor dial reading) before and after substitution, respectively.

In actual practice,  $R_2/R_1$  was kept fixed at unity and the standard air condenser at a suitable value under the two conditions of balance. Hence  $C$  and  $\phi$  were maintained also constant. From equations (1) and (3), we have

$$C_T = C_s - C'_s \quad \dots (5)$$

and from equations (2) and (4)

$$\phi'_T - \phi_s = \phi_2 - \phi'_2 \quad \dots (6)$$

Assuming however that  $\phi_s$  is negligible in comparison to  $\phi'_T$ , we get

$$\phi'_T = \phi_2 - \phi'_2 \quad \dots (7)$$

It is evident from equations (5) and (7) that the capacity and the effective diluted power factor of the test condenser can be obtained directly from the capacity and power factor dial readings of the bridge before and after substitution. The true power factor of the test condenser is then obtained from the relation

$$\phi_T = \frac{C_s}{C_T} \cdot \phi'_T \quad \dots (8)$$

while the permittivity,  $\epsilon$ , of the test sample is computed from the relation,

$$\epsilon = \frac{113C_T t}{C} \quad \dots (9)$$

where  $C_T$  is the capacity of the test condenser in micro-micro-farads,  $t$  is the thickness of the sample in cm. and  $S$  is the area of the electrodes in contact with the sample in sq. cms.

Knowing the values of permittivity ( $\epsilon$ ) and power factor ( $\phi_T$ ) of a particular sample at a constant temperature and at a given value of humidity, the dielectric loss factor ( $\epsilon''$ ) can be determined from the the well known relation given by

$$\epsilon'' = \epsilon \tan \delta$$

where  $\delta$  is the loss angle. Since  $\delta + \phi = \pi/2$ , we have  $\tan \delta = \cos \phi$ , when  $\delta$  is small and  $\phi$  is the phase angle. Hence we may write also

$$\begin{aligned} \epsilon'' &= \epsilon \cos \phi \\ &= \epsilon \phi_T \end{aligned} \quad \dots (10)$$

In other words, the dielectric loss factor of a sample is given by the product of its permittivity and power factor.

Tables I and II contain the data of permittivity, power factor and power loss measured at varying relative humidity for Bengal ruby and Madras green

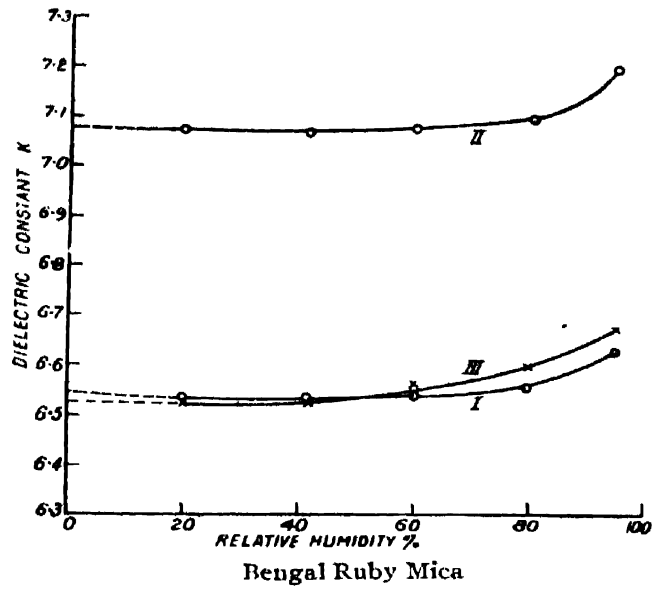
mica respectively. In each table column 1 gives the quality and column 2 the designation adopted by the Geological Survey of India of each mica sample. In Figs. 2 to 7, the variations of permittivity or dielectric constant, power factor and power loss of the different qualities of mica with varying relative humidity are shown graphically.

TABLE I  
Bengal Ruby Mica

Quality	Designation & colour.	Relative Humidity (%)	Thickness (cm.)	Contact area of electrodes (sq. cm.)	Capacity ( $\mu\mu\text{F}$ .)	Permittivity.	Power factor %	Power loss
Clear	B.C. 7—Ruby red	20	0'01	2'280	131'8	6'53	0'0116	0'0758
		41	0'01	2'280	131'8	6'53	0'0116	0'0759
		60	0'01	2'280	131'9	6'54	0'0123	0'0802
		80	0'01	2'280	132'2	6'55	0'0148	0'0970
		95	0'01	2'280	133'7	6'63	0'0318	0'2110
Stained	D.—Red	20	0'012	2'204	114'8	7'07	0'0134	0'0944
		41	0'012	2'204	114'8	7'07	0'0134	0'0944
		60	0'012	2'204	115'0	7'08	0'0141	0'0996
		80	0'012	2'204	115'3	7'09	0'0192	0'1362
		95	0'012	2'204	117'0	7'20	0'0415	0'2982
Stained & slightly spotted	A.—Red	20	0'012	2'010	95'5	6'52	0'0256	0'1671
		41	0'012	2'010	96'5	6'52	0'0256	0'1671
		60	0'012	2'010	97'0	6'56	0'0272	0'1784
		80	0'012	2'010	97'4	6'59	0'0357	0'2354
		95	0'012	2'010	98'6	6'67	0'0625	0'4166

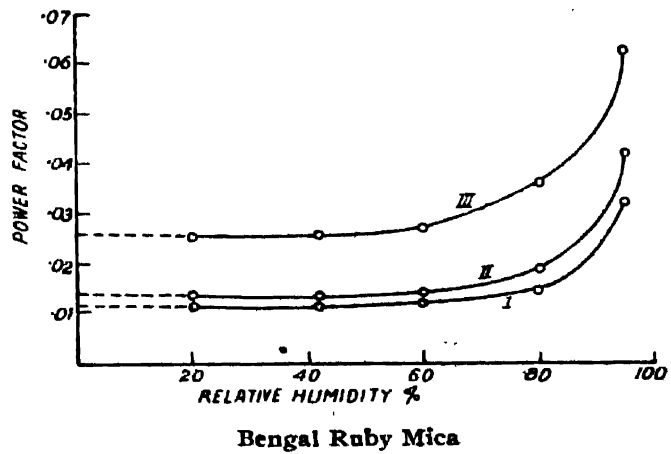
TABLE II  
Madras Green Mica

Quality	Designation & colour.	Relative Humidity (%)	Thickness (cm.)	Contact area of electrodes (sq. cm.)	Capacity ( $\mu\mu\text{F}$ .)	Permittivity.	Power factor %	Power loss.
Clear	M.C.—green	20	0'01	2'520	141'5	6'35	0'0192	0'1221
		41	0'01	2'520	141'6	6'35	0'0198	0'1256
		60	0'01	2'520	142'4	6'39	0'0209	0'1335
		80	0'01	2'520	143'2	6'42	0'0232	0'1488
		95	0'01	2'520	144'0	6'46	0'0362	0'2337
Stained	C—Green	20	0'013	1'370	64'4	6'80	0'0199	0'1355
		41	0'013	1'370	64'4	6'80	0'0199	0'1355
		60	0'013	1'370	64'4	6'80	0'0212	0'1477
		80	0'013	1'370	65'0	6'86	0'0236	0'1623
		95	0'013	1'370	65'0	6'92	0'0365	0'2526
Stained & spotted.	A—Green	20	0'018	2'323	80'5	7'05	0'0298	0'2098
		41	0'018	2'323	80'5	7'05	0'0298	0'2098
		60	0'018	2'323	80'5	7'05	0'0308	0'2167
		80	0'018	2'323	80'9	7'08	0'0327	0'2318
		95	0'088	2'323	81'5	7'14	0'0640	0'4670



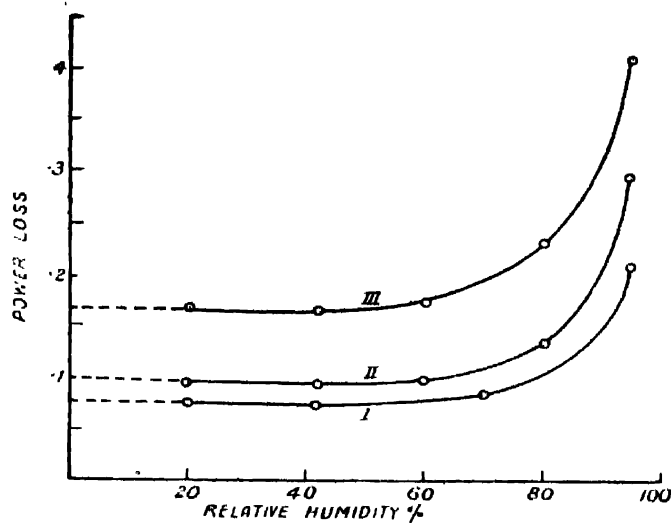
I—Clear, II—Stained, III—Stained and slightly spotted.

FIG. 2



I—Clear, II—Stained, III—Stained and slightly spotted.

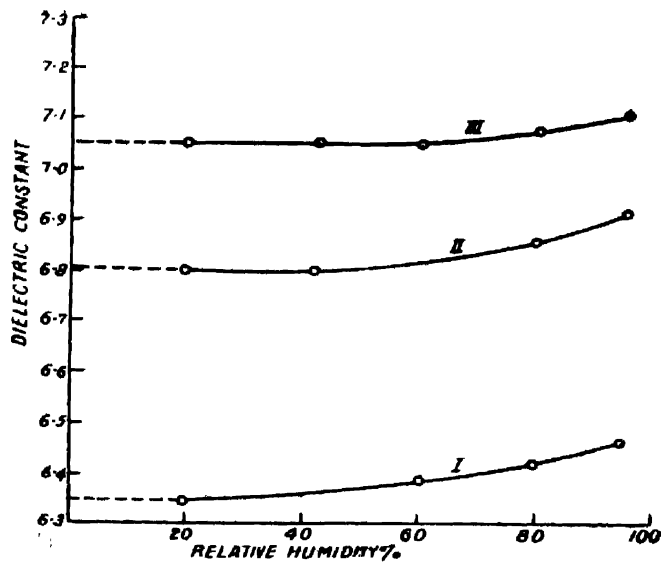
FIG. 3



Bengal Ruby Mica

I—Clear, II—Stained, III—Stained and slightly spotted

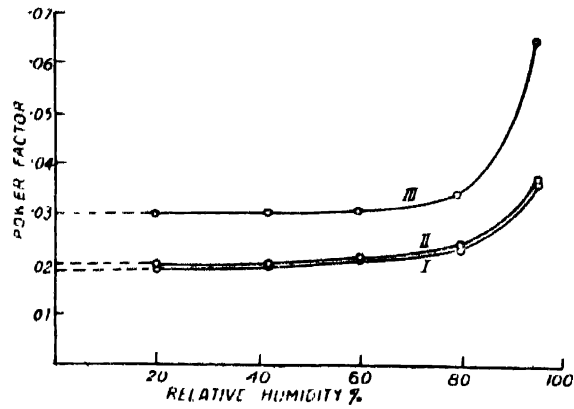
FIG. 4



Madras Green Mica

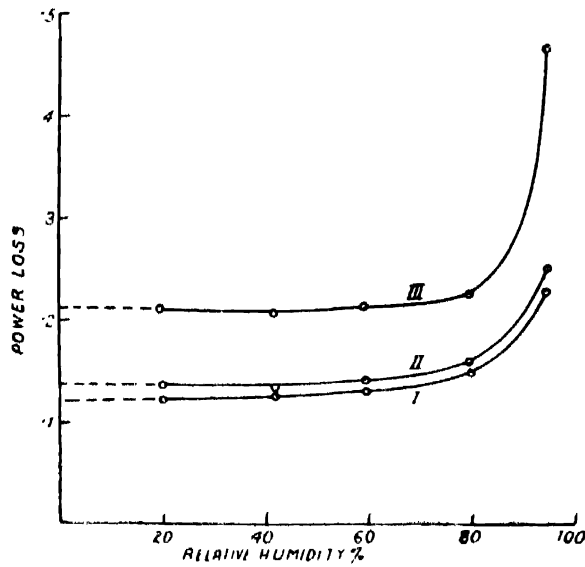
I—Clear, II—Stained, III—Stained and slightly spotted.

FIG. 5



Madras Green Mica  
I—Clear, II—Stained, III—Stained and slightly spotted.

FIG. 6



Madras Green Mica  
I—Clear, II—Stained, III—Stained and slightly spotted.

FIG. 7

### DISCUSSIONS

It is evident from the data in Tables I and II as well as from the graphs (Figs. 2—7) that humidity has an appreciable effect on the permittivity, power factor and power loss of each quality of mica tested, and that the nature of their variation is practically the same in all cases. It is found that the values of permittivity, power factor and power loss remain practically constant up to 40% relative humidity and then increase slowly, the rate of increase increasing



with varying humidity and being most marked above a humidity value of 80%. It may be of interest to note here that many investigations in this direction were carried out, notably in England, Germany and Italy, before the present world war. Dannatt and Goodall (1931) were of opinion that changes in the power factor of mica due to variation in the atmospheric humidity were too small to be of any importance from most points of view. But they were contradicted by Hartshorn and Rushton (1931) who found a considerable variation of the power factor of mica with increasing values of relative humidity. In fact they measured the power factor of a particular sample of ruby mica at a frequency of 800 cycles per second and at a temperature of 20° C, and found it to change very appreciably when the relative humidity was varied from 8% to 50%. More recently, they (Hartshorn and Rushton, 1936) have studied also the variation of power loss in typical samples of clear ruby mica with moisture content and have confirmed their earlier opinion. Schwarz (1936) in Germany also observed considerable variation in the power factor of mica with varying relative humidity. He found the value of power factor to decrease from 0.02% under the normal atmospheric humidity to 0.017% when kept under vacuum and to increase to 0.04% at a relative humidity of 90%, the time of conditioning the sample in each case being 24 hours. Tabaracci (1930) in Italy also observed that the loss angle of mica was a function of humidity. Our results are therefore in perfect agreement with the views of the above workers. It may however be noted here that as the capacity and the power factor dial readings of the bridge were practically the same at any value of relative humidity, whether this value was obtained with increasing or with decreasing humidity in the experimental chamber, one is led to infer that the variation observed in the electrical behaviour of mica is very likely due to surface absorption of moisture and is not a case of adsorption or any change in its chemical and capillary structures.

One finds further that the stained and spotted quality of each type of mica has, as one would expect, the largest value not only of power factor but also of power loss. On the otherhand, all the different qualities may be said to have practically the same value of permittivity in view of the fact that the average permittivity of muscovite mica of any type and quality is about 7 (Dye and Hartshorn, 1924; Dannatt and Goodall, 1931) while the individual values obtained from measurements on different samples even of the same quality and geographical origin lie within the limits of 5.83 to 9.64 (Lewis, Hall and Caldwell, 1931). It may however be mentioned here that we have used only one sample of each quality for our measurements since the main object of our present investigation was to study the effect of varying relative humidity on the electrical properties of Indian mica.

In conclusion, the authors acknowledge gratefully their thanks to Prof. P. N. Ghosh, for his kind interest and encouragement during the investigation and to Dr. W. D. West of the Geological Survey of

India for kindly supplying the clear qualities of mica samples used in our measurements.

MEASUREMENT AND STANDARDISATION LABORATORY,  
DEPARTMENT OF APPLIED PHYSICS,  
CALCUTTA UNIVERSITY.

R E F E R E N C E S

- Dannatt and Goodall (1931), *J.I.E.E.*, **69**, 490.  
Datta, Sen Gupta and Mahanti (1942), *Indian Jour. Phys.*, **17**, 79  
Dye and Hartshorn (1924), *Proc. Phys. Soc*, **37**, 42.  
Grover and Nicol (1940), *Jour. Soc. Chem. Industries*, **60**, 175.  
Hartshorn and Rushton, (1931), *J.I.E.E.*, **66**, 1034    (1939), *E.R.A*, *Report, Ref. L/T 60*  
24.  
Lewis, Hall and Caldwell (1931), *B.S.J.R.*, **7**, 403  
Schwarz (1936), *E.T.Z*, **57**, 7  
Tabaracci (1939), *Electrotechnica*, **26**, 649.